National Pollutant Inventory

# Emission Estimation Technique Manual

for

# Fuel and Organic Liquid Storage

## 19 May 2003
## Version 2.2

Environment Australia

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**Disclaimer**

The manual was prepared in conjunction with Australian States and Territories according to the National Environment Protection (National Pollutant Inventory) Measure.

While reasonable efforts have been made to ensure the contents of this manual are factually correct, the Commonwealth does not accept responsibility for the accuracy or completeness of the contents and shall not be liable for any loss or damage that maybe occasioned directly or indirectly through the use of, or reliance on, the contents of this manual.

## Erratum for Fuel and Organic Liquid Storage Emission Estimation Technique (EET) Manual (Version 2.2 – 19 May 2003)

| Page | Outline of alteration |
|---|---|
| Page 43 | Added clarification of substance names used in TANKS in (see 'Terminology section in 4.7.1 on page 43) |
| Page 52 | Updated conversion factor for determining petrol emissions (Table 13 and Table 14) and related elements in Example 4. Also updated elements of Example 3. |

## Version 2.1 – 10 July 2002.

| Page | Outline of alteration |
|---|---|
| Example 4 Page 54 | Corrected the tank type equation used. |

## Version 2.0 – 29 April 2002.

| Page | Outline of alteration |
|---|---|
| All | The manual has been extensively revised and rewritten compared to the version completed in February 1999. This version includes relevant details from the Addendum completed in August 2000 and replaces that document.<br><br>A major change is the inclusion of a simple method for estimating emission from fuel and organic liquid storage that does not involve the use of the USEPA software TANKS. |

**EMISSION ESTIMATION TECHNIQUES**
**FOR**
**FUEL AND ORGANIC LIQUID STORAGE**

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**EMISSION ESTIMATION TECHNIQUES**
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# 1 INTRODUCTION

## 1.1 About the NPI

The National Pollutant Inventory (NPI) is an Internet database providing information on the types and amounts of NPI substances emitted to air, land and water. In order to provide useful and reliable information to the community, industry, and government, Emission Estimation Techniques (EETs) used to generate data for the NPI must be consistent, and the process for developing these techniques transparent. This manual was developed, reviewed, and finalised in this context.

Users of this Manual should refer to the NPI Guide and the National Pollutant Inventory Environmental Protection Measure (NEPM) for further information about the NPI.

## 1.2 Purpose and Scope of this Manual

The purpose of all EET Manuals is to assist Australian manufacturing, industrial, and service facilities to estimate and report emissions of NPI listed substances. This Manual is one of several that form a NPI Industry Handbook for the Petroleum Product Wholesaling Industry. It is also used in conjunction with other EET Manuals to form handbooks for other industries. Together, these Manuals provide the EETs necessary to estimate emissions of NPI substances to complete NPI reporting.

This Manual describes the procedures and recommended approaches for estimating emissions from facilities engaged in storage of fuel, including petroleum and petroleum-based liquids, and organic liquids. It provides guidance in the use of TANKS 4.09, a modelling program used to determine emissions from fuel storage facilities. A simple technique has also been provided for facilities with total storage capacity less than 500 kL.

<u>Facilities with storages greater than 500 kL should use the TANKS 4.09 software to estimate emissions from fuel and organic liquid storage.</u>

| | |
|---|---|
| EET Manual: | Fuel and Organic Liquid Storage |
| HANDBOOK: | Petroleum Product Wholesaling |
| ANZSIC CODE: | 4521 |

This Manual was rewritten by PPK Environment and Infrastructure (PPK) in conjunction with Environment Australia, and with advice from Shell Australia and BP Australia, on behalf of the Commonwealth Government. It is based on the first version published in March 1999, as drafted by the NPI Unit of the Queensland Department of Environment and Heritage, a subsequent addendum released in August 2000, and further work undertaken by PPK. It has been developed through a process of consultation involving the NPI Implementation Working Group (IWG).

It is recognised that the data generated by the NPI process will have varying degrees of accuracy with respect to the actual emissions from Fuel and Organic Liquid Storage Tanks. In some cases there will be a large potential for error due to the inherent assumptions incorporated in emission estimation techniques (EETs) and/or a lack of available information concerning chemical processes.

This Manual aims to provide the most effective EETs available at the time of publication for the NPI substances relevant to organic liquid storage. The algorithms used in the models provided have been exhaustively developed by the US Environmental Protection Authority (USEPA) and are recognised as the best tool available for this purpose. However, the absence in this Manual of an EET for a specific substance or source does not mean that any known emissions should not be reported to the NPI. The obligation is to report all substance emissions exists where NPI reporting thresholds have been exceeded for those substances and it is reasonable to assume that a NPI reportable substance has been emitted.

## 1.3 Outline of Manual Contents

The key components of this Manual are:

| | |
|---|---|
| Section 2 | providing descriptions of the types of storage tanks used for fuel and organic liquids. Tank type is an important determinant of emissions. |
| Section 3 | giving background information on the NPI substance Total Volatile Organic Compounds (Total VOCs) and the other individual NPI substances that are VOCs but also require reporting separately. |
| Section 4 | describing the installation and use of the TANKS 4.09 program, the preferred tool for estimating emissions of Total VOCs and individual VOCs from storage tanks. Includes adaptations for use in Australia. |
| Section 5 | dexcribing a simple emissions estimation technique compared to TANKS that can be used for horizontal and vertical fixed roof tanks, and internal floating roof tanks, at smaller facilities. |

# 2 DESCRIPTION OF STORAGE TANKS AND EMISSIONS

In most, if not all industries, there are vessels commonly described as storage tanks. These vessels may contain many different substances but are nevertheless designed in three distinct and different ways. This Manual has been designed to assist in the estimation of emissions from storage vessels containing fuel and organic liquids, including gases existing as liquids under pressure and temperature constraints. There are five basic vessel configurations. These are:

1. Fixed Roof Tanks (Vertical and Horizontal);

2. External Floating Roof Tanks (Domed and Standard);

3. Internal Floating Roof Tanks;

4. Variable Vapour Space Tanks; and

5. Pressure Tanks (High and Low Pressure).

Emissions from storage tanks can be categorised as working and standing losses.

Working losses are the combined loss from filling and emptying a tank. As the liquid level increases, the pressure inside the tank increases and vapours are expelled from the tank. Losses during emptying occurs when air drawn into the tank becomes saturated with organic vapour and expands.

Standing losses occur through the expulsion of vapour from a tank due to the vapour expansion and contraction as a result of changes in temperature and barometric pressure (Reference 1).

Losses associated with each of the above tank types are described below.

This Manual does not include calculations for flash emissions from petroleum storage and transfer, or emissions from closed internal or closed domed external floating roof tanks.

## 2.1 Fixed Roof Tanks

Figure 1 illustrates the design of a typical vertical fixed roof tank. (Figure reproduced with the permission of the USEPA). There are three primary design considerations with fixed roof tanks and these centre on the type of roof construction. Usually these vessels are constructed from steel and consist of a cylindrical shell capped with either a flat, conical, or dome-shaped roof. As the name suggests, these tanks have the roof permanently affixed. To accommodate pressure build-up and to reduce costs, the fixed roof tank is generally allowed to vent freely to the atmosphere or have pressure/vacuum vents installed. The use of these vents allows the formation of internal working pressure to reduce the chance of vapours being emitted due to temperature, pressure, or liquid level changes.

The major differences between horizontal and vertical tanks is the orientation and the use of the tank as either an above ground or submerged (below ground) tank. Vertical tanks are only constructed above ground. As with vertical tanks, horizontal tanks are equipped with pressure/vacuum vents. The general rule of thumb in designing horizontal tanks is to ensure that the length of the shell is no more than six times its diameter. This design removes the chance of structural failure and restricts horizontal tanks to smaller capacities. Other control measures to ensure that the tank does not fail include cathodic protection (for corrosion), gauge hatches, and sample wells (in underground tanks). Since underground tanks are shielded from atmospheric conditions, the usual pressure/temperature change losses from vertical and above ground horizontal tanks are not associated with underground tanks.

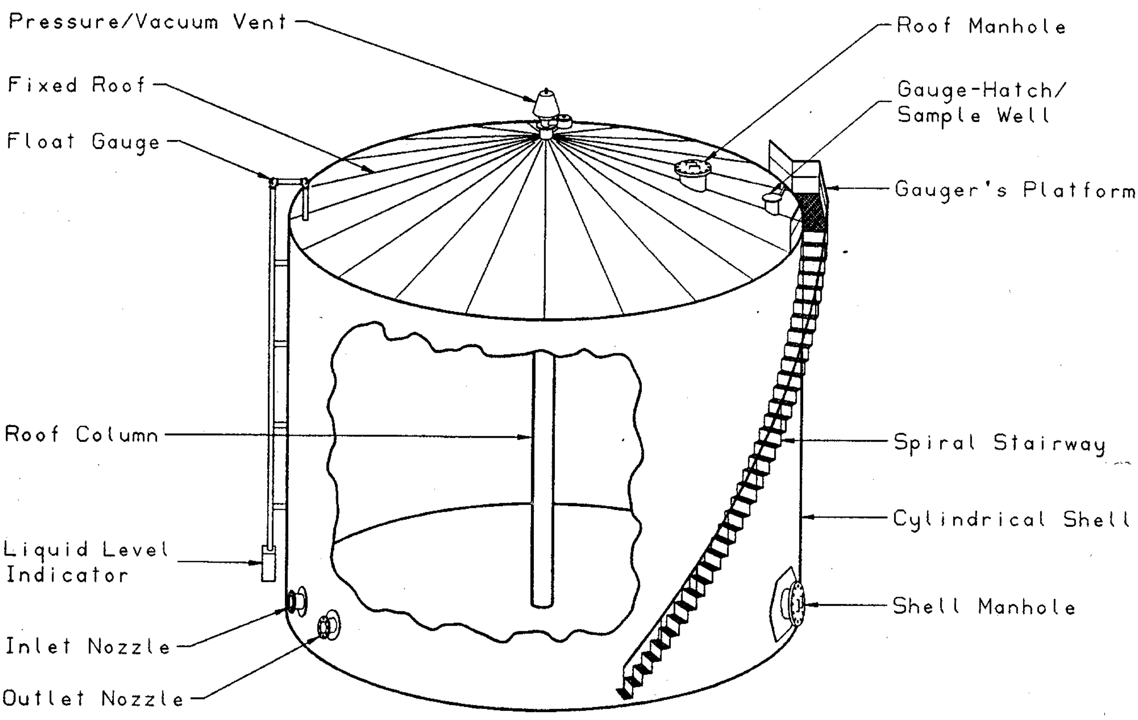


**Figure 1 Vertical Fixed Roof Tank (VFRT)**

Source: Reference 2.

The main emissions from fixed roof tanks are standing and working losses (see page 3). Standing losses are the result of atmospheric changes and the resulting changes in pressure and temperature of the vessel contents. This emission is the vapour lost from the expansion and contraction of the vessel contents without any resulting change in liquid level. Working losses arise from the filling and emptying of the storage tank. Filling operations incur a change in pressure in the tank, because of the change in liquid level in the tank. This pressure change forces expulsion of vapour to counter the change in pressure inside the vessel. The vapour lost is accounted for as evaporation losses from filling. Similarly when liquid is withdrawn from the vessel, air drawn into the tank from this operation becomes saturated with organic vapour and causes the internal pressure to increase, resulting in the relief valves to vent excess vapour and thus cause evaporation losses.

There are three main options available to reduce emissions from fixed roof tanks. Since emissions are directly related to vessel capacity, organic properties of the liquid, tank turnover rate, and atmospheric conditions, modification of existing structures provide the best control mechanisms. Options available are:

(1) ***Installation of an internal floating roof*** - installing a floating roof and the associated rim seal system can dramatically reduce evaporation emissions from fixed roof tanks by 60 to 90 percent (dependent on liquid properties and mechanical arrangements).

(2) ***Vapour balancing*** **–** essentially, vapours are trapped in an empty vessel while the storage vessel is being filled. This vessel is then transported to a vapour recovery system or vented to the atmosphere (the latter providing essentially no control). Vapour recovery can produce control efficiencies ranging from 90 to 98 percent.

(3) ***Vapour recovery systems*** **-** These systems condense the collected vapours for reuse. Common units utilise vapour compression, vapour cooling, vapour/solid adsorption and vapour/liquid absorption (Reference 2).

## 2.2 Floating Roof Tanks

There are two distinct types of floating roof tank designs utilised for storage of fuel and organic liquids. These are internal and external floating roof tanks, both of which can have variations in their final design.

A typical external floating roof tank consists of a shell and a roof that floats on the liquid surface. As climatic changes occur or tank turnovers occur, the tank's roof moves with the liquid. The structure of the floating roof can be of two types - pontoon or double deck. Figure 2 and Figure 3 illustrates these types. Evaporative losses are reduced by the implementation of a rim seal that joins to the floating roof and is attached to the tank wall. Since this design is utilised to minimise evaporative losses, the major losses occur from the rim seal system and deck that is attached to the floating roof. It is possible to have a fixed cover on an external floating roof tank and these vessels are generally labelled as 'dome covered external floating roof tanks'. The floating roof moves between the fixed roof and liquid surface and acts as a barrier to external conditions (i.e. wind). Figure 5 illustrates a typical design for a domed external floating roof tank.

Internal floating roof tanks are very similar in design to the dome-covered external floating roof tank. The major difference between the two is in the construction of the fixed roof support structure. Generally speaking, dome-covered external floating roof tanks have no internal support columns, whereas internal floating roof tanks may have dedicated internal support columns as illustrated in Figure 4. Retrofitting of both external floating roof tanks and fixed roof tanks contribute to the construction of internal floating roof tanks. The general rule is that converted fixed roof tanks will have internal column support and converted external floating roof tanks won't. The roof can either rest directly on the liquid surface or on pontoons making the roof rest above the liquid surface. These tanks also have a rim seal system and also fitting losses from the deck and associated supports. These internal tanks are also vented by circulation vents at the top of the fixed roof to prevent build-up of any flammable vapours. One tank type where this does not occur are pressure tanks.

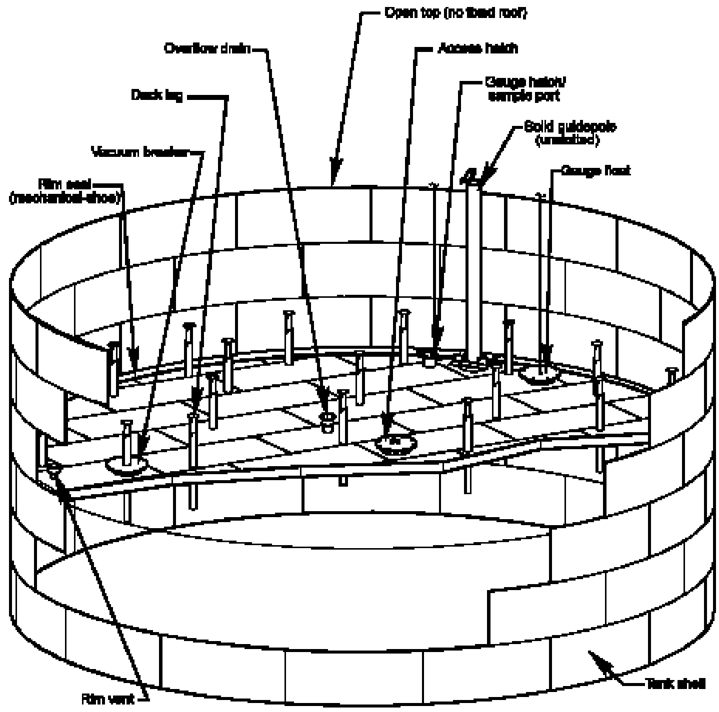


**Figure 2 External Floating Roof Tank (EFRT) - Double Deck Type Roof**

Source: Reference 2.

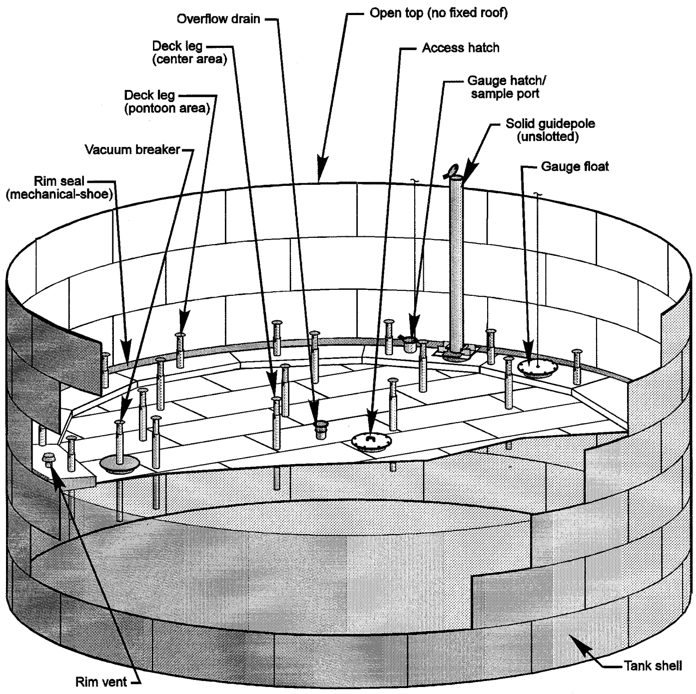


**Figure 3 External Floating Roof Tank (EFRT) - Pontoon Type Roof**

Source: Reference 2.

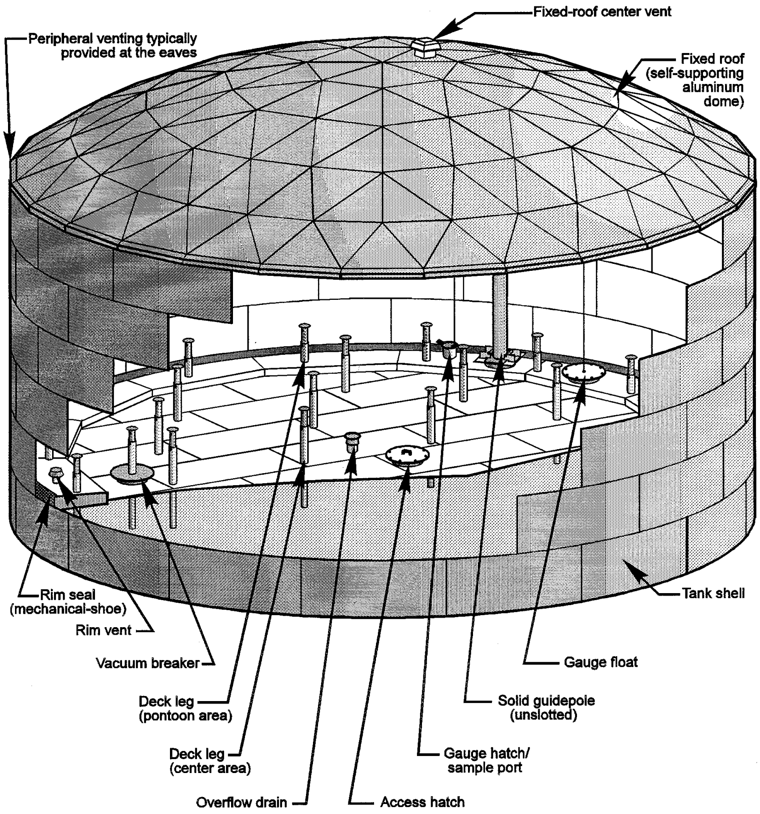


**Figure 4 Domed External Floating Roof Tank (EFRT)**

Source: Reference 2.

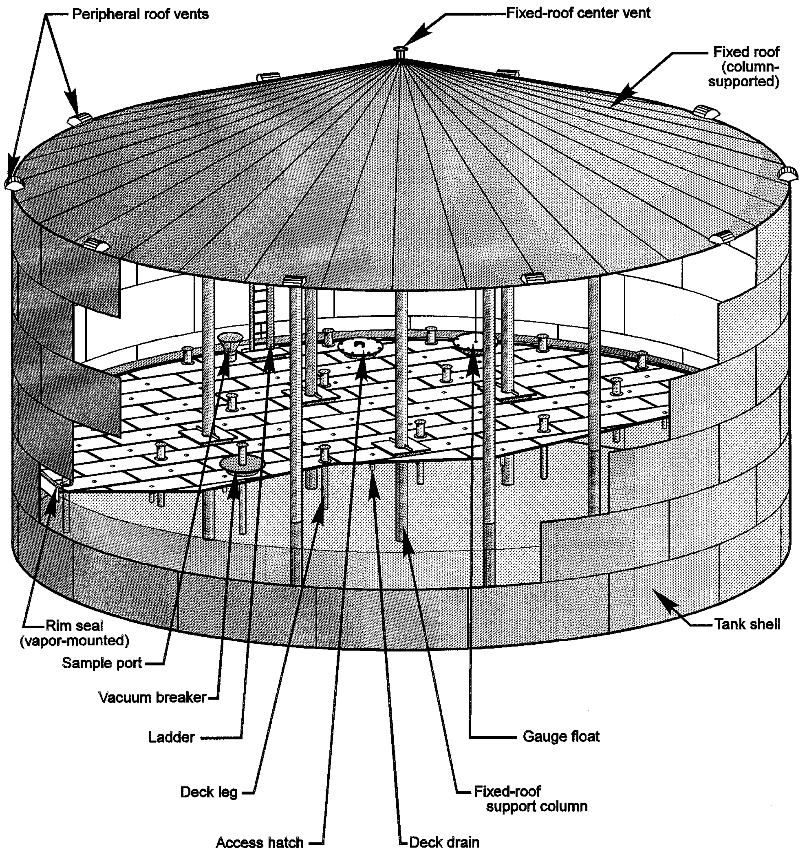


**Figure 5 Internal Floating Roof Tank (IFRT)**

Source: Reference 2.

Emissions from floating roof tanks are similar to fixed roof tanks in that standing and working emissions account for all losses accounted for using this manual. Other losses can result from spillage and similar events. Another source is standing emissions from atmospheric changes. Losses are very dependent on the construction and type of floating roof tank.

There are many common sources for emissions from both external and internal floating roof tanks. These emissions arise from the rim seal system, supports within the tanks, decks for the roof, access hatches, sample ports, vents, unwelded seams and other structural supports that are in contact with the liquid (Reference 3).

## 2.3 Variable Vapour Space Tanks

These tanks are primarily designed to accommodate vapour changes from barometric pressure and temperature effects on liquids being stored. While these tanks can be used independently, they are usually used in conjunction with fixed roof tanks. There are two common designs available, the lifter roof tank and the flexible diaphragm tank.

The lifter roof design incorporates a telescopic roof that fits loosely around the main tank wall. This roof design allows space to form between the roof and wall, which is contained by either a wet seal or a dry seal.

Flexible diaphragm tanks utilise flexible membranes to accommodate volume expansion. They can be independent units or units mounted on top of fixed roof tanks. At present the TANKS software does not calculate the emissions from these tanks due to a lack of reliable estimation techniques.

Emissions from these tank types are predominantly from working losses. The filling of the tanks causes vapour to be displaced by liquid. The variable vapour space within the tank reduces emissions from this process and emissions only occur when the vapour storage capacity is exceeded by the displaced vapour (Reference 3).

## 2.4 Pressure Tanks

The final type of tank structure is the pressure tank. This tank design operates as either high pressure or low-pressure tanks. The main use is to store organic liquids and gases that exhibit high vapour pressures. The main control is the pressure/vacuum vent, which is set to eliminate emissions from boiling and standing losses due to daily changes in barometric conditions. Under ideal operating conditions, high-pressure tanks can be used with little or no working losses, whereas low pressure tanks exhibit working losses from atmospheric venting.

Unfortunately there is minimal information in regard to emission estimation techniques for these tank designs and emissions from these tanks are not covered by the TANKS software.

# 3 EMISSIONS OF NPI SUBSTANCES

The NPI substances that are likely to be emitted from storage tanks are VOCs present in the liquid and Total VOCs which is the sum of all VOCs. For NPI reporting VOCs are any chemical compound based on carbon chains or rings (and also containing hydrogen) with a vapour pressure greater than 2mm of mercury (0.27 kPa) at 25ºC, excluding methane (see Appendix I for more detail). The storage of petroleum fuels is likely to result in emissions of the following NPI substances:

- Benzene;
- Cumene;
- Cyclohexane;
- Ethylbenzene;
- n-hexane;
- Lead and Compounds;
- Polycyclic aromatic hydrocarbons;
- Toluene (methylbenzene);
- Xylene (individual and mixed isomers); and
- Total VOCs.

Reference to toluene and xylenes within the Manual can be read as meaning Toluene (methylbenzene) and Xylene (individual and mixed isomers) respectively.

These substances can be emitted to air, water and land as described below.

## 3.1 Emissions to Air

Air emissions may be categorised as fugitive or point source emissions.

### 3.1.1 Fugitive Emissions

These are emissions that are not released through a vent or stack. Examples of fugitive emissions include dust from stockpiles, volatilisation of vapour from vats or open vessels, and material handling. Emissions emanating from ridgeline roof-vents, louvres, and open doors of a building as well as equipment leaks, and leaks from valves and flanges are also examples of fugitive emissions. Emission factor EETs are the usual method for determining fugitive emissions.

### 3.1.2 Point Source Emissions

These emissions are exhausted into a vent or stack and emitted through a single point source into the atmosphere. An air emissions control device such as a carbon adsorption unit, scrubber, baghouse, or afterburner may be added to the point source prior to the atmospheric release.

## 3.2 Emissions to Water

Emissions of substances to water can be categorised as discharges to:

- Surface waters (eg. lakes, rivers, dams, and estuaries);
- Coastal or marine waters; and
- Stormwater.

The most appropriate method for determining emissions to the environment via wastewater is to use direct measurement, however, you may use other EETs for the purposes of reporting to the NPI.

The discharge of NPI listed substances to a sewer or tailings dam is not required to be reported to the NPI but may be part of use calculations for determining if a substance exceeds NPI thresholds (see also Section 3 of *The NPI Guide*).

### 3.3 Emissions to Land

Emissions of substances to land on-site include losses of solid wastes, slurries, sediments, other spills and leaks, use of chemicals to control various elements of the environment, and similar activities where these emissions contain NPI listed substances. Emissions to land include emissions to groundwater.

Reporting of emissions is only required where the emissions occur at the facility for which reporting is being undertaken. For example, emissions from waste for which disposal has occurred at another facility need not be reported for the originating facility.

### 3.4 General Approach to Emission Estimation

Estimates of emissions of NPI listed substances to air, water and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on NPI reporting thresholds are contained in *The NPI Guide* at the front of this Handbook and on the web at http://www.npi.gov.au/.

The NPI Manuals seek to provide the most effective emission estimation techniques for the NPI substances relevant to industry. However, the absence of an EET for a substance in any EET Manual does not necessarily imply that an emission should not be reported to the NPI. The obligation to report on all relevant emissions remains for substances for which reporting thresholds have been exceeded.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility. The four types described in the *NPI Guide* are:

- sampling or direct measurement;
- mass balance;
- fuel analysis or other engineering calculations; and
- emission factors.

Select the EET (or mix of EETs) that is most appropriate for your purposes. For example, you might choose to use a mass balance to best estimate fugitive losses from pumps and vents, direct measurement for stack and pipe emissions, and emission factors when estimating losses from storage tanks and stockpiles.

If you estimate your emission by using any of these EETs, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of emission estimation techniques that are not outlined in this Handbook, your data will also be displayed as being of 'acceptable reliability'.

**You are able to use emission estimation techniques that are not outlined in NPI Handbooks. You must, however, seek the consent of your relevant environmental authority. For example, if your company has developed site-specific emission factors, you may use these if approved by your relevant environmental authority.**

In general, direct measurement is the most accurate method for characterising emissions and, where available, such data should be used in preference to other EETs presented in this Manual. However, additional direct measurement is not required for fulfilling NPI reporting requirements under the NPI NEPM. Direct measurement may be undertaken as an element of other NPI EETs or environmental reporting.

You should note that the EETs presented in this Manual relate principally to average process emissions. Emissions resulting from non-routine events are rarely discussed in the literature, and there is a general lack of EETs for such events. However, it is important to recognise that emissions resulting from significant operating excursions and/or accidental situations (eg: spills) will also need to be estimated. Emissions to land, air and water from spills must be estimated and added to process emissions when calculating total emissions for reporting purposes. The emission resulting from a spill is the net emission, i.e. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

### 3.5 Determining if Emissions Need to be Estimated and Reported

Emissions of an NPI substance need to be reported if any of its reporting thresholds are exceeded. The Category 1 and 1a reporting threshold relates to the 'use' of the substance. The Category 2 thresholds (2a and 2b) relate to the amount of fuel burnt by the facility. Total VOCs need to be reported if the 1a or 2a reporting thresholds are exceeded. Details of these Categories and the associated reporting thresholds are in *The NPI Guide* or at http://www.npi.gov.au/.

If the category 2a threshold is exceeded the emissions of the eight substances below need to be reported to the NPI:

- Carbon monoxide
- Fluoride compounds
- Hydrochloric acid
- Oxides of Nitrogen
- Particulate Matter 10.0 um
- Polycyclic aromatic hydrocarbons
- Sulfur dioxide
- Total Volatile Organic Compounds

The 21 Category 2b substances (which include all the Category 2a substances) for which NPI reporting is required if the Category 2b is exceeded are:

- Arsenic & compounds
- Beryllium & compounds
- Cadmium & compounds
- Carbon monoxide
- Chromium (III) compounds
- Chromium (VI) compounds
- Copper & compounds
- Fluoride compounds
- Hydrochloric acid
- Lead & compounds
- Magnesium oxide fume
- Mercury & compounds
- Nickel & compounds
- Nickel carbonyl
- Nickel subsulfide
- Oxides of Nitrogen
- Particulate Matter 10.0 um
- Polychlorinated dioxins and furans
- Polycyclic aromatic hydrocarbons
- Sulfur dioxide
- Total Volatile Organic Compounds

Note that reporting of emissions of nickel carbonyl or nickel subsulfide is not expected in relation to fuel organic storage. If nickel has to be reported it should be reported as nickel & compounds.

Table 1 provides typical contents of NPI substances, which are VOCs, in Australian fuels. These values can be used for calculating both Category 1 and 1a triggers. Triggering one or more Category 1 substances does not mean that you are required to report your facility's emissions of all Category 1 substances, only those substances that have been triggered.

Table 2 shows the volumes of a particular fuel, in this case diesel, that are required to trigger reporting of Category 1 and 1a NPI substances. Table 3 shows the equivalent for NPI substances triggered in Category 2a and 2b.

**Table 1 Weight percent of Various NPI Substances in the Liquid Phase for Indicative Australian Fuels**

| weight % (liquid) | PULP[4] | ULP[4] | LP[4] | Avgas[4] | Kerosene[5] | Diesel[5] | Heating Oil[5] | Fuel Oil F143[5] |
|---|---|---|---|---|---|---|---|---|
| **Benzene** | 4.3 | 3.7 | 3.6 | 1.3 | 0.01 | 0.06 | - | - |
| **Cumene** | 0.6 | 0.8 | ND | ND | 5.57* | 1.93* | - | 0.43* |
| **Cyclohexane** | 0.7 | 0.5 | 0.12 | ND | # | # | - | - |
| **Ethylbenzene** | 2.3 | 1.7 | 1.2 | ND | 0.38 | 0.19 | 0.07 | - |
| **n-hexane** | 2.5 | 3.0 | 2.2 | ND | # | # | - | - |
| **Lead and compounds** | 0.0001 | 0.001 | 0.019 | 0.073 | - | - | - | - |
| **PAH** | ND | 0.3 | 0.3 | ND | 0.43 | 0.42 | 0.80 | 0.47 |
| **Toluene** | 13.5 | 12.2 | 11.0 | 1.6 | 0.24 | 0.15 | 0.08 | - |
| **Xylenes** | 14.9 | 12.6 | 11.3 | 0.7 | 2.61 | 0.39 | 0.33 | - |
| **Total VOC** | **>99** | **>99** | **>99** | **ND** | **38** | **7.6** | **12** | **3.0** |
| **Average Fuel Density(kg/L)** | **0.739** | **0.739** | **0.739** | **ND** | **ND** | **0.836** | **ND** | **ND** |

Notes:
1. Source: References 4 and 5, as indicated above.
2. * all C3-alkylated benzene isomers
3. # grouped in C6-C10 compounds
4. ND = No Data
5. Scientific notation is used: e.g. 7.38E-02 represents 7.38 x $10^{-2}$ or 0.0738 and 7.38E+02 represents 7.38 x $10^{+2}$ or 738.

**Table 2 Diesel usage that triggers Category 1 and 1a thresholds for six NPI substances.**

| NPI Substance | Concentration in diesel (ppm)[1] | Threshold Category | Mass of NPI substance required to trigger (t) | Diesel usage required to trigger threshold (t) | Diesel usage required to trigger threshold (litres)[2] |
|---|---|---|---|---|---|
| Benzene | 600 | 1 | 10 | 16,667 | 2.0E+07 |
| Cumene | 19,300 | 1 | 10 | 518 | 6.2E+05 |
| Ethylbenzene | 1,900 | 1 | 10 | 5,263 | 6.3E+06 |
| Toluene | 1,500 | 1 | 10 | 6,667 | 8.0E+06 |
| Total VOCs | 76,000 | 1a | 25 | 329 | 3.9E+05 |
| Xylene | 3,900 | 1 | 10 | 2,564 | 3.1E+06 |

Notes:
1. Data drawn from Table 1.
2. Based on fuel density values given in the NPI Guide (v.2.8).
3. Scientific notation is used: e.g. 7.38E-02 represents 7.38 x $10^{-2}$ or 0.0738 and 7.38E+02 represents 7.38 x $10^{+2}$ or 738.

**Table 3 Approximate fuel usage required to trigger Category 2 thresholds.**

| Fuel type | Category 2a (minimum limits) | Category 2b (minimum limits) | Fuel Density[1] |
|---|---|---|---|
| Diesel | 4.78E+05 L per reporting year<br>OR<br>1.20E+03 L in any one hour during the reporting year | 2.39E+06 L per reporting year | 8.36E-01 kg/L |
| Petrol | 5.41E+05 L per reporting year<br>OR<br>1.35E+03 in any one hour during the reporting year | 2.71E+06 L per reporting year | 7.39E-01 kg/L |

Notes:
1. Based on fuel density values given in the NPI Guide (v.2.8).
2. Scientific notation is used: e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.

Example 1 and Example 2 show the calculations required to assess each of these categories.

## Example 1 Calculating triggers related to fuel storage and combustion.

This example illustrates the steps required to calculate threshold exceedances for fuel used in a small mine in the Pilbara region of Western Australia. The mine used 764kL of diesel during the reporting year.

***Step 1*** *Convert volume of fuel consumed from kilolitres to tonnes.*

To convert from kilolitres to tonnes, the volume of fuel is converted to litres (kL*1000) and then to tonnes using the specific gravity provided on the Material Safety Data Sheet (MSDS) and divided by 1000 to convert from kg to tonnes.

| *Fuel Type* | *Litres used* | | *Specific Gravity* | | *Kilograms Used* | | *Conversion from kg to t* | *Tonnes Used* |
|---|---|---|---|---|---|---|---|---|
| Diesel | 781,360 | * | 0.836 | = | 653,220 | / | 1000 | = 653.2 |
| | | | | | | | **Total tonnes burned** | **= 653.2t** |

This shows that more than 400t of fuel was consumed during the reporting period, hence triggering the Category 2a threshold.

***Step 2*** *Assess the Total VOC Content of the fuels to calculate whether the Category 1a Threshold is exceeded.*

The total VOC content of various fuels is provided in Table 1. Total VOC content for fuels not in the table may also be on the MSDS for that particular fuel type. This percentage needs to be multiplied by the Tonnes Used of each of the fuel types and divided by 100.

| *Fuel Type* | *Tonnes Used* | | *VOC Content (%)* | | | | *VOC Used (t)* |
|---|---|---|---|---|---|---|---|
| Diesel | 653.2 | * | 7.6 | / | 100 | = | 49.6 |
| | | | | | **Total VOCs Used** | **=** | **49.6t** |

The tonnage of Total VOCs used by the facility exceeds the threshold of 25 tonnes per year, hence the Category 1a threshold was triggered.

***Step 3*** *Determine the mass (in tonnes) of each NPI substance in the Diesel consumed.*

Multiply the tonnes of fuel consumed by the concentration of the particular NPI substance in the fuel. To convert this into tonnes (t), divide it by 100.

| *NPI Substance* | *Tonnes Consumed* | | *Conc. (%)* | | | | *Mass handled (t)* | *Triggered?* |
|---|---|---|---|---|---|---|---|---|
| Benzene | 653 | | 0.06 | / | 100 | = | 0.39 | No |
| Cumene | 653 | | 1.93 | / | 100 | = | 12.6 | Yes |
| Ethylbenzene | 653 | | 0.19 | / | 100 | = | 1.25 | No |
| Toluene | 653 | | 0.15 | / | 100 | = | 0.98 | No |
| Xylene | 653 | * | 0.39 | / | 100 | = | 2.55 | No |

The example shows that Cumene was triggered through the Category 1 threshold, Total VOCs through the Category 1a threshold and all Category 2a substances were triggered by this facility.

### Example 2 Calculating triggers related to fuel storage and combustion.

This example illustrates the steps required to calculate threshold exceedances for fuel used in a large industrial complex in the Pilbara region Western Australia. The operation used 2,716kL of diesel and 122kL of ULP during the reporting year.

***Step 1*** *Convert volume of fuel consumed from kilolitres to tonnes.*

To convert from kilolitres to tonnes, the volume of fuel is converted to litres (kL*1000) and then converted to tonnes using the specific gravity provided on the Material Safety Data Sheet (MSDS) and divided by 1000 to convert from kg to tonnes.

| *Fuel Type* | *Litres used* | | *Specific Gravity* | | *kg Used* | | *Conversion from kg to t* | *Tonnes Used* |
|---|---|---|---|---|---|---|---|---|
| Diesel | 2,716,000 | * | 0.836 | = | 2,270,576 | / | 1000 | = 2,270.6 |
| ULP | 122,000 | * | 0.739 | = | 90,158 | / | 1000 | = 90.2 |
| | | | | | | | **Total tonnes burned** | **= 2,361t** |

This shows that more than 2000t of fuel was burnt during the reporting period triggering the Category 2b threshold. Emissions of all Category 2 substances, from all sources, should be reported to the NPI.

***Step 2*** *Assess the Total VOC Content of the fuels to calculate whether the Category 1a Threshold is exceeded.*

The total VOC content of various fuels is provided in Table 1. Total VOC content for fuels not in the table may also be on the MSDS for that particular fuel type. This percentage needs to be multiplied by the Tonnes Used of each of the fuel types and divided by 100.

| *Fuel Type* | *Tonnes Used* | | *VOC Content (%)* | | | | *VOC Used (t)* |
|---|---|---|---|---|---|---|---|
| Diesel | 2,270.3 | * | 7.6 | / | 100 | = | 172.5 |
| ULP | 90.7 | * | 99.0 | / | 100 | = | 89.8 |
| | | | | | **Total VOCs Used =** | | **262.3 t** |

The use of Total VOCs used by the facility exceeds the threshold of 25 tonnes per year, hence the Category 1a threshold was triggered.

***Step 3*** *Determine the mass (in tonnes) of each NPI substance in the Diesel and ULP consumed to see whether relevant Category 1 thresholds are exceeded.*

Multiply the tonnes of fuel consumed by the concentration of the particular NPI substance in the fuel. To convert this into tonnes (t), divide it by 100.

**Example 2 (cont.)**

| *NPI Substance* | *Fuel used* | *Tonnes Consumed* | *Conc. (%)* | | | *Mass handled each fuel type (t)* | *Total mass handled (t)* | *Triggered (Yes/No)* |
|---|---|---|---|---|---|---|---|---|
| Benzene | Diesel | 2,270.3 | * 0.06 | /100 | = | 1.36 | | |
| | ULP | 90.7 | * 3.7 | / 100 | = | 3.34 | 4.7 | No |
| Cumene | Diesel | 2,270.3 | * 1.93 | / 100 | = | 43.8 | | |
| | ULP | 90.7 | * 0.8 | / 100 | = | 0.72 | 44.5 | Yes |
| Cyclohexane | Diesel | 2,270.3 | * 0 | / 100 | = | 0.00 | | |
| | ULP | 90.7 | * 0.5 | / 100 | = | 0.45 | 0.5 | No |
| Ethylbenzene | Diesel | 2,270.3 | * 0.19 | / 100 | = | 4.31 | | |
| | ULP | 90.7 | * 1.7 | / 100 | = | 1.53 | 5.8 | No |
| n-Hexane | Diesel | 2,270.3 | * 0 | / 100 | = | 0.00 | | |
| | ULP | 90.7 | * 3.0 | / 100 | = | 2.71 | 2.7 | No |
| Toluene | Diesel | 2,270.3 | * 0.15 | / 100 | = | 3.41 | | |
| | ULP | 90.7 | * 12.2 | / 100 | = | 11.0 | 14.4 | Yes |
| Xylene | Diesel | 2,270.3 | * 0.39 | / 100 | = | 8.86 | | |
| | ULP | 90.7 | * 12.6 | / 100 | = | 11.4 | 20.3 | Yes |

The tonnage of Cumene, Toluene and Xylene used by the facility exceeds 10 tonnes per year, hence the Category 1 threshold for these NPI substances was triggered by this facility.

A worksheet for the calculation of triggers is provided as Appendix II.

# 4 EMISSION ESTIMATION USING TANKS 4.09

This EET is required for facilities with a storage capacity of greater than 500kL of organic liquids.  For smaller facilities the EET in Chapter 5 can be used.

This section of the Manual provides installation and general use instructions for the TANKS software.

## 4.1 Introduction to TANKS 4.09b

The TANKS 4.09b program was developed by the American Petroleum Institute (API) to estimate air emissions from organic liquids in storage tanks (Reference 6).  The procedures and equations used in estimating emissions from this software are discussed in Reference 6 which can be obtained at http://www.epa.gov/ttn/chief/software/tanks/index.html.  The equations used are presented in Appendix III for further clarification and have been reproduced on the understanding that they remain the property of the API and will not be sold or reproduced without the written permission of the API (Reference 3).

TANKS allows users to enter information about their storage tanks (dimensions, construction design, paint condition), the liquid contents (chemical components), and the location of the tank (nearest town or city), to generate an estimation of air emissions for that substance or mixture of substances. The generated data provides an annual estimate of atmospheric emissions for all NPI-listed substances such as Benzene and Toluene (either singly or in mixtures) contained in the storage tank.

Version 4.09b of TANKS, represents an upgrade version of version 4.0 that includes new features and revisions. Although releases of version 3.1 and 4.08 including any later releases are acceptable it is recommended that the latest version of TANKS is used for NPI reporting.

It must be noted that the API developed the emission estimating equations that form the basis of the TANKS program. API retains the copyright to these equations. The API has granted permission for the non-exclusive, non-commercial distribution of this material to governmental and regulatory agencies. However, the API reserves its rights regarding all commercial duplication and distribution of its material. The TANKS program is therefore available for public use, but cannot be sold without written permission from the API.

## 4.2 Physical Units Used by TANKS

The TANKS program requires input data and results to be expressed in US units. In particular note any work involving TANKS the unit gallon or gal refers to US gallons. To assist Australian manufacturing, industrial and service facilities that predominantly work with metric (SI) units the unit conversion factors in Table 4 is provided.  To convert from the unit in Column 1 to that in Column 2 multiply by Column 3.

**Table 4 Unit conversion factors for use with TANKS 4.09b**

| COLUMN 1<br>To convert from | COLUMN 2<br>To convert to | COLUMN 3<br>Multiply by |
|---|---|---|
| ***Mass*** | | |
| Kilogram (kg) | Pound (lb) | 2.205E+00 |
| Pound (lb) | Kilogram (kg) | 4.540E-01 |
| Tonne (metric) | Ton (US~2 000lb) | 1.102E+00 |
| Ton (US~2 000lb) | Tonne (metric) | 9.070E-01 |
| Tonnes (t) | Kilograms (kg) | 1.000E+03 |
| Kilograms (kg) | Tonnes (t) | 1.000E-03 |
| ***Volume*** | | |
| US gallon[3] | Cubic metres ($m^3$) | 3.785E-03 |
| Cubic metres ($m^3$) | US gallon | 2.642E+02 |
| US gallons | Litres (L) | 3.785E+00 |
| Litres (L) | US gallons | 2.642E-01 |
| Litres (L) | Cubic foot ($ft^3$) | 3.530E-02 |
| Cubic foot ($ft^3$) | Litres (L) | 2.833E+01 |
| ***Length*** | | |
| Metres (m) | Foot (ft) | 3.280E+00 |
| Foot (ft) | Metres (m) | 3.040E-01 |
| ***Temperature*** | | |
| Celsius ($^oC$) | Fahrenheit ($^oF$) | $9/5*^oC + 32$ |
| Fahrenheit ($^oF$) | Celsius ($^oC$) | $(^oF – 32)*5/9$ |
| ***Pressure*** | | |
| lb per square inch (psi) | Hectopascal (hPa) | 6.900E+01 |
| Hectopascal (hPa) | lb per square inch (psi) | 1.449E-02 |
| Millibar | Hectopascal | 1 |

Note:
1. The unit psi is either psig (pound per square inch gauge) or psia (pounds per square inch absolute). Gauge is in reference to 1 atmosphere pressure (14.7 psia or 101.3 kPa)
2. Scientific Notation is used: e.g. 3.9E-02 represents $3.9 \times 10^{-2}$ or 0.039.
3. Note US gallons are **<u>not</u>** the same as UK gallons.
4. In relation to any work involving TANKS the unit gallon or gal refers to US gallons.

## 4.3 Installation of TANKS 4.09b

### 4.3.1 Hardware Requirements

The TANKS 4.09b program requires, at a minimum, an IBM-compatible 486 or higher processor with 8MB of Random Access Memory (RAM) and 10MB of free hard disk space. An additional 15MB of hard disk space will be required to accommodate large databases or back-up databases.

### 4.3.2 Software Requirements

TANKS 4.09b is a Windows-based application. To use this program you will need to be running under Windows 95, 98, or Windows NT.

### 4.3.3 Installation and Running of TANKS 4.09b

To download and install TANKS you may need to have System Administrator's Rights. To access the TANKS program you may obtain it free of charge from either your State or Territory's NPI section or download from the US EPA's website at: http://www.epa.gov/ttn/chief/software/tanks/index.html. If you download TANKS from the website check your systems requirements to ensure that your computer has the correct hardware configuration (Reference 6).

At the main page of the website click on 'Software and Tools' and then click on 'TANKS' in the 'CHIEF Software & Tools'. This will follow onto the 'TANKS Emission Estimation Software' page where you will select 'How to get *TANKS*'. The next step is to scroll down the page and click on the 'exe 14.3M' icon for 'Tanks 4.09b Installation File –32 bit'. Save the file and download it to a folder that you create on your hard drive. Once the download is completed go to where you saved the file and run the executable file (Tanks409b.exe).

The installation guide will prompt you through the setup process. Once the program is installed reboot your computer and follow the on-screen instructions for downloading the Users' Manual which will appear in Adobe Acrobat and/or WordPerfect format. The User's Manual explains the many features and options of TANKS. On-line help for every screen is available to assist you with the use of TANKS.

To access the program thereafter, you may start the program by selecting Start Menu/Programs/TANKS 4.0(32 bit)/TANKS40.

### 4.3.4 Installation of Australia's Climate and Fuel data

Figure 6 illustrates the specific regions, towns and cities where climatic data such as maximum and minimum temperatures are available. Default regional meteorological data has been developed using averaged data for various locations within each region. These data can be used in the absence of specific meteorological data for a given location.

The twelve regions outlined on the map are the South Australia South (1), Western Australia South (2), Western Australia Central (3), Australia North (4), Australia Central (5), Queensland Far North East (6), Queensland Central North (7), Queensland Central (8), Queensland South (9), New South Wales (10), Victoria (11), Tasmania (12). They are based on regions identified in the Australian Standard for automotive diesel fuel (Reference 7).


**Figure 6 National Climatic Map of meteorological data locations and 12 regions.**

To obtain meteorological data, select your nearest city or town or alternatively select the region that is most applicable to the location of your facility (Figure 6). Meteorological data for Australia (named AUStankdata.mdb) must be linked to the TANKS program in order to select the appropriate region. To obtain the Australian meteorological data, go to the NPI homepage (http://www.npi.gov.au) under Industry Manuals and Fuel and Organic Liquid Storage to download the database. Save the AUStankdata.mdb file in the same location as TANKS 4.09b on the hard drive for example – C:/Program Files/TANKS 4.0. Then run the TANKS program from Start/Programs/TANKS 4.0/TANKS40.

The following steps will enable you to access the AUStankdata.mdb file once the TANKS program has been downloaded to your hard drive.

***Step One***

Open up the program and then select the 'Change Database Locations' by selecting the 'File' menu tab at the top left of the main page. A small window titled 'Change Database Files' will appear (Figure 7). This will allow you to change the tank data and the client database files that are currently being used by TANKS. The 'Tank database' contains the chemical, meteorological, fitting, rim seal, deck seam and profile information. The 'Client database' contains stored information used during the data entry for each tank record.

*Step Two*

In this case, only the tank database is to be changed (the client database should remain as the default) by choosing the 'Browse' button in this window and scrolling down to select Program Files/TANKS 4.0.

*Step Three*

Select the AUStankdata.mdb file and click 'Open'. Then click 'OK' when you have specified the new tank database. You will now be asked if you want to backup the tank database prior to the new database location being changed.

*Step Four*

If you select 'yes' to backup the tank database, a window titled 'Backup to Tank Database To' will appear on the screen and the program will prompt you for a file location (Figure 8). The system will overwrite current data with the file selected that means it will replace the data in the current database. If you do not choose to backup your tank database and immediately following a backup, another small window will open and acknowledge the database locations are changed once you press 'OK'.

The TANKS program is now ready for use with Australian meteorological data.

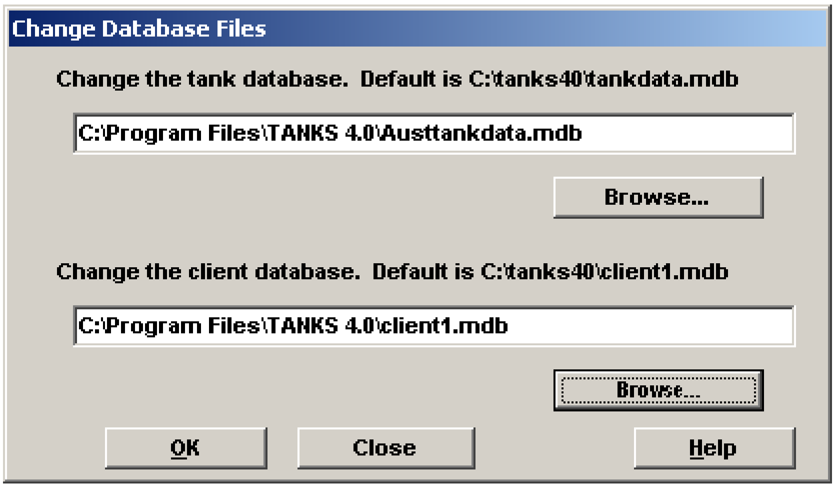


**Figure 7 Change Database Locations Screen**

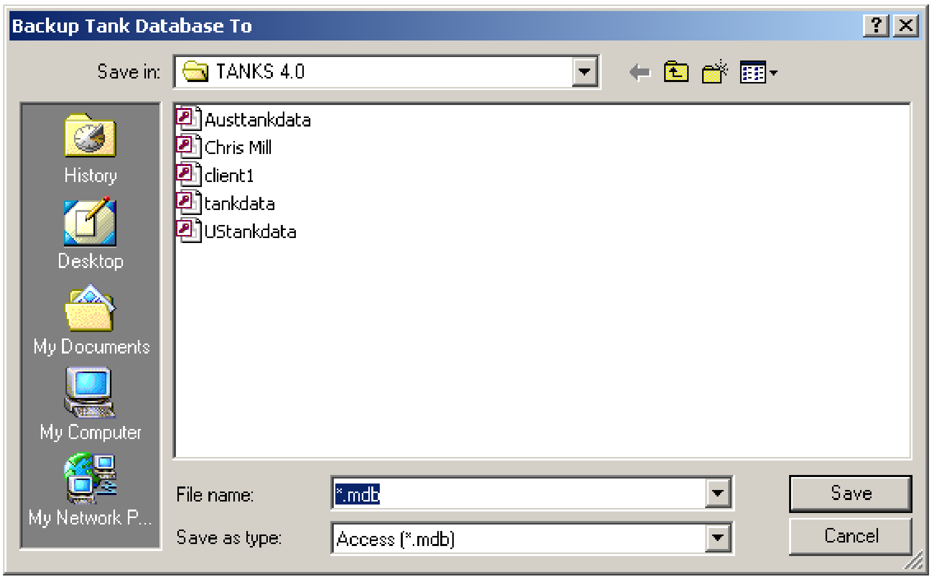


**Figure 8 Backup Tank Database to ensure data is not lost**

## 4.4 Using TANKS 4.09b

The TANKS calculations completes the emission estimates for tanks individually, but the client database can contain details of all the tanks operated by a facility and provides reports on the total emissions from all the tanks at a facility.

To start TANKS 4.09b, go to the Start menu/Programs and select TANKS 4.0 (32-bit)/tanks40 to execute the program. Upon start-up, a screen will appear describing the API's copyright to the emissions equations. Click 'OK' to continue to the TANKS Main Menu. The five main options on the main menu are as follows:

**File.** This menu allows you to create a new client database or change the database locations. The client database contains information specific to your facility's tanks. Use a filename that is useful to you and your organisation. Be sure to back-up the file after any changes are made.

The tank database contains the chemical, meteorological, rim seal, fitting, deck seam and speciation profile data. The Austtanks.mdb database should be used in place of the default file provided with TANKS. Additional site-specific data can be added this file (e.g. meteorological or chemical data) if required. Be sure to back-up the file after any changes are made.

**Data.** This menu contains the major data functions including options to create, edit, delete, import, export and/or print: tank records, chemical data, meteorological data, fittings data, rim seam data, deck seam data and profile data.

**Report.** This menu allows you to select the level of detail for tank records on an annual or monthly basis for emissions report.

**Backup.** This menu allows you to backup and restore data for both the client and tank databases.

**Help.** This menu allows you to access the online help and a brief description of the TANKS 4.09b program.

The TANKS program requires specific information about a storage tank and the liquid it contains to calculate the tank's air emissions. This information is entered and stored in the tank records. The four categories of information in a tank record are as follows:

1. **Identification Information** that enables the user to enter information allowing identification of the tank for future reference.

2. **Physical Characteristics** on the construction type and physical characteristics of the storage tank.

3. **Site Information** involving the tank's nearest major city for which meteorological data are available, is necessary to assign average ambient temperature, maximum and minimum temperature, atmospheric pressure and wind speed variables to the tank information. New cities may be added to the database using the DATA/Meteorological/Edit Database option from the program's main menu.

4. **Liquid Information** identifies the chemical components and properties of the stored liquid including the time they are stored that is required to determine the overall vapour pressure of the liquid and its constituents present in many air emissions. New chemicals or mixtures may be added to the database using the DATA/Chemical/Edit Database option from the program's main menu.

It is important to enter as much information as possible to ensure that each variable in the calculations is available to the program. Insufficient information may prevent the program from generating an emissions report (User's Guide to Tanks, Emission Factor and Inventory Group, 1999).

## 4.5 Specific Instructions for Various Tanks

To create a new record, you can either select 'Create a New Tank Record' and the appropriate Tank Type on the 'welcome screen' (Figure 9) or if the programme has been previously opened then to create a new record one of the buttons shown in Figure 10 needs to be selected. For all tank types the input screen are the same except for the physical characteristics. Definitions of all input screens are provided in Table 5.


**Figure 9 Welcome to TANKS4.0 Screen**


**Figure 10 Selecting a New Tank Record**

Where the acronyms are as follows:

- HFRT = Horizontal Fixed Roof Tank
- VFRT = Vertical Fixed Roof Tank
- IFRT = Internal Floating Roof Tank
- EFRT = External Floating Roof Tank
- DEFRT = Domed External Floating Roof Tank.

Once the tank type has been selected, the programme provides a data entry screen for the specific tank type chosen. Descriptions of each of these have been provided in the subsections 4.5.1 to 4.5.5.

**Table 5 Definition of Input Screens for all Tank Types**

| Type of Input Screen | Details |
|---|---|
| Identification | This screen allows the user to add identification details for each individual tank. Identification details include an identification number and a description of the tank which are both mandatory fields. Optional details may be added into the following fields – State, City and the Company of which the tank is located. |
| Physical Characteristics | This screen allows the tank physical characteristics to be entered for a particular tank. The Physical Characteristics input screens are specific to each tank type. All fields under tank dimensions, shell characteristics, roof characteristics and breather vent settings must be entered. |
| Site Selection | Site Selection is identical for all 5 tank types. This input screen is in relation to the nearest major city from which meteorological data has been obtained from the nearest weather station. If the tank's location is not included in the list of cities, it may be added to the list if all the meteorological data are available. |
| Tank Contents | Tank Contents provides the information required to estimate emissions for individual components that are contained in fuel. This input screen varies according to the tank type. The type of information recorded applies to the liquid contents and whether the tank is heated. |
| Monthly Calculations | At the monthly calculations input screen, monthly data is entered to calculate emissions for the year. The throughput volume of fuel is assumed to apply to the entire year however if the tank has a different monthly throughput other than the default, the value for that month may be changed at this screen. |

### 4.5.1 Horizontal Fixed Roof Tanks (HFRT)

Horizontal Fixed Roof Tanks are constructed for both above-ground and underground storage with the axis parallel to the foundation. The fixed roof may be dome-shaped or cone-shaped. Horizontal fixed roof shells may consist of steel, steel with a fibreglass overlay or fibreglass-reinforced polyester. Input parameters required for horizontal tanks are shown in Table 6 and the data entry screens that need to be completed for horizontal tanks are shown below.

**Table 6 Input Parameters Required for Horizontal Fixed Roof Tanks**

| **Inputs** | |
|---|---|
| *Tank characteristics* | *Shell characteristics* |
| Tank shell height (ft) | Shell colour/shade |
| Tank shell diameter (ft) | Shell condition |
| Turnovers/yr (number of times the tank was filled) | |
| Working Volume (gal) (average refill volume) | *Vent settings* |
| Tank heated or not heated | Vacuum settings (psig)[1] |
| Tank underground or above ground | Pressure settings (psig)[1] |
| [1] Default Values are automatically provided in the software if no site specific data is available | |

### *Identification Screen*

Regardless of the tank type chosen, an Identification Input Screen will be provided where the following can be entered into the tank records: Identification Number, Description, State, City and Company (Figure 11). Use Identification Number details which make sense in reference to that used at your facility in order to locate the appropriate file at a later date.

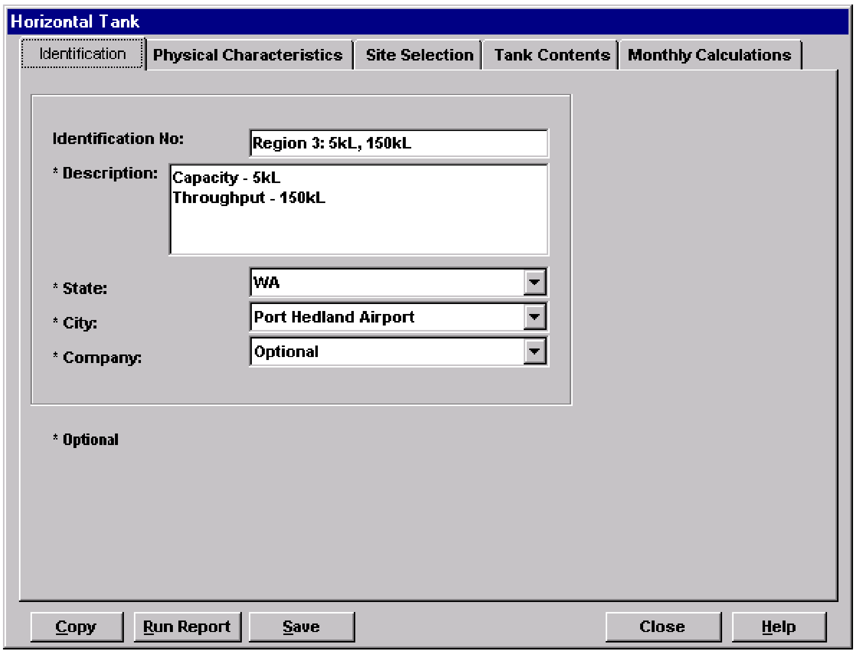


**Figure 11 Identification Input Screen for all tank types**

**Identification Number** - This allows the user to enter a name identifying the record for future use.

**Description** - This is an optional field where the user can enter any information about a tank record.

**City** - This is an optional field used to identify the city in which the storage tank is located. A city may be chosen from the pull-down menu or entered as one if not on the list. The city chosen may be different to that selected on the Site Selection menu.

**State** - This is an optional field to identify the state in which the storage tank is located. A State that is chosen may be different to the one selected on the Site Selection menu.

**Company -** This is an optional field used to identify the company that owns or uses the storage tank(s). A company name may be chosen from the pull-down menu or entered as one if not on the list.

***Physical Characteristics***

After entering in the identification information, the physical Characteristics tab must be selected and the fields completed on this screen (Figure 12).

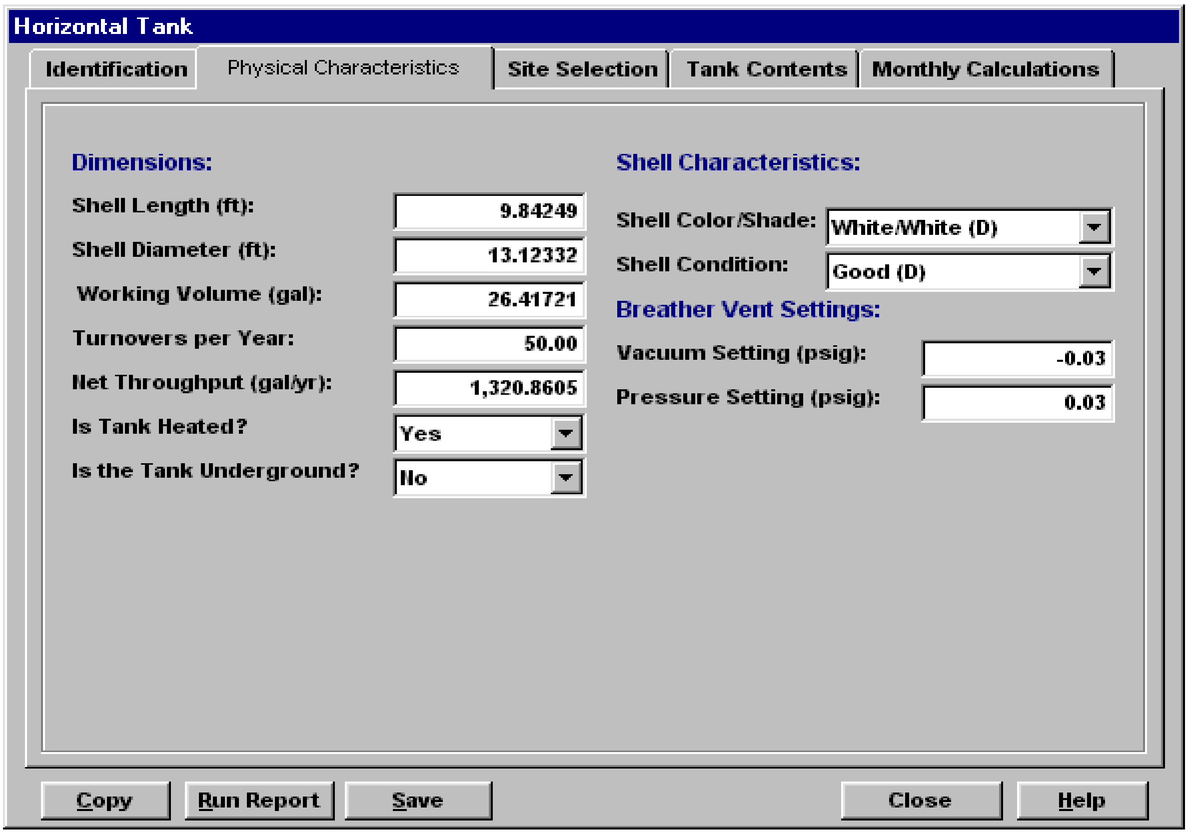


**Figure 12 Example of Horizontal Fixed Roof Tank Input Screen**

**Shell Height -** This is the total length of the tank shell in feet.

**Diameter -** This is the width in feet of the cross section of the tank shell.

**Working Volume -** This is the average volume (gallons) transferred into the tank each time the tank is refilled.

**Turnovers per Year -** This is the number of times per year the tank refilled. To calculate the number of turnovers per year, divide the throughput per year by the working volume.

**Net Throughput -** This is the annual net throughput in gallons per year. Once the working volume and the number of turnovers per year have been entered, the program will automatically calculate the net throughput.

**Is Tank Heated?** Select 'Yes' if the tank is heated or temperature controlled so that the ambient temperature conditions are not the sole factors affecting the surface temperature of the liquid stored in the tank. When entering chemical data for a new substance (not stored in the TANK's chemical database) the operator will be asked to provide the surface temperature (maximum, minimum and average temperatures) and the bulk temperature of the liquid.

**Is the Tank Underground?** If the tank is stored underground select 'Yes', or if not select 'No' from the pull-down list. Underground tanks are assumed to have no 'breathing' losses, since the insulation of the earth limits the diurnal (daily) temperature change.

**Shell Colour/Shade -** This is the colour and shade combination of the paint on the shell (sides) of the tank. Select the nearest colour/shade combination of the tank by viewing the options from the pull-down menu. If the tank colour is unknown, the default colour should be chosen, that is select 'White/White'. It must be noted that this field only applies to above-ground tanks.

**Shell Condition -** The shell condition refers to the condition of the paint on the sides of the tank shell. If the condition of the shell paint is unknown, use the default condition, that is select 'Good'. Note that this field only applies to above-ground tanks.

**Vacuum Setting -** This is the storage tank vacuum setting in psig units. The vacuum setting selected must be between 0 and –1psig. If the vacuum setting is unknown, use the default setting of –0.03psig. Note that the program will automatically change the value of the number from positive to negative.

**Pressure Setting -** This is the storage tank pressure setting in psig units. The pressure setting must be between 0 and 1psig. The default pressure setting is 0.03psig. Note that the fixed roof tank emissions estimation procedures do not apply to low and high pressure tanks. For constant temperature tanks and underground tanks, the breather and pressure vent settings must be set to zero.

### *Site Selection*

The Site Selection Input Screen is identical for all five tanks (Figure 13). The user is required to enter the nearest major city (or region as shown in Figure 6). To display the list of cities and regions in the database, use the pull-down menu.

Note that once the nearest major city is selected, meteorological data is automatically given for average temperature, wind speed, solar insulation and atmospheric pressure.

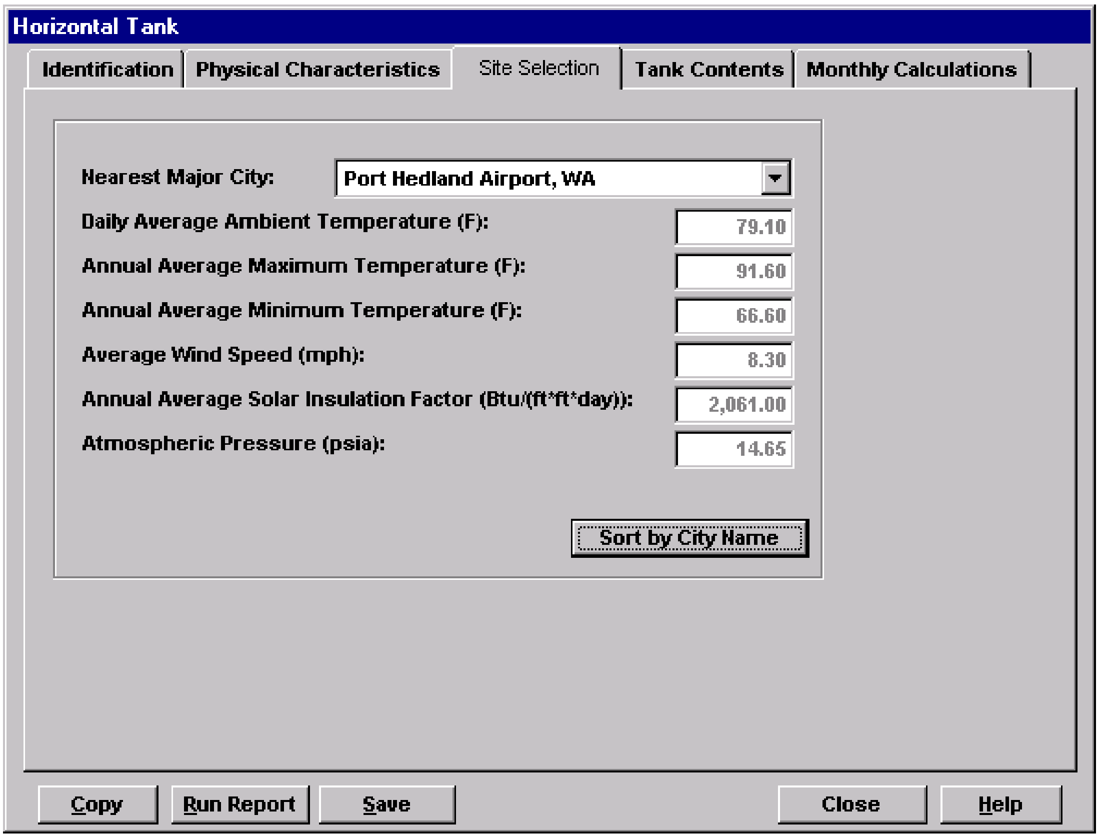


**Figure 13 Site Selection Input Screen for Horizontal Fixed Roof Tanks**

### *Tank Contents*

After entering all tank, fitting (if applicable) and site data for the tank, click on the 'Tank Contents' tab as shown in Figure 14. This field will vary depending on what type of tank is chosen, whether the tank is heated and the liquid contents. The Tank Contents fields give the information based on the stored liquid components in order to make an estimation of emissions.

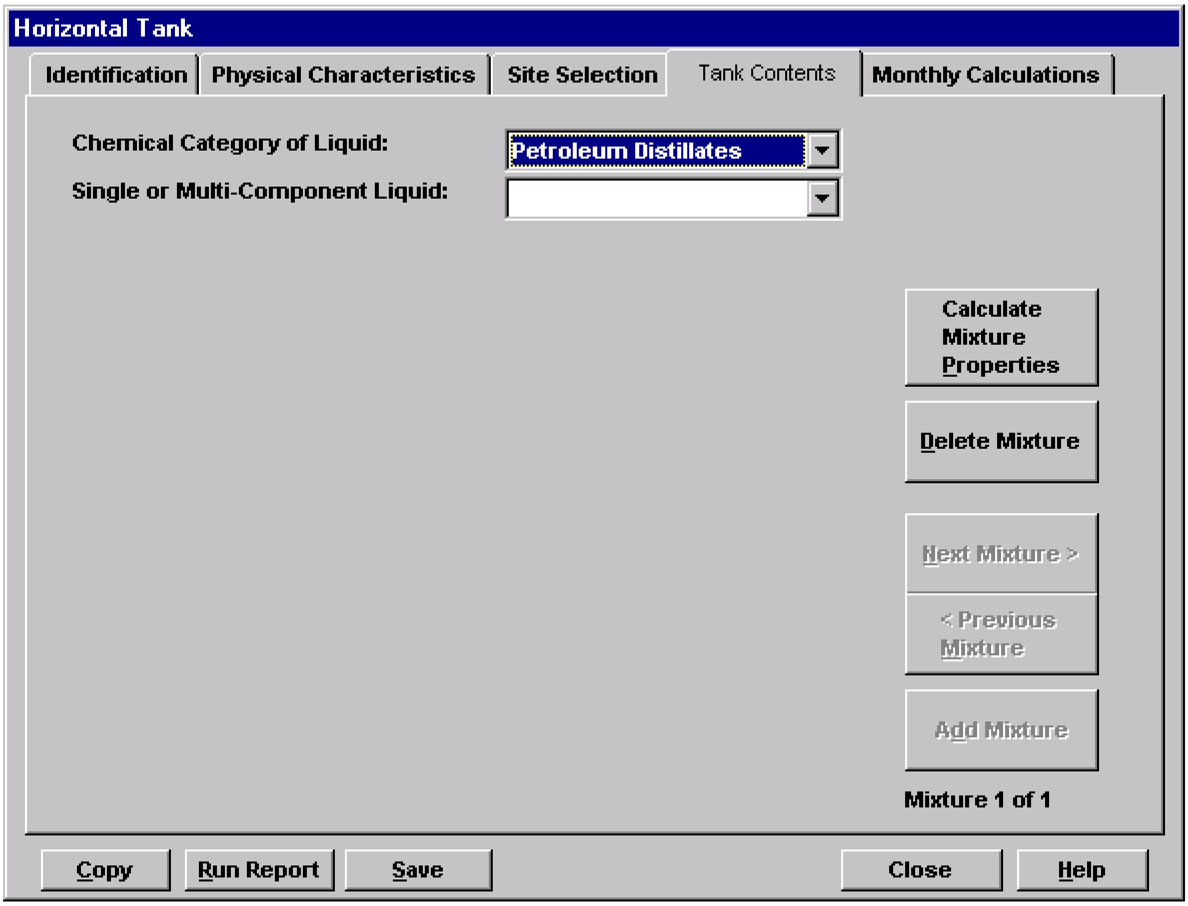


**Figure 14 Tank Contents Input Screen for all tank types**

The following liquid information fields apply to all tanks:

**Chemical Category of Liquid**

The three chemical categories of liquid to choose from as follows: Organic Liquids, Petroleum Distillates and Crude Oils. To select the appropriate chemical category use the pull-down menu to display these options. Click to select the category chosen.

Note Petroleum distillates include refined petroleum stocks, jet fuels, gasoline and distillate fuels. Crude Oils are unrefined petroleum stocks. Organic liquids include all other organic compounds.

**Single or Multi-Component Liquid**

This field indicates whether the liquid stored in the tank consists of a single component or a mixture of components. If the contents of the mixture are known then select 'Single' by the pull-down menu and click on the highlighted component selected (Figure 15). If the contents of a mixture are unknown, partially known or mixtures of components listed in the chemical database, select 'Multiple'.

For further information on using the Multiple-Component option refer to Section 4.7.1.

When changing from a Single to Multiple component, the program may erase other fields of liquid data. Petroleum distillates and crude oils may be entered as Single-Component liquids if the emissions estimates of individual substances are not required (this will produce a report detailing the quantity of Total VOCs emitted from the tank). However if a breakdown of emissions by underlying components is needed from TANKS, for example, benzene emissions from storing gasoline, enter the liquid data as a Multi-Component Liquid.

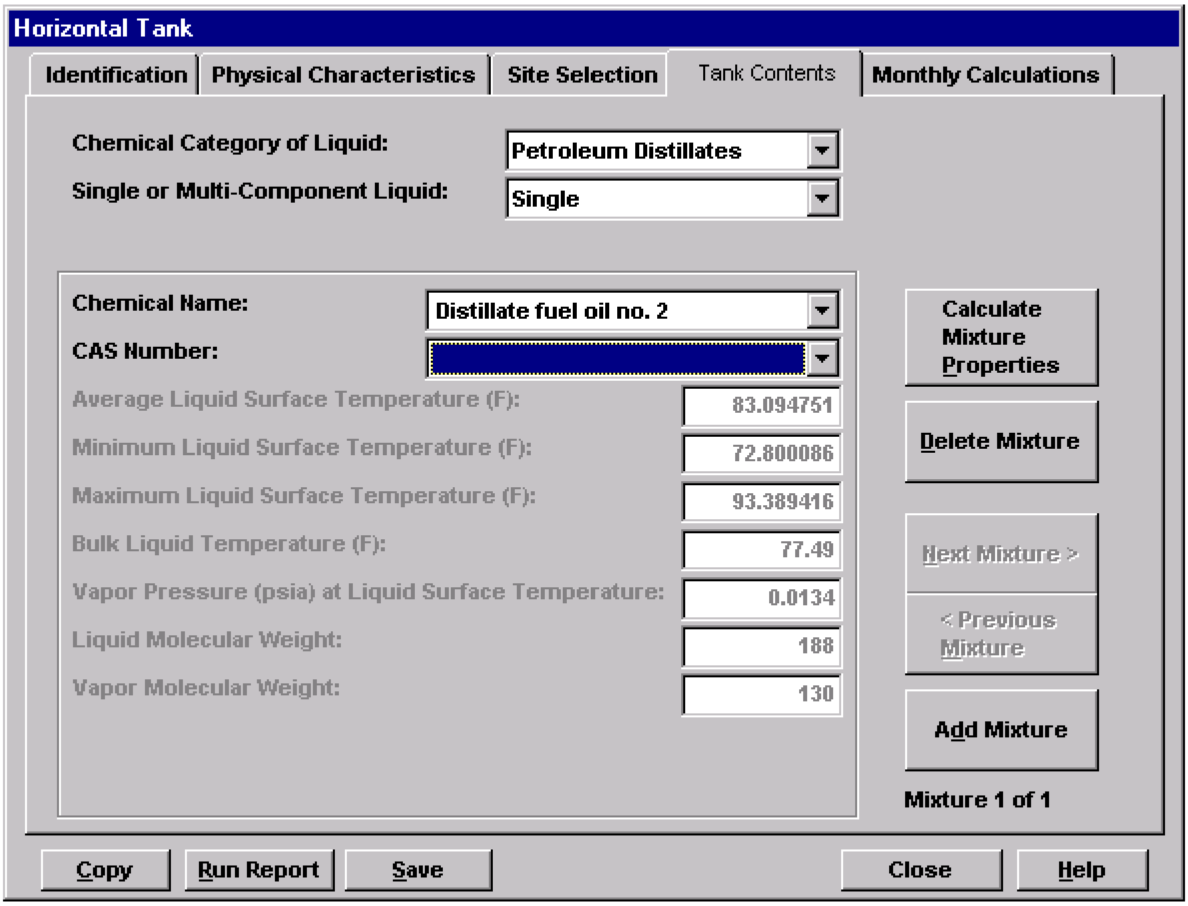


**Figure 15 Tank Contents Input Screen using Single-Component Liquid**

For a single-component liquid, the Tanks Content screen contains the field for the chemical name, Chemical Abstract Service (CAS) number (optional), vapour pressure (psia) at liquid surface temperature, and liquid and vapour molecular weights. To select a chemical or component name from the chemical database by using the pull-down menu in the Chemical Name field. The program will automatically calculate and or provide the remaining data using the chemical and meteorological databases.

The program may be forced to update the data by clicking on 'Calculate Mixture Properties'.

Note that the liquid surface temperature may not be changed manually unless you have selected the heated tank option in the Physical Characteristics Input Screen.

### *Monthly Calculations*

To calculate annual emissions, the monthly data must be entered in the Monthly Calculations Input Screen (Figure 16) after the entering the required liquid information in the previous fields.

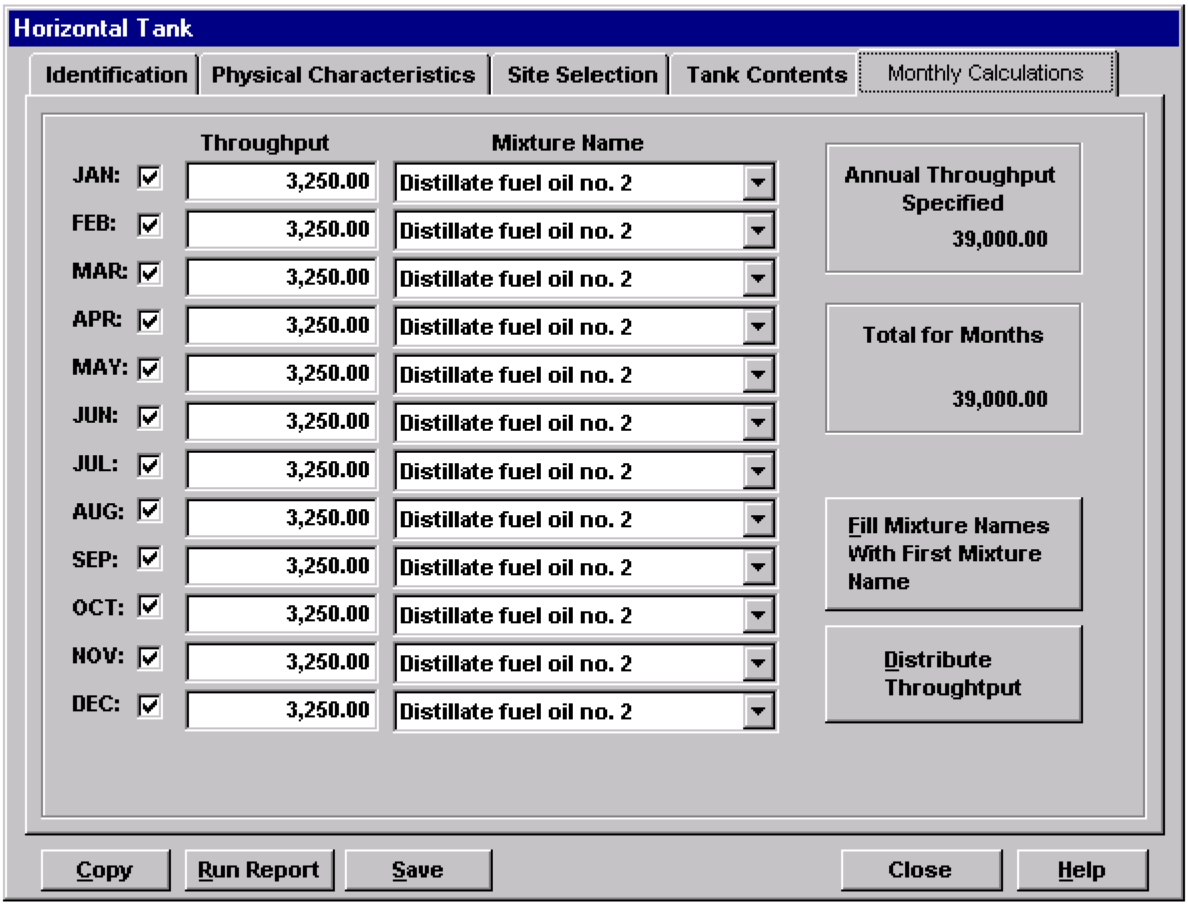


**Figure 16 Monthly Calculations Input Screen**

Initially the entire throughput volume entered for the tank and the liquid information is assumed to apply to the entire year. However it is possible to change the monthly throughput volumes and enter data for other chemical mixtures stored in the tank during the year. The monthly calculation tab shows the throughput for each month of the year as the total annual throughput (from the Physical Characteristics screen) divided by 12. This assumes that the same chemical mixture is stored in the tank for the whole year, whilst the monthly throughput remains constant. However if the tank has a differently monthly throughput than the default throughput the value for that month may be changed.

The following options are available if different throughput values are to be entered and to identify other mixtures and components stored in the tank:

**Mixture Name -** This field may be automatically filled based on the entries made on the Tank Contents screen. To view the other available options use the pull-down menu and select the required mixture. If you select the 'Fill Mixture Names With First Mixture Name' tab this will automatically read the chemical specified in the Tank Contents Screen for all selected months of the year.

**Active Months -** To select or de-select a month, click on the check box next to the month of interest.

**Throughput -** For selected months enter the throughput in gallons for the liquid. For each month where there is no throughput data, de-select the check box next to the month. After selecting the months of interest and the chemical mixture name, click on the 'Distribute Throughput' tab to determine even throughput for the entire year.

### 4.5.2 Vertical Fixed Roof Tanks (VFRT).

Vertical Fixed Roof Tanks consist of cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. Vertical fixed roof tank shells are usually constructed of steel and may be specified as 'heated' in the program. Input parameters required for vertical fixed roof tanks are listed in Table 7.

**Table 7 Input Parameters Required for Vertical Fixed Roof Tanks**

| **Inputs** | |
|---|---|
| *Tank characteristics* | *Roof characteristics* |
| Tank shell height (ft) | Colour/shade |
| Tank shell diameter (ft) | Condition |
| Maximum liquid height (ft) | Type |
| Average liquid height (ft) | Height (ft) |
| Turnovers/yr (number of times the tank was filled) | |
| Working Volume (gal) (average refill volume) | |
| Tank heated or not heated | |
| | *Breather vent settings* |
| *Shell characteristics* | Vacuum setting (psig)[1] |
| Shell colour/shade | Pressure setting (psig)[1] |
| Shell condition | |
| [1] Default Values are automatically provided in the software if no site specific data is available. | |

These input parameters need to be entered in the physical characteristics page shown in Figure 17.

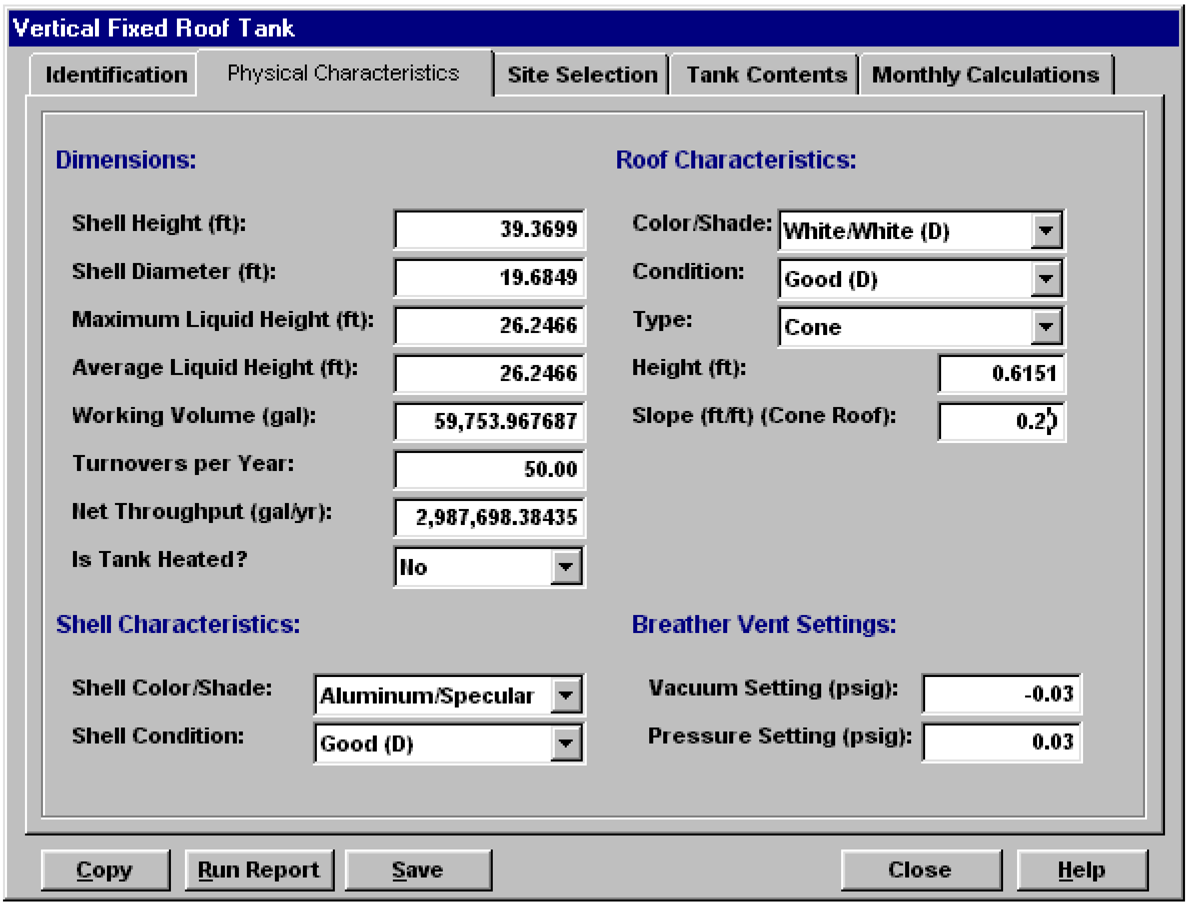


**Figure 17 Example of Vertical Fixed Roof Tank Input Screen**

Identification, site selection, tank contents and monthly calculations screens are to be completed as demonstrated under the horizontal tanks example.

### 4.5.3 Internal Floating Roof Tanks

Internal Floating Roof Tanks have both a permanent fixed roof and a floating deck. Table 8 lists the input parameters required for internal floating roof tanks.

These parameters need to be entered on the physical characteristics screen shown in Figure 18.

**Table 8 Input Parameters Required for Internal Floating Roof Tanks**

| Inputs | |
|---|---|
| *Tank characteristics* | *Shell characteristics* |
| Tank diameter (ft) | Internal shell condition |
| Tank volume (gal) | External shell colour/shade |
| Self supporting roof | Roof paint condition |
| Effective column diameter (ft) | |
| Turnovers/yr (number of times the tank was filled) | |
| Working Volume (US gal) (average refill volume) | |
| *Rim Seal system characteristics* | *Deck characteristics* |
| Primary seal | Deck type |
| Secondary seal | Deck fitting categories |
| [1] Default Values are automatically provided in the software if no site specific data is available | |

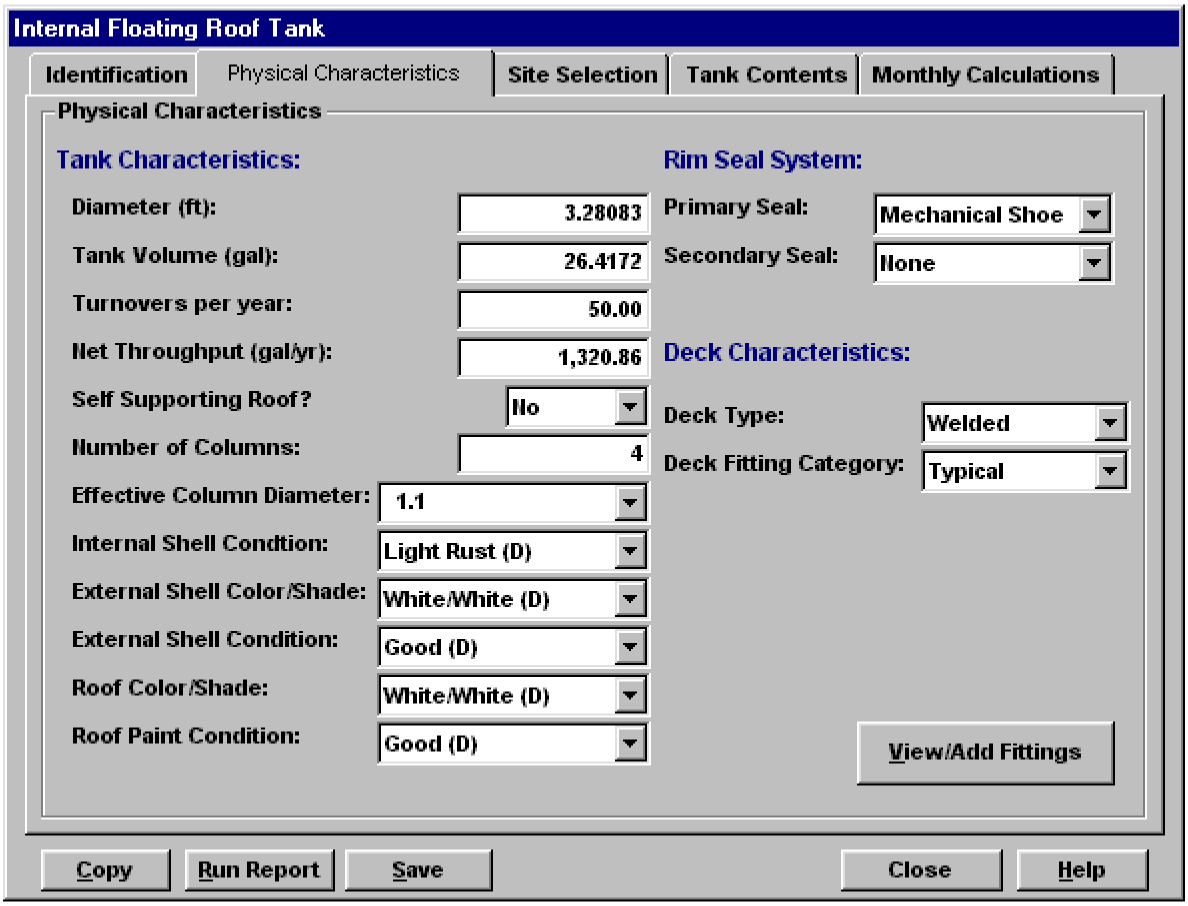


**Figure 18 Example of Internal Floating Roof Tank Input Screen**

Identification, site selection, tank contents and monthly calculations screens are to be completed as demonstrated under the horizontal tanks example.

### 4.5.4 External Floating Roof Tanks (EFRT)

External Floating Roof Tanks consist of a cylindrical steel shell equipped with a roof that floats on the surface of the stored liquid. Table 9 lists the input parameters required for external floating roof tanks.

**Table 9 Input Parameters Required for External Floating Roof Tanks**

| Inputs | |
|---|---|
| *Tank characteristics*<br>Tank diameter (ft)<br>Tank volume (gal)<br>Turnovers/yr (number of times the tank was filled)<br>Working Volume (gal) (average refill volume)<br><br>*Shell characteristics*<br>Internal shell conditions<br>Paint colour/shade<br>Paint condition | *Roof characteristics*<br>Roof type<br>Roof fitting<br><br>*Tank construction and Rim-seal system*<br>Tank construction<br>Secondary seal<br>Primary seal |
| Note:<br>1. Default Values are automatically provided in the software if no site specific data is available | |

These input parameters need to be entered in the physical characteristics page as shown in Figure 19.

Identification, site selection, tank contents and monthly calculations screens are to be completed as demonstrated under the horizontal tanks example.

### 4.5.5 Domed External Floating Roof Tanks (DEFRT)

Domed External Floating Roof Tanks are external floating roof tanks that have been retrofitted with a domed fixed roof. Table 10 lists the input parameters required for domed external floating roof tanks.

These input parameters need to be entered in the physical characteristics page as shown in Figure 20.

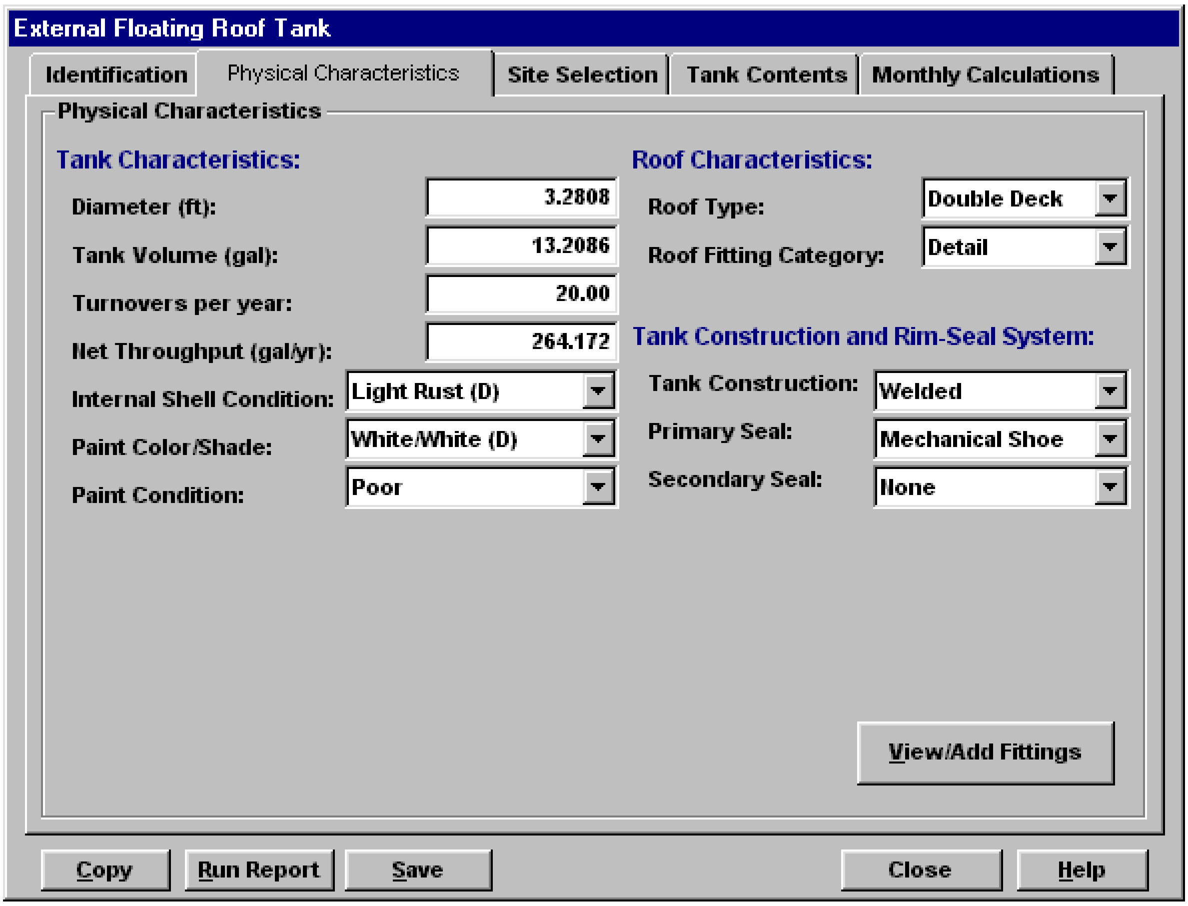


**Figure 19 Example of External Floating Roof Tank Input Screen**

**Table 10 Input Parameters Required for Domed External Floating Roof Tanks**

| **Input** | |
|---|---|
| *Tank characteristics*<br>Tank diameter (ft)<br>Tank volume (gal)<br>Turnovers/yr (number of times the tank was filled)<br>Working Volume (gal) (average refill volume)<br><br>*Roof characteristics*<br>Roof type<br>Roof fitting | *Shell characteristics*<br>Internal shell condition<br>Paint colour/shade<br>Paint condition<br><br><br>*Tank construction and Rim-seal system*<br>Tank construction<br>Primary seal<br>Secondary seal |
| [1] Default Values are automatically provided in the software if no site specific data is available | |

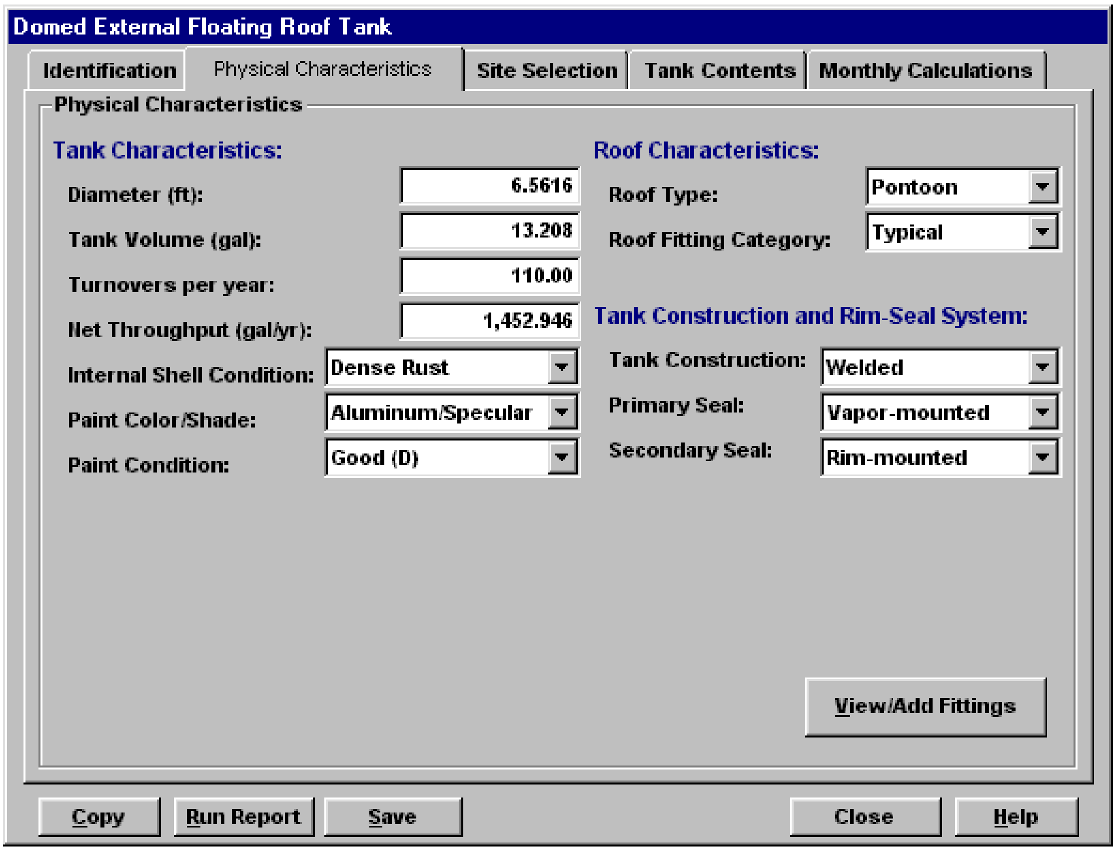


**Figure 20 Example of Domed External Floating Roof Tank Input Screen**

Identification, site selection, tank contents and monthly calculations screens are to be completed as demonstrated under the horizontal tanks example.

## 4.6 Calculating Emissions

The TANKS 4.09b reporting feature is designed to provide users with emission reports that contain as little or as much information as required. The report may contain the total emissions from storage tanks over an entire year or provide calculated emissions for every selected month within that year.

To calculate emissions from your storage tank, you need to press the button titled 'run report' at the bottom of the Input Screen (Figure 11) assuming you have completed all fields associated with the Physical Characteristics, Site Selection and Tank Contents Input Screens. Note that regardless of the type of tank, calculated emissions are generated by running a report via this button or via the Report menu on the main menu of the TANKS program (see further explanation below).

The advantage of using the Report menu from the main menu is to generate reports for more than one tank at a time whilst the advantage of running a report within the Tank Records Input Screens is that any errors in the data that become apparent as the report is generated may be immediately corrected.

### 4.6.1 Report Type

After pressing the 'run report' tab, a new screen will appear as 'Report Type' (Figure 21).

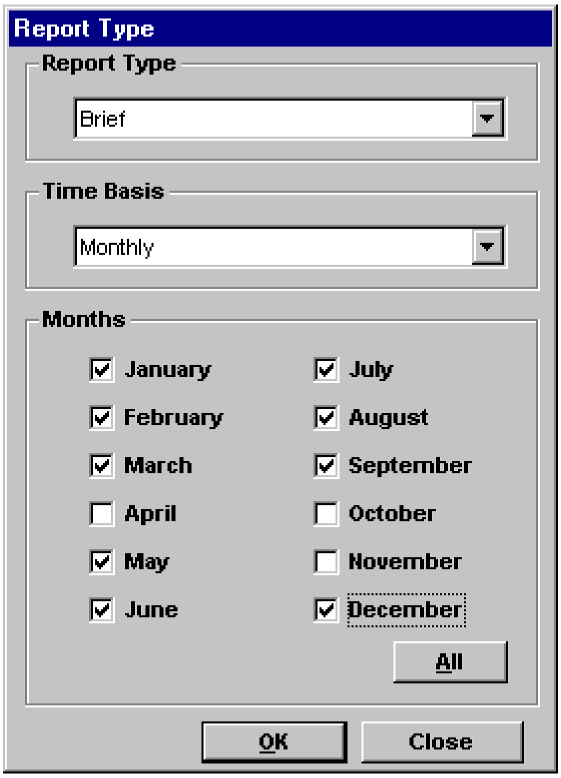


**Figure 21 Report Type Input Screen for Single tanks of any tank type**

To select the type of report you would like to generate choose one of the following three options from the pull-down menu.

**Brief** - A brief report will contain the following information; the date the report was run, identification information, the standing and working losses and the total emissions in pounds. A breakdown of components will be included when using Full, Partial or Vapour Weight Speciation in the Tank Contents screen (refer to section 4.7.1 for further information).

**Summary** - The summary report contains all the data included in the brief report with specific information about the tank, including tank dimensions, paint, roof and deck characteristics, breather vent settings, tank constructions descriptions, and the choice of roof or deck fitting options, if applicable. This report also includes information on liquid temperature and vapour pressure and a table of emissions by chemical component for each type of loss and for total losses.

**Detail** - The detailed report includes the data presented in the summary report and all values calculated during the report generation, grouped by loss category. These values include liquid temperatures, paint factors, vapour pressures, chemical data, fitting factors, and other constants. The data is provided for each month selected and for each chemical component.

### 4.6.2 Time Basis

The program may generate an emissions report based on an annual or monthly time basis. Select the preferred option by highlighting your choice in the pull-down menu in the Time Basis field.

If a monthly report is chosen, a list of months may be selected or de-selected by clicking in the check boxes next to the months. This option is useful for tanks that store different products during the year or for determining emissions during the high ozone season. To select all the months of the year press the ‘ALL’ tab on the bottom right corner of the screen.

### 4.6.3 Print Report

When a report is generated the program will display a ‘Print Report’ window from which the following destination options may be selected

**Window**

If you select print report window the report will appear on your monitor as an emissions report depending on the level of detail chosen. At this screen you may use the ‘Zoom’ option to increase or decrease the size of the report by selecting the required level using the pull-down menu at the bottom of the screen next to the ‘Page’ option. Use the Page option to scroll through the pages of the report. Note you can maximise the screen to view more of the report.

If there is an error in the data a window will appear stating the error(s) to be corrected in order to generate an emissions report. Errors or blank fields in the data that make an emission calculation impossible will prevent the report being generated. Prior to generating another report, correct the errors and/or fill in the blank fields.

**Printer**

This will send the report directly to the printer. To change the printer location and printer options use the Printer Setup button.

**File**

If you select file this will export the report to a file of your choice. TANKS 4.09 offers you five different formats in which to export the report or emissions data; Access, dBaseIV, FoxPro, Excel or Text. Once you select an export option, you can then specify the new file name and path.

The final report generated is not saved in any database form, so it will be necessary to print out the report and add to any other emissions data for NPI reporting.

To generate a report via the Report menu from the TANKS 4.09 main menu, a list of tanks will appear. Select the level of detail to bring up the Choose Tank(s) for Report window, click and drag to select more than one tank in the Choose Tanks(s) field and then press the ‘Select’ button to confirm each of the tanks selected for reporting. The report is generated by pressing the ‘Run Report’ tab at the bottom of the screen and proceed following the prompts as described above.

### 4.7 Speciation of Total Volatile Organic Compounds

Speciation of Total VOCs can be undertaken by:

- TANKS 4.09b (section 4.7.1).

Use of TANKS 4.09b may require additional input of data for some NPI substances.

#### 4.7.1 Speciation using TANKS 4.09b

**Basic Procedure**

To speciate total volatile organic compounds of fuels using the TANKS 4.09 program, the multiple–component liquid option must be chosen at the ‘Tank Contents’ screen for the specific tank record.

If the multiple component liquid option is chosen, you will be prompted to select a speciation option. There are four speciation options – Full Speciation, Partial Speciation, Vapour Weight Speciation, and None (No-Speciation) that may be selected from the ‘pull-down’ menu from the ‘Speciation Option’ field (Figure 22 below).

The first three options provide a method of estimating emissions of individual components within a mixture whereas the ‘None’ (No Speciation) option will only calculate emissions for the total mixture.

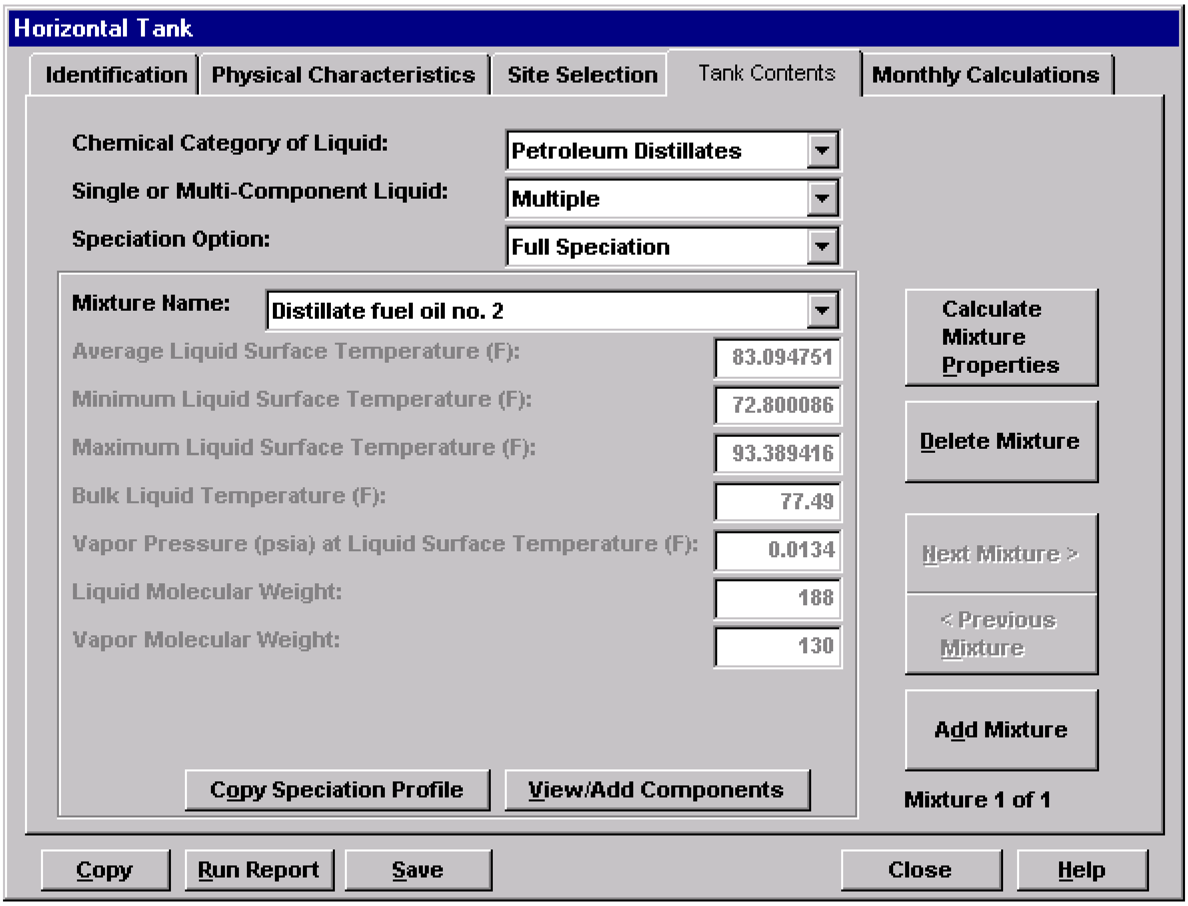


**Figure 22 Tank Contents Input Screen for Multiple-Component Liquids**

At the 'Tank Contents' screen the following fields will appear: mixture name, average, minimum, maximum liquid surface temperatures, bulk temperatures, vapour pressure at liquid surface temperature, including liquid and vapour molecular weights for fixed roof tanks (horizontal or vertical). For floating roof tanks, the program does not require maximum and minimum temperature, however liquid molecular weight, vapour molecular weight and liquid density fields will appear for internal and external (including domed) floating roof tanks (Figure 23 below).

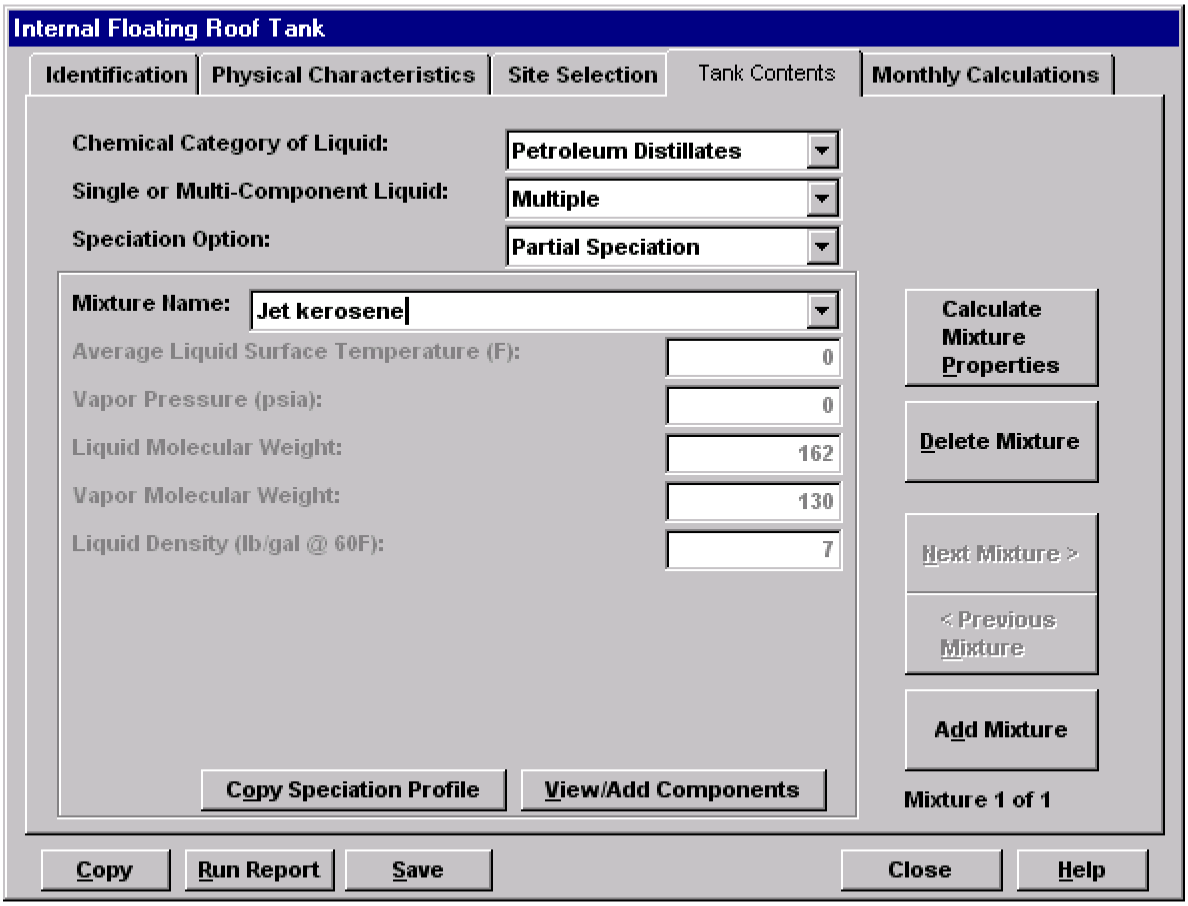


**Figure 23 Multiple-Component Liquid Input Screen for Internal Floating Roof Tanks**

Select the mixture name by the pull-down menu or type in an alternative tank contents. For diesel fuel, select “Distillate fuel oil no.2” and for ULP or PULP select “Gasoline (RVP 13)”. If selecting Gasoline (RVP 13), and Full or Partial Speciation has been specified, go to the Copy Speciation Profile tab and select Aust PULP of Aust ULP. This database was imported with the Australian meteorological data, as described on p.22.

If the mixture is not listed in the chemical database, the program will use the chemical data for each component of the mixture to calculate the properties of the total mixture using Raoult’s Law. In this case, the component data is entered first.

After selecting the speciation, select the ‘View/Add Components’ button to reach the Specify Components Screen (Figure 24) (except in the case of No speciation (see below).

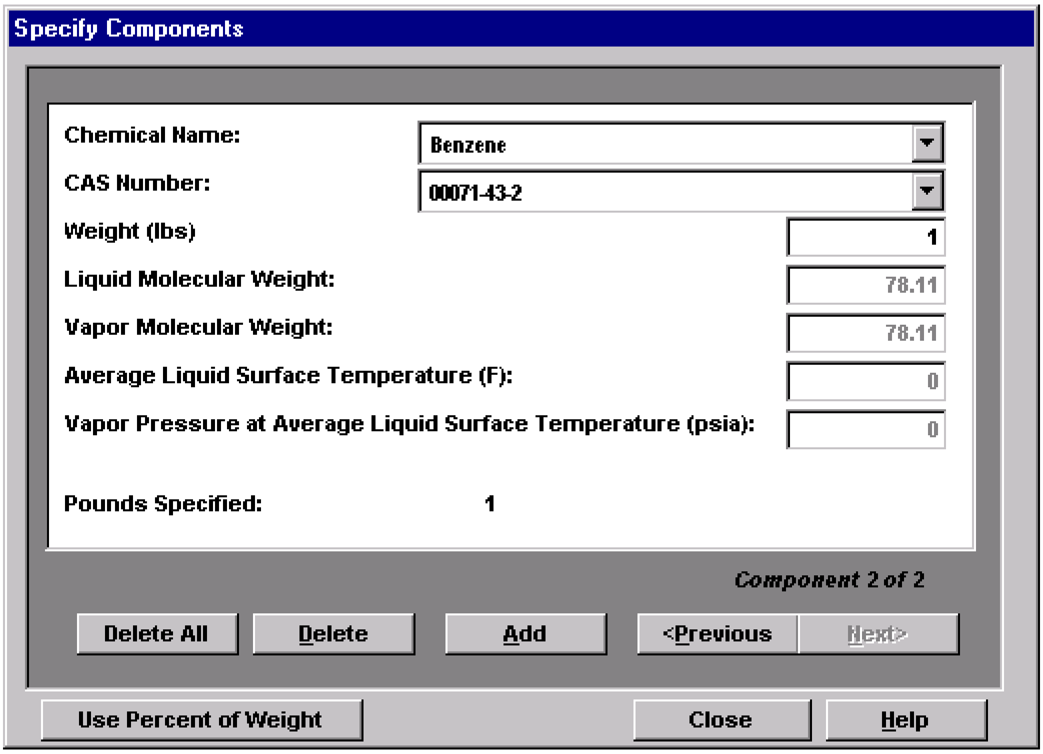


**Figure 24 Specify Components Input Screen for Full Speciation of Multiple-component liquids**

At the Specify Components screen, use the pull-down menu or the 'Add' button to select any components of the mixture and specify the percentage of the component liquid weight within the total mixture. It is mandatory to provide the liquid concentration (by weight) for every chemical in the mixture so that the total adds up to 100%. However the concentration must be expressed as weight/weight by clicking on the 'Use Relative Weight' at the bottom of the 'Specify Components' screen (Figure 25 above) and entering the relative liquid weight in pounds.

If you need to delete the current chemical component, click on the 'Delete' button on the screen. After all components are selected, click on the 'Close' button to return to the Tank Contents screen.

TANKS 4.09b, uses Raoult's Law for calculating speciated estimates of emissions. These calculations assume that the mixture is homogenous and consists of components with similar vapour pressures in an ideal situation.

### Full speciation

If all the chemical components and the concentrations (percentage of total liquid weight) are known for example; 50% benzene and 50% toluene this option may be selected.

For a Full speciation of a multiple-component liquid, the program will calculate the fields shown on the Tank Contents screen after each component of the mixture has been specified. To update the data within the program, click on 'Calculate Mixture Properties'.

**Partial Speciation**

You may select the Partial speciation option if you can provide the chemical data (for example vapour pressure, molecular weight etc) for the entire mixture, or select the mixture from the chemical database (such as distillate fuel or gasoline) and you can identify any chemical component required to estimate emissions.

Note that for each component that you list and provide a concentration for (% total weight) the report will calculate the air emissions for the component in addition to calculating emissions for the entire mixture.

The 'Copy Speciation Profile' must be used with the Partial Speciation option to specify the type of chemical profile required. To use a speciation profile, click on the
'Copy Speciation Profile' button after selecting the chemical category, multiple-component liquid, and the speciation option. A 'Specify Profile' window will appear, select the appropriate profile from the pull-down menu and click 'OK'. To view the speciation data click on 'View/Add Components' and use the 'NEXT' button to scroll through the components.

**Vapour Weight Speciation**

Selecting this option means that you will either provide the chemical data such as vapour pressure, density, molecular weight for the whole mixture or select the mixture from the chemical database. In addition, you must provide the percentage of total vapour weight (vapour composition) for any other chemicals needed in an emissions report.

**None (No-Speciation)**

If you select this option, you must provide all the chemical data for the liquid (liquid and vapour molecular weight, or choose a chemical from the database. However you will not have to specify any chemical components as this option will not allow emission estimates for individual components.

Note that only annual reports or single reports for each month may be generated using the no-speciation option as the program does not contain the chemical data necessary to calculate vapour pressures at different average monthly temperatures for the mixture.

**Terminology**

Note that there are some differences in terminology between NPI substances and those listed in the TANKS program. Known differences are shown in Table 11.

**Table 11 Nomenclature differences between NPI substances and the TANKS program.**

| NPI substance | TANKS equivalent | CASR No. |
|---|---|---|
| Chloroethane (ethyl chloride) | Ethyl chloride | 75-00-3 |
| Cumene (1-methylethylbenzene) | Isopropyl benzene | 98-82-8 |
| Dichloromethane | Methylene chloride | 75-09-2 |
| Ethanol | Ethyl alcohol | 64-17-5 |

## 4.8 Worked Example using TANKS 4.09

Example 3 demonstrates the use of TANKS to calculate emissions from storage tanks.

### Example 3 Estimation of Total VOC emissions from a small mine using TANKS

This example illustrates the steps for estimating VOC emissions from a small mine in the Tanami region of the Northern Territory with three vertical fixed roof storage tank for diesel, each with a 55kL capacity. The mine used 3574 kL of diesel during the reporting year. Throughput for the individual diesel tanks was not known.

***Step 1:*** *Create a new record.*

Using TANKS 4.09b, create a new record by selecting HFRT icon and entering an identifying label (Tanami 1) in the Identification window.

***Step 2:*** *Enter details of tanks.*

In the Physical Characteristics window, enter the required data in the units requested. Conversions can be undertaken using Table 4. In this example, the following data is used:

- Shell length (ft) – 19
- Shell Diameter (ft) – 11
- Working Volume (gal) – 14500
- Net Throughput (gal/year) – 315,000 (equivalent to one third of overall diesel throughput for the three tanks to obtain a value for one tank)
- Is Tank Heated? – No
- Is the Tank Underground? – No
- Shell Color/Shade – Aluminium/Specular
- Shell Condition – Good

***Step 3:*** *Enter meteorological data.*

In the Site Selection window, select Region 5, the climatic zone (Figure 6) in which the tank occurs.

***Step 4:*** *Enter fuel type.*

In the Tank Contents window, select the following:

- Chemical Category of Liquid – Petroleum Distillates
- Single or Multi-Component Liquid – Multiple
- Chemical Name – Distillate fuel oil no. 2 (approximately equivalent to diesel)

Check “View/Add Components” and ensure contents are the same as that shown in Table 1. Use “Distillate fuel oil no.2” for the balance to ensure the total (in pounds) is 100. Note that TANKS does not calculate emissions of Lead and compounds or PAH.

**Example 3 (cont.)**

***Step 5:*** *Enter period of emissions.*

In the Monthly Calculations window, ensure all months are ticked and that the mixture name in each case is Distillate fuel oil no. 2.

***Step 6:*** *Generate emissions report.*

Click on the Run Report icon. Under Report Type indicate 'Detailed' and under Time Basis indicate 'Annual'. An Emissions Report is generated indicating that the total emissions from one diesel tank is 28.48 lb (equivalent to 12.9 kg – the total from the three tanks is 38.7 kg).

***Step 7:*** *Convert TANKS output and correct for additional tanks.*

Convert value on Emissions Report to kg (using Table 4 conversion factors) and multiply by three to obtain the emissions for all three diesel tanks.

$$E_{TVOC}\ (kg) = 28.48 * 4.54E\text{-}01 * 3 = 38.7\ kg$$

***Step 8:****Complete speciation of Total VOC emissions into other NPI substances.*

Complete speciation of Total VOCs by using the values obtained in Step 6 and applying the conversion factors and allow for the number of tanks:

| ***NPI Substance*** | ***Emissions of Total VOCs (kg)*** | | ***Conversion to kilograms*** | | ***No. of tanks*** | | ***Emissions (kg)*** |
|---|---|---|---|---|---|---|---|
| Benzene | 2.57 | * | 4.54E-01 | * | 3 | = | 3.50 |
| Cumene | 4.23 | * | 4.54E-01 | * | 3 | = | 5.76 |
| Ethylbenzene | 0.85 | * | 4.54E-01 | * | 3 | = | 1.16 |
| Toluene | 1.92 | * | 4.54E-01 | * | 3 | = | 2.62 |
| Xylene | 1.46 | * | 4.54E-01 | * | 3 | = | 1.99 |

(note: Scientific notation is used: e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.)

Note that TANKS does not calculate emissions of Lead and compounds or PAHs. These can be calculated using the Total VOCs calculated by TANKS and multiplying by the values given in Table 14.

If reporting for the NPI substances listed above has been triggered, the calculated emissions are reportable.

# 5 SIMPLE EMISSION ESTIMATION TECHNIQUE

## 5.1 Development of Simple EET

A simple EET has been developed for estimating emissions of Total VOCs and other VOCs that are NPI substances from storage tanks. The intention of this simple technique is to provide users with relatively small storage tank installations, and therefore relatively small emissions, an alternative option to the use of the TANKS program. Facilities with a total fuel storage capacity of 500 kL or more should continue to use TANKS. Facilities with total fuel storage capacity of less than 500 kL may use either TANKS or the simple EET described in this chapter. This demarcation level was determined by comparing the storage capacities of larger fuel storage facilities with smaller facilities where fuel storage may not be the primary activity.

The simple EET has been developed using the TANKS program based on the five key variables identified: climate zone, fuel type, tank type, tank size and annual throughput. The EET was developed using South Australia South (see Figure 6) as the standard climatic zone and diesel as the standard fuel type. With the exception of the key variables, all other variables were standardised in the TANKS calculations, and calculated for a number of scenarios. The output was used to produce regression equations, which form the EETs provided here. Details of all the variables used, the input data and the development of the emission estimation equations are given in Appendix IV.

The equations 1 to 3 provide the estimate of the mass (kg) of Total VOCs emissions from diesel stored in the South Australia South climate region (climate region 1). Emission estimates then need to be adjusted for the climate region where the facility is located (Section 5.4.4) and fuel type if fuels other than diesel are stored (Section 5.4.5) to estimate the final emissions of Total VOCs from fuel storage at the facility. The final step is to determine the emissions of NPI substances that make up the Total VOCs by speciating the Total VOC emissions (Equation 4 in Section 5.4.6). These substances need to be reported if substance reporting thresholds are exceeded (Section 3.5).

Note that the simple EET is designed to be used for individual tanks and not for aggregated tank capacities and throughputs (see Example 4). Where multiple tanks occur and the throughput for each is not known, total fuel throughput can be divided amongst them in a logical manner and the EET calculated for each tank.

## 5.2 Data Requirements

The following information is required to use this simple EET:

1. Tank Type: select tank type from the types available (Horizontal Fixed Roof, Vertical Fixed Roof or Internal Floating Roof).
2. Tank Size: capacity of tank in kL. Each tank will need to be assessed separately.
3. Annual Throughput: total amount in kL passing through the tank in the reporting period/year.
4. Climatic Zone: determine which region your facility is within using Figure 6.
5. Fuel type stored in the tank.

## 5.3 Units Used in Alternative EETs

All of the calculations in the simple EET are to be made using System International (SI) units. The units required are clearly specified in the following text.

## 5.4 Simple EETs for Various Tank Types

### 5.4.1 Horizontal Fixed Roof Tanks

The following equation can be used for calculating Total VOCs emissions from Horizontal Fixed Roof Tanks:

$$E_{HFRT} = 4.7E\text{-}02 + 8.1E\text{-}02 * C_{HFRT} + 1.1E\text{-}03 * T_{HFRT} \qquad \textbf{(Equation 1)}$$

Where:

$E_{HFRT}$ = uncorrected emissions of Total VOCs from horizontal fixed roof tank (kg/year)
$C_{HFRT}$ = tank capacity (kL)
$T_{HFRT}$ = tank throughput (kL)

### 5.4.2 Vertical Fixed Roof Tanks

The following equation can be used for calculating Total VOCs emissions from Vertical Fixed Roof Tanks:

$$E_{VFRT} = 1.2E\text{-}01 + 7.4E\text{-}02 * C_{VFRT} + 1.1E\text{-}03 * T_{VFRT} \qquad \textbf{(Equation 2)}$$

Where:

$E_{VFRT}$ = uncorrected emissions of Total VOCs from vertical fixed roof tank (kg/year)
$C_{VFRT}$ = tank capacity (kL)
$T_{VFRT}$ = tank throughput (kL)

### 5.4.3 Internal Floating Roof Tanks

The following equation can be used for calculating Total VOCs emissions from Internal Floating Roof Tanks:

$$E_{IFRT} = 8.0 - 3.3E\text{-}03 * C_{IFRT} + 1.0E\text{-}03 * T_{IFRT} \qquad \textbf{(Equation 3)}$$

Where:

$E_{IFRT}$ = uncorrected emissions of Total VOCs from internal floating roof tank (kg/year)
$C_{IFRT}$ = tank capacity (kL)
$T_{IFRT}$ = tank throughput (kL)

### 5.4.4 Climate Zone Corrections

The equations given above have been developed using the South Australian South climatic zone shown in Figure 6. Climatic variations (particularly maximum and minimum temperature) are an important determinant of Total VOCs emissions, and as such a correction factor must be applied to the value obtained from the equations if your facility is located in a zone other than South part of South Australia (region 1 in Figure 6 and Table 12). Internal Floating Roof Tanks are less sensitive to climatic conditions and therefore require a different correction factor than those provided for Horizontal and Vertical Tanks. To apply the correction factor, select the climate zone appropriate to your location from Figure 6, and multiply the value obtained from the equations by the factor given in Table 12.

**Table 12 Correction Factors for Climatic Zones**

| Climate Region (Figure 6) | Horizontal and Vertical Fixed Roof Tanks | Internal Floating Roof Tanks |
|---|---|---|
| 1 | 1.00 | 1.00 |
| 2 | 1.13 | 1.03 |
| 3 | 1.62 | 1.11 |
| 4 | 1.72 | 1.13 |
| 5 | 1.38 | 1.10 |
| 6 | 1.52 | 1.10 |
| 7 | 1.55 | 1.10 |
| 8 | 1.46 | 1.08 |
| 9 | 1.28 | 1.05 |
| 10 | 1.10 | 1.03 |
| 11 | 0.96 | 1.00 |
| 12 | 0.79 | 0.97 |

### 5.4.5 Correction for Fuel Type

The equations given above were developed using diesel as the fuel type. Correction factors need to be used to allow for other fuel types. To calculate the reportable Total VOCs, the climate corrected losses must be corrected for fuel type by multiplying by the relevant value listed for Total VOCs in Table 13 below.

**Table 13 Correction factors for fuel type.**

| NPI Substance | Correction Factor | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Diesel | ULP | PULP | LP | Avgas | Kerosene | Heating Oil | Fuel Oil F143 |
| **Total VOCs** | **1** | **1000** | **1000** | **1000** | **ND** | **ND** | **ND** | **ND** |

Note:
1. ULP – unleaded petrol, PULP – premium unleaded petrol, LP – leaded petrol.

### 5.4.6 Speciation

To speciate the Total VOCs emissions calculation into emissions for various NPI substances, the emission of Total VOCs for the particular fuel type needs to be multiplied by the emission factor for the particular substance as given in Table 14, and for PAHs and lead & compounds, Table 1:

$$E_x = E_{TVOC} * EF_{SPEC} \quad \textbf{(Equation 4)}$$

Where:

$E_x$ = emissions (kg) of NPI substance
$E_{TVOC}$ = calculated emissions (kg) of Total VOCs
$EF_{SPEC}$ = emission factor for fuel type from Table 14 (for PAHs and lead & compounds, Table 1.)

**Table 14 Correction factors for fuel type based on sample TANKS calculations**

| Substance | LP/PULP/ ULP | Diesel |
|---|---|---|
| Benzene | 1.0E-02 | 1.9E-03 |
| Cumene | 1.4E-03 | ND |
| Cyclohexane | 1.1E-04 | ND |
| Ethylbenzene | 4.8E-04 | 3.2E-03 |
| n-hexane | 1.3E-02 | 4.2E-04 |
| Toluene | 1.0E-02 | 2.3E-02 |
| Xylenes | 2.8E-03 | 5.9E-02 |

Notes:
1. ND = No Data
2. Scientific notation is used; e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.

## 5.5 Calculation Steps for Using Simple Fuel Storage Tank EET

The steps involved in using the simple EET are:

***Step 1***

Using the equations under section 5.4, calculate the uncorrected losses of Total VOCs from the capacity and throughput for each storage tank.

***Step 2***

Add emissions from each storage tank to obtain overall uncorrected losses of Total VOCs from storage tanks.

***Step 3***

Correct the emissions obtained from Step 3 for climatic region by multiplying value by relevant figure from Table 12.

***Step 4***

Correct emissions from Step 2 for fuel type by multiplying value(s) by relevant figure(s) from Table 13.

***Step 5***

Where relevant NPI substances have been triggered, speciate the Total VOCs values obtained in Step 4 using the values given in Table 14 (for PAHs and lead & compounds, Table 1.).

Example 4 shows the application of the simple EET.

**Example 4 Calculating fuel storage tank emissions using the simple EET**

This example illustrates the steps for estimating VOC emissions from fuel storage tanks at a small mine in the Tanami region of the Northern Territory with three vertical fixed roof tanks (VFRTs) for diesel, each with a 55kL capacity ($C_{VFRT}$), as for Example 3 (see page 48). In this example, a horizontal fixed roof tank (HFRT) for unleaded petrol (ULP) with a 5kL capacity ($C_{HFRT}$) is also used. The mine used 3574 kL ($T_{VFRT}$) of diesel during the reporting year and 57 kL ($T_{HFRT}$) of ULP. Throughput for the individual diesel tanks was not known.

__*Step 1*__ *Estimate emissions from one diesel tank.*

Using the equations under section 5.4, calculate the uncorrected losses of Total VOC emissions from each of the diesel tanks as follows:

$$E_{HFRT} = 1.2E\text{-}01 + 7.4E\text{-}02 * C_{HFRT} + 1.1E\text{-}03 * T_{HFRT}$$
$$= 0.12 + (0.074 * 55) + (0.0011 * (3574 / 3))$$
$$= 0.12 + 4.07 + 1.310$$
$$= 5.500 \text{ (kg Uncorrected Total VOCs per tank)}$$

__*Step 2*__ *Adjust to consider all diesel tanks.*

Multiply by the number of diesel tanks to obtain the total uncorrected losses of Total VOC emissions from all diesel tanks as follows:

$$E_{HFRT} = 5.500 * 3$$
$$= 16.500 \text{ (kg Uncorrected Total VOCs for all three diesel tanks)}$$

**Example 4 (cont.)**

***Step 3*** *Estimate emissions from the ULP tank.*

Using the equations under section 5.4, calculate the uncorrected losses of Total VOC emissions from the ULP tank as follows:

$$E_{VFRT} = 1.2E\text{-}01 + 7.4E\text{-}02 * C_{VFR} + 1.0E\text{-}03 * T_{VFR}$$

$$= 0.12 + (0.074 * 5) + (0.0011 * 57)$$

$$= 0.12 + 0.37 + 0.063$$

$$= 0.553 \text{ (kg Uncorrected Total VOCs for the ULP tank)}$$

***Step 4*** *Correct for fuel type.*

Correct emissions from Steps 2 and 3 for fuel type by multiplying value by relevant figure from Table 13:

$E_{TVOCS}$ (ULP) = 0.553 * 1000

= 553 kg Uncorrected Total VOCs

$E_{TVOCS}$ (Diesel) = 16.500 * 1

= 16.500 kg Uncorrected Total VOCs

***Step 5*** *Correct for climatic region.*

Correct emissions from Steps 4 for climatic region by multiplying uncorrected value by relevant factor (1.38) from Table 12 (in this instance Region 5):

$E_{TVOCS}$ (ULP) = 553 * 1.38 = 763 kg Total VOCs

$E_{TVOCS}$ (Diesel) = 16.500 * 1.38 = 22.8 kg Total VOCs

$E_{TVOCS}$ (Total) = 763 + 22.8

= 786 kg Total VOCs

The overall emissions of Total VOCs, assuming no other sources, was 790 kg (to two significant figures).

***Step 6*** *Speciating the Total VOC values.*

To calculate the components of the Total VOCs value, each of the Total VOCs emissions of diesel and ULP needs to be multiplied with the factors given in Table 14 (and Table 1 for PAHs and lead & compounds) for the different NPI substances. The totals for diesel and ULP have to be summed to determine the total emissions to be reported to the NPI (assuming no other sources):

**Example 4 (cont.)**

| *Substance* | *Diesel VOC Emissions(kg)* | | *Diesel Factor* | | *ULP VOC Emissions(kg)* | | *ULP Factor* | | *Total (kg)* |
|---|---|---|---|---|---|---|---|---|---|
| Benzene | 22.77 | * | 1.9E-03 | + | 763 | * | 1.0E-02 | = | 7.67E+00 |
| Cumene | 22.77 | * | - | + | 763 | * | 1.1E-04 | = | 2.31E-03 |
| Cyclohexane | 22.77 | * | - | + | 763 | * | 1.4E-03 | = | 1.07E+00 |
| Ethylbenzene | 22.77 | * | 3.2E-03 | + | 763 | * | 4.8E-04 | = | 4.39E-01 |
| n-hexane | 22.77 | * | 4.2E-04 | + | 763 | * | 1.3E-02 | = | 9.93E+00 |
| Lead and Compounds | 22.77 | * | - | + | 763 | * | 1.14E-05 | = | 8.70E-03 |
| Polycyclic aromatic hydrocarbons | 22.77 | * | 1.0E-02 | + | 763 | * | - | = | 2.28E-01 |
| Toluene | 22.77 | * | 2.3E-02 | + | 763 | * | 1.0E-02 | = | 8.15E+00 |
| Xylenes | 22.77 | * | 5.9E-02 | + | 763 | * | 2.8E-03 | = | 3.48E+00 |

(note: Scientific notation is used: e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.)

The speciated emissions are as shown in the right hand column above and should be reported if the particular NPI substance has been triggered.

# 6 EMISSION FACTOR RATING

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry Manuals. They are based on rating systems developed by the United States Environmental Protection Agency (USEPA), and by the European Environment Agency (EEA). Consequently, the ratings may not be directly relevant to Australian industry. Sources for all emission factors cited can be found in the reference section of this document. The emission factor ratings will not form part of the public NPI database.

When using emission factors, you should be aware of the associated EFR code and what that rating implies. An A or B rating indicates a greater degree of certainty than a D or E rating. The less certainty, the more likely that a given emission factor for a specific source or category is not representative of the source type. These ratings notwithstanding, the main criterion affecting the uncertainty of an emission factor remains the degree of similarity between the equipment/process selected in applying the factor, and the target equipment/process from which the factor was derived.

The EFR system is as follows:

A - Excellent
B - Above Average
C - Average
D - Below Average
E - Poor
U - Unrated

Estimating your facility's emissions based on emission factors only, and without taking into account any control measures, may have an uncertainty as high as 100%.

Other EETs, such as release calculations based on mass balance of solvent consumption and without taking into account control measures, may have an uncertainty of 50%.

An EET based on an audit or direct measurement, and taking into account control measures, may have an uncertainty of 20%.

# 7 GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

| Term | Definition |
|---|---|
| API | American Petroleum Institute |
| DEFRT | Domed External Floating Roof Tank – see definition in Section 2. |
| EEA | European Environmental Agency |
| EETs | Emission Estimation Techniques |
| EFR Code | Emission Factor Rating Code |
| EFRT | External Floating Roof Tank – see definition is Section 2. |
| HFRT | Horizontal Fixed Roof Tank – where the long axis of the tank is parallel to the ground |
| IFRT | Internal Floating Roof Tank – see definition in section 2. |
| kL | Kilolitres |
| LP | Leaded Petrol |
| MB | Megabyte |
| MSDS | Material Safety Data Sheet |
| ND | No data |
| NEPM | National Environment Protection Measure |
| NPI | National Pollutant Inventory |
| PAH's | Polycyclic Aromatic Hydrocarbons – see NPI website for definition http://www.npi.gov.au |
| PULP | Premium Unleaded Petrol |
| Scientific Notation | Is used where appropriate in this document e.g. 3.9E-02 represents $3.9 \times 10^{-2}$ or 0.039. |
| SI Units | System International Units |
| RAM | Random Access Memory |
| TANKS 4.09 | Software programme used for calculation emissions from storage tanks. |
| Toluene | Also referred to as methylbenzene - see NPI website for physical and chemical properties http://www.npi.gov.au |
| Total VOCs | Total Volatile Organic Compounds – See Appendix I for Definition |
| TVOC | Total Volatile Organic Compounds (as a subscript in equations) |
| ULP | Unleaded Petrol |
| US | United States |
| USEPA | United States Environmental Protection Agency |
| VFRT | Vertical Fixed Roof Tank – see definition in Section 2. |
| VOCs | Volatile Organic Compounds – see Appendix I for Definition |
| Xylene | Includes individual or mixed isomers – see NPI website for physical and chemical properties http://www.npi.gov.au |

# 8 REFERENCES


1. USEPA. September 1997. *Section 7.1 Organic Liquid Storage Tanks*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards Emission Factor and Inventory Group. Midwest Research Institute, USA.
2. USEPA. October 1997. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, *fifth edition, AP-42. Section 7.0 Liquid Storage Tanks.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
3. Environment Australia. National Pollutant Inventory. Fuel and Organic Liquid Storage Emissions Estimation Manual. Version 1.0.
4. Australian Institute of Petroleum 1999. 'NPI Gasoline Speciation'.
5. Personal communication, Ms. N. Smrk, BP Australia Marketing and Technical Services.
6. USEPA. September 1999. *User's Guide to TANKS, Storage Tank Emissions Calculation Software Version 4.0*. United States Environmental Protection Agency, Emission Factor and Inventory Group Emissions, Monitoring and Analysis Division, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
7. Standards Australia. Australian Standard AS 3570 – 1998. Automotive diesel fuel.
8. Personal communication, Mr. A. King, BP Australia.

# Appendix I – Total VOCs and the NPI

## Background

For the purposes of the National Pollutant Inventory, Total Volatile Organic Compounds (Total VOCs) has been included as a Table 2 reportable substance (see The NPI Guide) because it represents photochemical smog precursors, and as such can be generally defined as 'any organic compound that participates in atmospheric photochemical reactions.' Total VOCs represent a significant risk to health and the environment.

The intent of the inclusion of Total VOCs is in recognition of the combined effect of compounds that contribute to smog formation that may not otherwise have been captured due to individual substances not meeting a usage threshold in their own right. The most common sources of Total VOCs emissions are from the storage and use of liquid and gaseous fuels, the storage and use of solvents and the combustion of fuels.

A pragmatic definition of VOCs is offered below, drawing on earlier sources, for the purposes of reporting to the NPI:

> *Any chemical compound based on carbon chains or rings (and also containing hydrogen) with a vapour pressure greater than 2mm of mercury (0.27 kPa) at $25^0$ C, excluding methane.*
>
> Note :
>
> *These compounds may contain oxygen, nitrogen and other elements, but specifically excluded are carbon monoxide, carbon dioxide, carbonic acid, metallic carbides and carbonate salts.*

## Total VOCs in Fuels

Most fossil fuels consist of a mixture of a number of different carbon compounds and other substances. In many fuels, some of these carbon compounds (also called organic compounds) will meet the above VOC definition, while others will not. Hence it is not possible to describe a particular fuel as a Total VOCs. Rather, it is necessary to describe what percentage of the fuel is made up of Total VOCs.

Table 1 provides details of the Total VOCs (and other selected NPI substances which are VOCs) content of various fuels in the liquid phase. Note that the data is indicative only and does not reflect the variability across fuel types used throughout Australia. Local data should be substituted where available.

### Total VOCs in Solvents and Other Products

In a similar fashion to fuels, Total VOCs are often a component of products such as paints and solvents. The Material Safety Data Sheet for a product is often the best means of identifying its Total VOCs content.

**Table 15 Weight percent of Various NPI Substances in the Vapour Phase for Indicative Australian Fuels**

| weight % (vapour) | PULP | ULP | LP | Avgas | Kerosene | Diesel | Heating Oil | Fuel Oil F143 |
|---|---|---|---|---|---|---|---|---|
| Benzene | 2.09 | 1.80 | 1.75 | 0.63 | 0.01 | 0.03 | - | - |
| Cumene | 0.02 | 0.02 | ND | ND | 0.14* | 0.05* | - | 0.01* |
| Cyclohexane | 0.35 | 0.25 | - | ND | # | # | - | - |
| Ethylbenzene | 0.12 | 0.08 | 0.06 | ND | 0.02 | 0.004 | 0.004 | - |
| n-hexane | 1.93 | 2.32 | 1.70 | ND | # | # | - | - |
| Lead and compounds | 1.14E-05 | 1.14E-04 | 2.16E-03 | 8.31E-03 | - | - | - | - |
| PAH | ND | 6.7E-06 | 6.7E-06 | ND | 3 | 0.01 | 0.15 | 0.09 |
| Toluene | 1.96 | 1.77 | 1.60 | 0.23 | 0.04 | 0.02 | 0.01 | - |
| Xylenes | 0.57 | 0.48 | 0.43 | 0.03 | 0.10 | 0.02 | 0.01 | - |

Notes:
1. Source: Reference 7.
2. all C3-alkylated benzene isomers
3. # grouped in C6-C10 compounds
4. ND = No Data
5. Scientific notation is used: e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.

The speciation of Total VOCs in varying fuel types and their weight fraction (% mass) in the vapour phase was calculated using Raoult's Law to determine the partial pressure of each reportable substance. The partial pressure of each VOC substance was calculated by dividing the total pressure of the mixture to determine the mole fraction, of the VOC in its vapour phase. Raoult's Law states the mole fraction of the VOC component in the liquid multiplied by the vapour pressure of the pure VOC at the daily average liquid surface temperature (P) is equal to the partial pressure of (Pi) of that component:

$P_i = (P)*(x_i)$ **(Equation 5)**

Where:

$P_i$ = partial pressure of VOC component i (psia)
P = vapour pressure of pure VOC i at the daily average liquid temperature (psia)
$x_i$ = liquid mole fraction of VOC component i (kg-mole/kg-mole)

Next the saturated vapour pressure of each VOC component was calculated using Antoine's constants as specified from Table 3-5 Vapour pressure equation constants for organic liquids in *AP-42 5th Edition Volume 1 Chapter 7 Manual of Liquid Storage Tanks* or alternatively from the TANKS 4.O - *User's Guide to TANKS.* In order to use Raoult's Law the liquid mole fraction is determined from the liquid weight fraction hence the known liquid mole fraction and the vapour pressure of the VOC component can be substituted into the equation above.

<u>It must be noted that the speciation of Total VOCs vapour content in fuels is not a weighted average nor representative of any particular state or region.</u>

To determine the weight fractions in the vapour phase the mole fractions in the vapour phase were calculated for each VOC component. Firstly, the vapour mole fraction was calculated by dividing the partial pressure of the component into the total vapour pressure of the solution (ie: fuel). The weighted fraction in the vapour phase was calculated using the following equation

$Z_{Vi} = y_i M_i / Mv_i$ **(Equation 6)**

Where:

$Z_{Vi}$ = vapour weight fraction of VOC component i, ,kg/kg
$y_i$ = vapour mole fraction of component i, kg-mole/kg-mole
$M_i$ = molecular weight of VOC component i, kg/kg-mole
$M_{vi}$ = molecular weight of vapour stock, kg/kg-mole

**Total VOCs Thresholds**

There are three NPI thresholds relating to Total VOCs:

*Category 1*
This threshold is tripped if, at a facility, 10 tonnes or more of a VOC (for example: benzene, cumene) is used in the reporting period.

Triggering one Category 1 threshold does not mean that you are required to report your facility's emissions of all Category 1 substances. You are required to report emissions only for those substances for which usage is 10 tonnes or more.

*Category 1a*
This threshold is tripped if, at a facility, 25 tonnes or more of Total VOCs is used in the reporting period. If your facility is a bulk storage facility its design capacity also needs to exceed 25kT of substances containing Total VOCs.

For example, if a facility uses 300 tonnes per year of a fuel that consists of 10% Total VOCs by weight, then it is said to use 30 tonnes (300 x 10/100) of Total VOCs and hence trips this threshold.

*Category 2a*
This threshold is tripped if, at a facility, 400 tonnes or more of fuel or waste is burnt in the reporting period; or 1 tonne or more of fuel or waste is burnt in any hour (peak hourly usage) during the reporting period.

If this threshold is tripped, the facility is required to report emissions of a range of substances, including Total VOCs.

## Total VOCs Emissions

Industry handbooks for the NPI provide emission estimation techniques for estimating Total VOCs from fuel burning, fuel storage and other solvent use. For fuel storage, all losses from standing and refilling are to be regarded as Total VOCs emissions.

For use of solvents, paints and other such products, the Total VOCs emissions often are equal to the Total VOCs content of the product. These emissions may be reduced by techniques such as vapour recovery.

## Total VOCs species

Total VOCs is a Category 1a substance and emissions reporting is based on the Category 1a threshold. Many Category 1 substances are classed as VOCs, and emission of such individual species must be estimated should the Category 1 threshold for the substance be tripped. The reason for their inclusion as individual substances is on the basis of their toxicity to plant, animal and human health, not directly because of their possible activity as a precursor to the formation of photochemical smog.

**Table 16 Examples of VOCs from the NPI Reporting List**

| Table 1 or 2* | Substance (NPI Category) | CASR Number | Table 1 or 2* | Substance (NPI Category) | CASR Number |
|---|---|---|---|---|---|
| 2 | Acetaldehyde (1) | 75-07-0 | 2 | Ethylene oxide (1) | 72-21-8 |
| 2 | Acetic acid (ethanoic acid) (1) | 64-19-7 | 2 | Di-(2-Ethylhexyl) phthalate (DEHP) (1 and 2a) | 117-81-7 |
| 1 | Acetone (1) | 67-64-1 | 2 | Formaldehyde (methyl aldehyde) (1) | 50-00-0 |
| 2 | Acetonitrile (1) | 75-05-8 | 2 | n- Hexane (1) | 110-54-3 |
| 2 | Acrylonitrile (2-propenenitrile) (1) | 107-13-1 | 2 | Methanol (1) | 67-56-1 |
| 2 | Aniline (benzenamine) (1) | 62-53-3 | 1 | 2- Methoxyethanol (1) | 109-86-4 |
| 1 | Benzene (1) | 71-43-2 | 2 | 2- Methoxyethanol acetate (1) | 110-49-6 |
| 1 | 1,3 – Butadiene (1) | 106-99-0 | 2 | Methyl ethyl ketone (1) | 78-93-3 |
| 2 | Chloroethane (ethyl chloride) (1) | 75-00-3 | 1 | Methyl isobutyl ketone (1) | 108-10-1 |
| 2 | Chloroform (trichloromethane) (1) | 67-66-3 | 1 | Methyl methacrylate (1) | 80-62-6 |
| 2 | Cumene (1-methylethylbenzene) (1) | 98-82-8 | 1 | 4,4- Methylene bis 2,4 aniline (MOCA) (1) | 101-14-4 |
| 2 | Cyclohexane (1) | 110-82-7 | 2 | Methylene bis (phenylisocyanate) (1) | 101-68-8 |
| 1 | 1,2- Dibromoethane (1) | 106-93-4 | 1 | Styrene (ethenylbenzene) (1) | 100-42-5 |
| 2 | 1,2- Dichloroethane (1) | 107-06-2 | 1 | 1,1,1,2- Tetrachloroethane (1) | 630-20-6 |
| 1 | Dichloromethane (1) | 75-09-2 | 2 | Tetrachloroethylene (1) | 127-18-4 |
| 2 | Ethanol (1) | 64-17-5 | 1 | Toluene (methylbenzene) (1) | 108-88-3 |
| 1 | 2- Ethoxyethanol (1) | 110-80-5 | 1 | 1,1,2- Trichloroethane (1) | 79-00-5 |
| 1 | 2- Ethoxyethanol acetate | 111-15-9 | 2 | Trichoroethylene (1) | 79-01-6 |

| Table 1 or 2* | Substance (NPI Category) | CASR Number | Table 1 or 2* | Substance (NPI Category) | CASR Number |
|---|---|---|---|---|---|
| | (1) | | | | |
| 2 | Ethyl acetate (1) | 141-78-6 | 1 | Vinyl Chloride Monomer (1) | 75-01-4 |
| 2 | Ethyl butyl ketone (1) | 106-35-4 | 2 | Xylenes (individual or mixed isomers) (1) | 1330-20-7 |
| 2 | Ethylbenzene (1) | 100-41-4 | | | |

** Note that all Table 1 substances are included in Table 2.*

It is important to note that emissions of Total VOCs and those of VOC species, as given above, must not be added as emissions of VOC species are implicitly included in the Total VOCs calculations.

## Appendix II – Worksheets to assist in Category 1, 1a, 2a and 2b usage calculations to determine if thresholds are exceeded

**Category 2a and 2b**

Category 2a and 2b substances are to be reported if fuel usage exceeds 400t or 2000 t respectively. Each threshold can also be triggered by other usage factors. More information on these is provided in the NPI Guide.

The following table, if required, can be used to convert usage to tonnes.

| Fuel Type | Quantity Used (A) | Units | Conversion Factor[1] (B) | Usage (tonnes) (A x B) |
|---|---|---|---|---|
| | | | | |
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Notes:
1. Use factors given in Table 5 of the NPI Guide (version 2.8) and, if necessary, Table 4 of this Manual.

**Category 1 and 1a**

Category 1 and 1a substances are to be reported if their use is more than 10 tonnes per reporting year (or 25 tonnes in the case of Total VOCs) – see the NPI Guide for more details.

Having determined the overall fuel usage in tonnes, and also considering other organic liquid usage, usage of individual Category 1 and 1a NPI substances can be determined using the following table:

| Fuel and Organic Liquid Type | Quantity Used (t) (A) | NPI Substance (See Table 1.) | Content (%) (B) | Usage (tonnes) (A x B / 100) |
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Usage of each NPI substance within each fuel and organic liquid must be totalled to determine if thresholds are exceeded.

# Appendix III – Equations Used to Calculate Emissions in TANKS 4.09

The following equations and text are extracted from Reference 2, a USEPA publication that can be sourced at http://www.epa.gov/ttn/chief/. These equations can be used as a hand calculation tool although the referenced tables need to be consulted from the original document. The references in the following text can only be found in the original document (Reference 2).

It must be noted that the information in the Appendices is for reference only and must not be used as a calculation tool. Refer to the relevant standard parameters and figures within the main body of the report for calculation purposes.

***List of Variables and Symbols***

| Variable | Description | Units | Variable | Description | Units |
|---|---|---|---|---|---|
| $L_T$ | Total losses | lb/y | $\Delta T_V$ | daily vapour temperature range | R |
| $L_S$ | standing storage losses | lb/y | $\Delta P_V$ | daily vapour pressure range | psia |
| $L_W$ | working losses | lb/y | $\Delta P_B$ | breather vent pressure setting | psig |
| $V_V$ | vapour space volume | $ft^3$ | $P_A$ | atmospheric pressure | psi |
| $W_V$ | vapour density | $lb/ft^3$ | $\Delta T_A$ | daily ambient temp range | °R |
| $K_E$ | vapour space expansion factor | - | $P_{VX}$ | vapour pressure at daily max liquid surface temp. | psia |
| $K_S$ | vented vapour saturation factor | - | $P_{VN}$ | vapour pressure at daily min liquid surface temp. | psia |
| D | tank diameter | ft | $P_{BP}$ | breather vent pressure setting | psig |
| $H_{VO}$ | vapour space outage | ft | $P_{BV}$ | breather vent vacuum setting | psig |
| $H_S$ | tank shell height | ft | Q | annual net throughput | bbl/y |
| $H_L$ | liquid height | ft | $K_N$ | turnover factor | - |
| $H_{RO}$ | roof outage | ft | N | number of turnovers per year | - |
| $H_R$ | tank roof height | ft | $\pi$ | constant (3.14159) | - |
| $S_R$ | tank cone roof slope | ft/ft | $V_{LX}$ | tank max liquid volume | $ft^3$ |
| $R_S$ | tank shell radius | ft | $H_{LX}$ | max liquid height | ft |
| $R_R$ | tank dome roof radius | ft | $K_P$ | working loss product factor for fixed roof tanks | - |
| $M_V$ | vapour molecular weight | lb/lbmole | $L_R$ | rim seal loss | lb/y |
| R | ideal gas constant | psiaft³/lbmole R | $L_{WD}$ | withdrawal loss | lb/y |
| $P_{VA}$ | vapour pressure at daily average liquid surface temperature. | Pisa | $L_F$ | deck fitting loss | lb/y |
| $T_{LA}$ | daily average | R | $K_{RA}$ | zero wind speed rim seal | lbmole/f |

| Variable | Description | Units | Variable | Description | Units |
|---|---|---|---|---|---|
| | liquid surface temperature | | | loss factor | t y |
| $M_I$ | molecular weight of component | lb/lb mole | $K_{RB}$ | wind speed dependant rim seal loss factor | lbmole/ $(mph)^n$ft y |
| $y_i$ | vapour mole fraction of component | lbmole/ lbmole | v | average wind speed | mph |
| $x_I$ | liquid mole fraction of component | lbmole/lbmol e | n | seal related wind speed exponent | - |
| P | true vapour pressure of component I | pisa | P* | vapour pressure function | - |
| A | constant in vapour pressure equation | - | $F_R$ | rim deck loss factor | lbmole/f t y |
| B | constant in vapour pressure equation | R | $K_C$ | product factor for floating roof tanks | - |
| $T_{AA}$ | daily average ambient temperature | R | C | shell clingage | bbl/ 1 000 $ft^2$ |
| $T_B$ | liquid bulk temperature | R | $W_L$ | average organic liquid density | lb/gal |
| α | tank paint solar absorptance | - | $F_F$ | total deck fitting loss factor | lbmole/ y |
| I | daily total solar insolation | Btu/$ft^2$d | $N_C$ | number of columns | - |
| $T_{AX}$ | daily maximum ambient temperature | R | $N_{VB}$ | number of vacuum breakers | - |
| $T_{AN}$ | daily minimum ambient temperature | R | $N_D$ | number of drains | - |
| $D_E$ | effective tank diameter | ft | $N_I$ | number of deck legs | - |
| L | length of tank | Ft | $n_f$ | total number of different types of fittings | - |
| $K_{fi}$ | loss factor for a particular type of deck fitting | lbmole/y | $P_i$ | partial pressure of component i | psia |
| $N_{fai}$ | zero wind speed loss factor for a particular type of deck fitting | lbmole/y | $Z_{li}$ | liquid weight fraction of component i | lb/lb |
| $N_{fbi}$ | wind speed dependant loss factor for a particular type of deck fitting | lbmole/ $mph^m$y | $M_L$ | molecular weight of liquid mixture | lb/lbmol e |

| Variable | Description | Units | Variable | Description | Units |
|---|---|---|---|---|---|
| $K_V$ | fitting wind speed correction factor | - | $Z_{vi}$ | vapour weight fraction of component i | lb/lb |
| $m_i$ | loss factor for a particular type of deck fitting | - | $N_{TOTAL}$ | total number of mole in mixture | lbmole |
| i | 1,2,…,n | - | $W_i$ | liquid density of component i | lb/ft$^3$ |
| $L_D$ | deck seam loss | lb/y | $L_{ti}$ | emission rate of component i | lb/y |
| $F_C$ | effective column diameter | ft | $L_v$ | variable vapour space filling loss | lb/1000 gal |
| $K_D$ | deck seam loss per unit seam length factor | - | $V_1$ | volume of liquid pumped into system | bbl/y |
| $S_D$ | deck seam length factor | ft/ft$^2$ | $V_2$ | volume expansion capacity | Bbl |
| $L_{seam}$ | total length of deck seam | ft | $N_2$ | number of transfers into system | - |
| $A_{deck}$ | area of deck | ft$^2$ | | | |

***Total Losses from Fixed Roof Tanks*** [4]

The following equations, provided to estimate standing and working loss emissions, apply to tanks with vertical cylindrical shells and fixed rooves. These tanks must be substantially liquid- and vapour-tight and must operate approximately at atmospheric pressure. Total losses from fixed roof tanks are equal to the sum of the standing loss and working loss:

$$L_T = L_S + L_W \qquad (1\text{-}1)$$

where:

$L_T$ = total losses, 1b/yr
$L_S$ = standing losses, 1b/yr
$L_W$ = working losses, 1b/yr

<u>Standing Loss</u> - Fixed roof tanks standing or standing losses can be estimated from:

$$L_S = 365\, V_V\, W_V K_E K_S \qquad (1\text{-}2)$$

where:

$L_S$ = standing loss, 1b/yr
$V_V$ = vapour space volume, ft$^3$
$W_V$ = vapour density, 1b/ft3
$K_E$ = vapour space expansion factor, dimensionless
$K_S$ = vented vapour saturation factor, dimensionless
365 = constant, d/yr

<u>Tank Vapour Space Volume, $V_V$</u> - The tank vapour space volume is calculated using the following equation:

$$V_V = \frac{\pi}{4}\, D^2 H_{VO} \qquad (1\text{-}3)$$

where:

$V_V$ = vapour space volume, $ft^3$
D = tank diameter, ft see Note 1 for horizontal tanks
$H_{VO}$ = vapour space outage, ft

The vapour space outage, $H_{VO}$ is the height of a cylinder of tank diameter, D, whose volume is equivalent to the vapour space volume of a fixed roof tank, including the volume under the cone or dome roof. The vapour space outage, $H_{VO}$, is estimated from:

$$H_{VO} = H_S - H_L + H_{RO} \quad (1\text{-}4)$$

where:

$H_{VO}$ = vapour space outage, ft
$H_S$ = tank shell height, ft
$H_L$ = liquid height, ft
$H_{RO}$ = roof outage, ft; see Note 2 for a cone roof or Note 3 for a dome roof

***Notes:***

1. The emission estimating equations presented above were developed for vertical fixed roof tanks. If a user needs to estimate emissions from a horizontal fixed roof tank, some of the tank parameters can be modified before using the vertical tank emission estimating equations. First, by assuming that the tank is one-half filled, the surface area of the liquid in the tank is approximately equal to the length of the tank times the diameter of the tank. Next, assume that this area represents a circle, which is the liquid is an upright cylinder. Therefore, the effective diameters, $D_E$, is then equal to:

$$D_E = \sqrt{\frac{LD}{0.785}} \quad (1\text{-}5)$$

where:

$D_E$ = effective tank diameter, ft
L = length of tank, ft
D = actual diameter of tank, ft

One-half of the actual diameter of the horizontal tank should be used as the vapour space outage, $H_{VO}$. This method yields only a very approximate value for emissions from horizontal storage tanks. For underground horizontal tanks, assume that no standing or standing losses occur ($L_S = 0$) because the insulating nature of the earth limits the diurnal temperature change. No modifications to the working loss equation are necessary for either above ground or underground horizontal tanks.

2. For a cone roof, the roof outage, $H_{RO}$, is calculated as follows:

$$H_{RO} = \frac{1}{3} H_R \quad (1\text{-}6)$$

where:

$H_{RO}$ = roof outage (or shell height equivalent to the volume contained under the roof) ft
$H_R$ = tank roof height, ft

The tank roof height, $H_R$, is equal to $S_R$ $R_S$

where:

$S_R$ = tank cone roof slope, if unknown, a standard value of 0.0625 ft/ft is used, ft/ft

$R_S$ = tank shell radius, ft

3. For a dome roof, the roof outage, $H_{RO}$, is calculated as follows:

$$H_{RO} = H_{RO}\left[\frac{1}{2}+\frac{1}{6}\left[\frac{H_R}{R_S}\right]^2\right] \quad (1\text{-}7)$$

where:

$H_{RO}$ = roof outage, ft

$H_R$ = tank roof height, ft

$R_S$ = tank shell radius, ft

The tank roof height, $H_R$, is calculated:

$$H_R = R_R - \left(R_R^{\,2} - R_S^{\,2}\right)^{0.5} \quad (1\text{-}8)$$

where:

$H_R$ = tank roof height, ft

$R_R$ = tank dome roof radius, ft

$R_S$ = tank shell radius, ft

The value of $R_R$ usually ranges from 0.8D to 1.2D, where D = 2 $R_S$. If $R_R$ is unknown, the tank diameter is used in its place. If the tank diameter is used as the value for $R_R$, Equations 1-7 and 1-8 reduce to $H_R$ = 0.268 $R_S$ and $H_{RO}$ = 0.137 $R_S$.

Vapour Density, $W_V$ - The density of the vapour is calculated using the following equation:

$$W_V = \frac{M_V P_{VA}}{RT_{LA}} \quad (1\text{-}9)$$

where:

$W_V$ = vapour density, 1b/ft$^3$

$M_V$ = vapour molecular weight, lb/1b-mole; see Note 1

R = the ideal gas constant, 10.731 psia.ft$^3$/1b-mole.°R

$P_{VA}$ = vapour pressure at daily average liquid surface temperature, psia; see Notes 1 and 2

$T_{LA}$ = daily average liquid surface temperature, °R; see Note 3

***Notes:***

1. The molecular weight of the vapour, $M_V$, can be determined from Table 7.1- 2 and 7.1-3 for selected petroleum liquids and volatile organic liquids, respectively, or by analysing vapour samples. Where mixtures of organic liquids are stored in a tank, $M_V$ can be calculated from the liquid composition. The molecular weight of the vapour, $M_V$, is equal to the sum of the molecular weight, $M_i$, multiplied by the vapour mole fraction, $y_i$, for each component. The vapour mole fraction is equal to the partial pressure of component i divided by the total vapour pressure. The partial pressure of component i is equal to the true vapour pressure of component i (P) multiplied by the liquid mole fraction, ($x_i$). Therefore,

$$M_V = \Sigma M_i y_i = \Sigma M_i \left[\frac{P_{xi}}{P_{VA}}\right] \qquad (1\text{-}10)$$

where:

$P_{VA}$, total vapour pressure of the stored liquid, by Raoult's Law, is:

$$P_{VA} = \Sigma P_{xi} \qquad (1\text{-}11)$$

For more detailed information, please refer to Section 7.1.4.

2. True vapour pressure is the equilibrium partial pressure exerted by a volatile organic liquid, as defined by ASTM-D 2879 or as obtained from standard reference texts. Reid vapour pressure is the absolute vapour pressure of volatile crude oil and volatile nonviscous petroleum liquids, except liquefied petroleum gases, as determined by ASTM-D-323. True vapour pressures for organic liquids can be determined from Table 7.1-3. True vapour pressure can be determined for crude oils using Figures 7.1-13a and 7.1-13b. For refined stocks (gasoline and naphtha), Table 7.1-2 or Figures 7.1-14a and 7.1-14b can be used. In order to use Figures 7.1-13a, 7.1-13b, 7.1-14a, or 7.1-14b, the stored liquid surface temperature, $T_{LA}$, must be determined in degrees Fahrenheit. See Note 3 to determine $T_{LA}$.

   Alternatively, true vapour pressure for selected petroleum liquid stocks, at the stored liquid surface temperature, can be determined using the following equation:

$$P_{VA} = \exp\left[A - \left(\frac{B}{T_{LA}}\right)\right] \qquad (1\text{-}12a)$$

where:

| | |
|---|---|
| exp | = exponential function |
| A | = constant in the vapour pressure equation, dimensionless |
| B | = constant in the vapour pressure equation, °R |
| $T_{LA}$ | = daily average liquid surface temperature, °R |
| $P_{VA}$ | = true vapour pressure, psia |

   For selected petroleum liquid stocks, physical property data is presented in Table 7.1-2. For refined petroleum stocks, the constants A and B can be calculated from the equations presented in Figure 7.1-15 and the distillation slopes presented in Table 7.1-4. For crude oil stocks, the constants A and B can be calculated from the equations presented in Figure 7.1-16. Note that in Equation 1-12a, $T_{LA}$ is determined in degrees Rankine instead of degrees Fahrenheit.

   The true vapour pressure of organic liquids at the stored liquid temperature can be estimated by Antoine's equation:

$$\text{Log } P_{VA} = A - \frac{B}{T_{LA} + C} \qquad (1\text{-}12b)$$

where:

| | |
|---|---|
| A | = constant in vapour pressure equation |
| B | = constant in vapour pressure equation |
| C | = constant in vapour pressure equation |
| $T_{LA}$ | = daily average liquid surface temperature, °C |
| $P_{VA}$ | = vapour pressure at average liquid surface temperature, mmHg |

For organic liquids, the values for the constants A, B, and C are listed in Table 7.1-5. Note that in Equation 1-12b, $T_{LA}$ is determine in degrees Celsius instead of degrees Rankine. Also, in Equation 1-12b, $P_{VA}$ is determined in mm of Hg rather than psia (760 mm Hg = 14.7 psia).

3. If the daily average liquid surface temperature, $T_{LA}$, is unknown, it is calculated using the following equation:

$$T_{LA} = 0.44T_{AA} + 0.56T_B + 0.0079\,\alpha I \qquad (1\text{-}13)$$

where:

$T_{LA}$ = daily average liquid surface temperature, °R
$T_{AA}$ = daily average ambient temperature, °R; see Note 4
$T_B$ = liquid bulk temperature, °R; see Note 5
$\alpha$ = tank paint solar absorptance, dimensionless; see Table 7.1-6
I = daily total solar insolation factor, Btu/ft$^2$.d; see Table 7.1-7

If $T_{LA}$ is used to calculate $P_{VA}$ from Figures 7.1-13a, 7.1-13b, 7.1-14a, or 7.1-14b, $T_{LA}$ must be converted from degrees Rankine to degrees Fahrenheit (°F = °R - 460). If $T_{LA}$ is used to calculate $P_{VA}$ from Equation 1-12b, $T_{LA}$ must be converted from degrees Rankine to degrees Celsius (°C = [°R - 492]/1.8). Equation 1-13 should not be used to estimate liquid surface temperature from insulated tanks. In the case of insulated tanks, the average liquid surface temperature should be based on liquid surface temperature measurements from the tank.

4. The daily average ambient temperature, $T_{AA}$, is calculated using the following equation:

$$T_{AA} = \frac{[T_{AX} + T_{AN}]}{2} \qquad (1\text{-}14)$$

where:

$T_{AA}$ = daily average ambient temperature, °R
$T_{AX}$ = daily maximum ambient temperature, °R
$T_{AN}$ = daily minimum ambient temperature, °R

Table 7.1-7 gives values of $T_{AX}$ and $T_{AN}$ for selected U.S. cities.

5. The liquid bulk temperature, $T_B$, is calculated using the following equation:

$$T_B = T_{AA} + 6\alpha - 1 \qquad (1\text{-}15)$$

where:

$T_B$ = liquid bulk temperature, °R
$T_{AA}$ = daily average ambient temperature, °R, as calculated in Note 4
$\alpha$ = tank paint solar absorptance, dimensionless; see Table 7.1-6.

<u>Vapour Space Expansion Factor, $K_E$</u> - The vapour space expansion factor, $K_E$, is calculated using the following equation:

$$K_E = \frac{\Delta T_V}{T_{LA}} + \frac{\Delta P_V - \Delta P_B}{P_A - P_{VA}} \qquad (1\text{-}16)$$

where:

$\Delta T_V$ = daily vapour temperature range, °R; see Note 1
$\Delta P_V$ = daily vapour pressure range, psi; see Note 2
$\Delta P_B$ = breather vent pressure setting range, psi; see Note 3

$P_A$ = atmospheric pressure, psia
$P_{VA}$ = vapour pressure at daily average liquid surface temperature, psia; see Notes 1 and 2 for Equation 1-9
$T_{LA}$ = daily average liquid surface temperature, °R; see Note 3 for Equation 1-9

***Notes:***

1. The daily vapour temperature range, $\Delta T_V$, is calculated using the following equation:

$$\Delta T_V = 0.72\Delta T_A + 0.028\alpha I \quad (1\text{-}17)$$

where:
$\Delta T_V$ = daily vapour temperature range, °R
$\Delta T_A$ = daily ambient temperature range, °R; see Note 4
$\alpha$ = tank paint solar absorptance, dimensionless; see Table 7.1 -6
I =daily total solar insolation factor, $Btu/ft^2.d$; see Table 7.1-7

2. The daily vapour pressure range, $\Delta P_V$, can be calculated using the following equation:

$$\Delta P_V = P_{VX} - P_{VN} \quad (1\text{-}18)$$

where:

$\Delta P_V$ = daily vapour pressure range, psia
$P_{VX}$ = vapour pressure at the daily maximum liquid surface temperature, psia; see Note 5
$P_{VN}$ = vapour pressure at the daily minimum liquid surface temperature, psia; see Note 5

The following method can be used as an alternate means of calculating $\Delta P_V$ for petroleum liquids:

$$\Delta P_V = \frac{0.50\ BP_{VA}\ \Delta T_V}{T_{LA}^{\ 2}} \quad (1\text{-}19)$$

where:
$\Delta P_V$ = daily vapour pressure range, psia
B = constant in the vapour pressure equation, °R; see Note 2 to Equation 1-9
$P_{VA}$ = vapour pressure at the daily average liquid surface temperature, psia; see Notes 1 and 2 to Equation 1-9
$T_{LA}$ = daily average liquid surface temperature, °R, see Note 3 to Equation 1-9

$\Delta T_V$ = daily vapour temperature range, °R; see Note 1

3. The breather vent pressure setting range, $\Delta P_B$, is calculated using the following equation:

$$\Delta P_B = P_{BP} - P_{BV} \quad (1\text{-}20)$$

where:
$\Delta P_B$ = breather vent pressure setting range, psig
$P_{BP}$ = breather vent pressure setting, psig
$P_{BV}$ = breather vent vacuum setting psig

If specific information on the breather vent pressure setting and vacuum setting is not available, assume 0.03 psig for $P_{BP}$ and -0.03 psig for $P_{BV}$ as typical values. If the fixed roof tank is of bolted or riveted construction in which the roof or shell plates are not vapour tight, assume that $\Delta P_B$=0, even if a breather vent is used. The estimating equations for fixed roof tanks do not apply to either low or high-pressure tanks. If the breather vent pressure or vacuum setting exceeds 1.0 psig, the standing losses could potentially be negative.

4. The daily ambient temperature range, $\Delta T_A$, is calculated using the following equation:

$$\Delta T_A = T_{AX} - T_{AN} \qquad (1\text{-}21)$$

where:

$\Delta T_A$ = daily ambient temperature range, °R
$T_{AX}$ = daily maximum ambient temperature,°R
$T_{AN}$ = daily minimum ambient temperature, °R

Table 7.1-7 gives values of $T_{AX}$ and $T_{AN}$ for selected cities in the United States. [11]

5. The vapour pressures associated with daily maximum and minimum liquid surface temperature, $P_{VX}$ and $P_{VN}$, respectively are calculated by substituting the corresponding temperatures, $T_{LX}$ and $T_{LN}$, into the vapour pressure function discussed in Notes 1 and 2 to Equation 1-9. If $T_{LX}$ and $T_{LN}$ are unknown, Figure 7.1-17 can be used to calculate their values.

Vented Vapour Saturation Factor, $K_S$ - The vented vapour saturation factor, $K_S$, is calculated using the following equation:

$$K_S = \frac{1}{1 + 0.053\, P_{VA} H_{VO}} \qquad (1\text{-}22)$$

where:

$K_S$ = vented vapour saturation factor, dimensionless
$P_{VA}$ = vapour pressure at daily average liquid surface temperature, psia; see Notes 1 and 2 to Equation 1-9
$H_{VO}$ = vapour space outage, ft, as calculated in Equation 1-4

Working Loss - The working loss, $L_W$, can be estimated from:

$$L_W = 0.0010 M_V P_{VA} Q K_N K_P \qquad (1\text{-}23)$$

where:

$L_W$ = working loss, 1b/yr
$M_V$ = vapour molecular weight, 1b/1b-mole; see Note 1 to Equation 1-9
$P_{VA}$ = vapour pressure at daily average liquid surface temperature, psia; see Notes 1 and 2 to Equation 1-9
Q = annual net throughput (tank capacity [bbl] times annual turnover rate), bb1/yr
$K_N$ = turnover factor, dimensionless; see Figure 7.1-18
for turnovers >36, $K_N$ = (180 + N)/6N
for turnovers ≤ 36, $K_N$ = 1
N = number of turnovers per year, dimensionless

$$N = \frac{5.614\, Q}{V_{LX}} \qquad (1\text{-}24)$$

where:

N = number of turnovers per year, dimensionless

$Q$ = annual net throughput, bb1/yr
$V_{LX}$ = tank maximum liquid volume, $ft^3$

and

$$V_{LX} = \frac{\pi}{4} D^2 H_{LX} \qquad (1\text{-}25)$$

where:

$D$ = diameter, ft
$H_{LX}$ = maximum liquid height, ft
$K_P$ = working loss product factor, dimensionless, 0.75 for crude oils. For all other organic liquids, $K_P = 1$.

***Total Losses From Floating Roof Tanks*** [3-5,13,15-17]

Total floating roof tank emissions are the sum of rim seal, withdrawal, deck fitting, and deck seam losses. The equations presented in this subsection apply only to floating roof tanks. The equations are not intended to be used in the following applications:

1. To estimate losses from unstable or boiling stocks or from mixtures of hydrocarbons or petrochemicals for which vapour pressure is not known or cannot readily be predicted;

2. To estimate losses from closed internal or closed domed external floating roof tanks (tanks vented only through a pressure/vacuum vent); or

3. To estimate losses from tanks in which the materials used in the rim seal and/or deck fittings are either deteriorated or significantly permeated by the stored liquid.

Total losses from floating roof tanks may be written as:

$$L_T = L_R + L_{WD} + L_F + L_D \qquad (2\text{-}1)$$

where:

$L_T$ = total loss, 1b/yr
$L_R$ = rim seal loss, 1b/yr; see Equation 2-2
$L_{WD}$ = withdrawal loss, 1b/yr; see Equation 2-4
$L_F$ = deck fitting loss, 1b/yr; see Equation 2-5
$L_D$ = deck seam loss (internal floating roof tanks only), 1b/yr; see Equation 2-9

Rim Seal Loss - Rim seal loss from floating roof tanks can be estimated using the following equation:

$$L_R = \left(K_{RA} + K_{RB} v^n\right) D P^* M_V K_C \qquad (2\text{-}2)$$

where:

$L_R$ = rim seal loss, 1b/yr
$K_{Ra}$ = zero wind speed rim seal loss factor, 1b-mole/ft.yr; see Table7.1-8
$K_{Rb}$ = wind speed dependent rim seal loss factor, 1b-mole/(mph)$^N$ft.yr; see Table 7.1-8
$v$ = average ambient wind speed at tank site, mph; see Note 1
$n$ = seal-related wind speed dimensionless; see Table 7.1-8
$P^*$ = vapour pressure function, dimensionless; see Note 2

$$P^* = \frac{\left(\frac{P_{VA}}{P_A}\right)}{\left[1 + \left(1 - \left(\frac{P_{VA}}{P_A}\right)\right)^{0.5}\right]^2} \quad (2\text{-}3)$$

where:

$P_{VA}$ = vapour pressure at daily average liquid surface temperature, psia; See Notes 1 and 2 to Equation 1-9 and Note 3 below

$P_A$ = atmospheric pressure, psia

D = tank diameter, ft

$M_V$ = average vapour molecular weight, 1b/1b-mole; see Note 1 to Equation 1-9,

$K_C$ = product factor; $K_C$ = 0.4 for crude oils; $K_C$ = 1 for all other organic liquids.

***Notes:***

1. If the ambient wind speed at the tank site is not available, use wind speed data from the nearest local weather station or values from Table 7.1-9. If the tank is an internal or domed external floating roof tank, the value of v is zero.

2. P* can be calculated or read directly from Figure 7.1-19.

3. The API recommends using the stock liquid temperature to calculate PVA for use in Equation 2-3 in lieu of the liquid surface temperature. If the stock liquid temperature is unknown, API recommends the following equations to estimate the stock temperature:

| Tank Colour | Average Annual Stock Temperature, $T_S$ (°F) |
|---|---|
| White | $T_{AA} + 0$[a] |
| Aluminium | $T_{AA} + 2.5$ |
| Grey | $T_{AA} + 3.5$ |
| Black | $T_{AA} + 5.0$ |

[a]$T_{AA}$ is the average annual ambient temperature in degrees Fahrenheit.

Withdrawal Loss - The withdrawal loss from floating roof storage tanks can be estimated using Equation 2-4.

$$L_{WD} = \frac{(0.943)QCW_L}{D} + \left[1 + \frac{N_C F_C}{D}\right] \quad (2\text{-}4)$$

where:

$L_{WD}$ = withdrawal loss, 1b/yr

Q = annual throughput (tank capacity [bbl] times annual turnover rate), bbl/yr

C = shell clingage factor, bbl/1,000 $ft^2$; see Table 7.1-10

$W_L$ = average organic liquid density, 1b/gal; see Note 1

D = tank diameter, ft

0.943 = constant, 1,000 $ft^{3\cdot}$ $gal/bbl^2$

$N_C$ = number of fixed roof support columns, dimensionless; see

Note 2

$F_C$ = effective column diameter, ft (column perimeter [ft]/π); see Note 3

***Notes:***

1. A listing of the average organic liquid density for select petrochemicals is provided in Tables 7.1-2 and 7.1-3. If $W_L$ is not known for gasoline, an average value of 6.1 1b/gal can be assumed.

2. For a self-supporting fixed roof or an external floating roof tank:

$N_C = 0.$

For a column-supported fixed roof:

$N_C$ - use tank-specific information or see Table 7.1-11.

3. Use tank-specific effective column diameter or

$F_C$ = 1.1 for 9-inch by 7-inch built-up columns, 0.7 for 8-inch-diameter pipe columns, and 1.0 if column construction details are not known.

Deck Fitting Loss - Deck fitting losses from floating roof tanks can be estimated by the following equation:

$$L_F = F_F P^* M_V K_C \qquad (2\text{-}5)$$

where:

$L_F$ = the deck fitting loss, 1b/yr

$F_F$ = total deck fitting loss factor, 1b-mole/yr

$$F_F = \left[\left(N_{F_1} + K_{F_1}\right) + \left(N_{F_2} + K_{F_2}\right) + \ldots + \left(N_{F_{NF}} + K_{F_{NF}}\right)\right] \qquad (2\text{-}6)$$

where

$N_{Fi}$ = number of deck fittings of a particular type (i = 0,1,2,...,$n_f$), dimensionless

$K_{Fi}$ = deck fitting loss factor for a particular type fitting (i = 0,1,2,...,$n_f$), 1b-mole.yr; see Equation 2-7

$n_f$ = total number of different types of fittings, dimensionless

P*, $M_V$, $K_C$ are as defined for Equation 2-2.

The value of $F_F$ may be calculated by using actual tank-specific data for the number of each fitting type ($N_F$) and then multiplying by the fitting loss factor for each fitting ($K_F$).

The deck fitting loss factor, $K_{Fi}$ for a particular type of fitting, can be estimated by the following equation:

$$K_{F_i} = K_{Fa_i} + K_{Fb_i}\left(K_V v\right)^{m_i} \qquad (2\text{-}7)$$

where:

$K_{Fi}$ = loss factor for a particular type of deck fitting, 1b-mole/yr

$K_{fai}$ = zero wind speed loss factor for a particular type of fitting, 1b-mole/yr

$K_{Fbi}$ = wind speed dependent loss factor for a particular type of fitting, 1b-mole/(mph)$^{m\cdot}$yr

$m_i$ = loss factor for a particular type of deck fitting, dimensionless

i = 1,2, ..., n, dimensionless

$K_v$ = fitting wind speed correction factor, dimensionless; see below

v = average ambient wind speed, mph

For external floating rook tanks, the fitting wind-speed correction factor, $K_V$, is equal to 0.7. For internal and domed external floating roof tanks, the value of v in Equation 2-7 is zero and the equation becomes:

$$K_{F_i} = K_{Fa_i} \qquad (2\text{-}8)$$

Loss factors $K_{Fa}$, $K_{Fb}$, and m are provided in Table 7.1-12 for the most common deck fittings used on floating roof tanks. These factors apply only to typical deck fitting conditions and when the average ambient wind speed is below 15 miles per hour. Typical numbers of deck fittings for floating roof tanks are presented in Tables 7.1-11, 7.1-12, 7.1-13, 7.1-14, and 7.1-14.

Deck Seam Loss - Neither welded deck internal floating roof tanks nor external floating roof tanks have deck seam losses. Internal floating roof tanks with bolted decks may have deck seam losses. Deck seam loss can be estimated by the following equation:

$$L_d = K_D S_D D^2 P^* M_V K_C \qquad (2\text{-}9)$$

where:

$K_D$ = deck seam loss per unit seam length factor, 1b-mole/ft-yr
= 0.0 for welded deck
= 0.34 for bolted deck; see Note

$S_D$ = deck seam length factor, ft/ft$^2$

$$S_D = \frac{L_{SEAM}}{A_{DECK}}$$

where:

$L_{seam}$ = total length of deck seams, ft

$A_{deck}$ = area of deck, ft2 = π D2/4

D, P*, $M_V$, and $K_C$ are as defined for Equation 2-2

If the total length of the deck seam is not known, Table 7.1-16 can be used to determine $S_D$. For a deck constructed from continuous metal sheets with a 7-ft spacing between the seams, a value of 0.14 ft/ft$^2$ can be used. A value of 0.33 ft/ft$^2$ can be used for $S_D$ when a deck is constructed from rectangular panels 5ft by 7.5 ft. Where tank-specific data concerning width of deck sheets or size of deck panels are unavailable, a default value for $S_D$ can be assigned. A value of 0.20 ft/ft$^2$ can be assumed to represent the most common bolted decks currently in use.

Note: Recently vendors of bolted decks have been using various techniques in an effort to reduce deck seam losses. However, emission factors are not currently available in *AP-42* that represent the emission reduction achieved by these techniques. Some vendors have developed specific factors for their deck designs; however, use of these factors is not recommended until approval has been obtained from the governing regulatory agency or permitting authority.

***Variable Vapour Space Tanks***[18]–

Variable vapour space filling losses result when vapour is displaced by liquid during filling operations. Since the variable vapour space tank has an expandable vapour storage capacity, this loss is not as large as the filling loss associated with fixed roof tanks. Loss of vapour occurs only when the tank's vapour storage capacity is exceeded. Equation 3-1 assumes that one-fourth of the expansion capacity is available at the beginning of each transfer.

Variable vapour space system filling losses can be estimated from:

$$L_V = \left(2.40x10^{-2}\right)\frac{M_V P_{VA}}{V_1\left[V_1 - \left(0.25V_2N_2\right)\right]} \qquad (3-1)$$

where:

$L_V$ = variable vapour space filling loss, 1b/1 000 gal throughput
$M_V$ =molecular weight of vapour in storage tank, 1b/1b-mole; see Note 1 to Equation 1-9
$P_{VA}$ = true vapour pressure at the daily average liquid surface temperature, psia; see Notes 1 and 2 to Equation 1-9
$V_1$ = volume of liquid pumped into system, throughput, bbl/yr
$V_2$ = volume expansion capacity of system, bbl; see Note 1
$N_2$ = number of transfers into system, dimensionless; see Note 2

***Notes:***

1. V2 is the volume expansion capacity of the variable vapour space achieved by roof lifting or diaphragm flexing.

2. $N_2$ is the number of transfers into the system during the time period that corresponds to a throughput of $V_1$.

   The accuracy of Equation 3-1 is not documented. Special tank operating conditions may result in actual losses significantly different from the estimates provided by Equation 3-1. For example, if one or more tanks with interconnected vapour spaces are filled while others are emptied simultaneously, all or part of the expelled vapours will be transferred to the tank, or tanks, being emptied. This is called balanced pumping. Equation 3-1 does not account for balanced pumping, and will overestimate losses under this condition. It should also be noted that, although not developed for use with heavier petroleum liquids such as kerosene and fuel oils, the equation is recommended for use with heavier petroleum liquids in the absence of better data.

## Appendix IV – Development of the Simple Technique

This appendix lists assumptions and default parameters used for the development of simple EETs for different fuel storage tanks. The meteorological data set for South Australia South (SAS – Zone 1) (see Table 6) was used. Test data was generated by running a number of scenarios in TANKS 4.09 for each of three tank types (Tables 16-18). Models were developed by determining multiple regression equations (Table 21).

**Table 17 Assumption and input data for TANKS program**

| Tank Characteristics | Horizontal Fixed Roof Tank | Vertical Fixed Roof Tank | Internal Floating Roof Tank |
|---|---|---|---|
| Tank capacity (kL) | 5,20,50,100 | 22,150,400,1300 | 22,150,400,1300 |
| Turnovers per Year | 10,20,30,40,50,100 | 10,20,30,40,50,100 | 10,20,30,40,50,100 |
| Net Throughput (kL/yr) | Varies depending on Tank Capacity and Turnovers per Year | | |
| Tank heated | No | No | NA |
| Tank underground | No | NA | NA |
| Shell colour/shade | Aluminium/ Specular | Aluminium/ Specular | NA |
| Shell condition | Good | Good | NA |
| Maximum Liquid Height (ft) | NA | Equivalent to Tank height | NA |
| Average Liquid Height (ft) | NA | Maximum Liquid Height divided by factor of 2 | NA |
| Roof colour/shade | NA | Aluminium/ Specular | White/White |
| Roof condition | NA | Good | NA |
| Roof paint condition | NA | NA | Good |
| Roof type | NA | Dome | NA |
| Roof height (ft) | NA | 1ft | NA |
| Roof radius (ft) | NA | Automated as equal to tank diameter | NA |
| Self supporting roof | NA | NA | No |
| Number of columns | NA | NA | Automated based on tank diameter |
| Effective column diameter (ft) | NA | NA | 1ft (selected as unknown) |

**Table 17 (cont.)**

| Tank Characteristics | Horizontal Fixed Roof Tank | Vertical Fixed Roof Tank | Internal Floating Roof Tank |
|---|---|---|---|
| Internal shell condition | NA | NA | Light rust |
| | | | |
| External shell condition | NA | NA | White/White |
| Primary seal | NA | NA | Vapour-mounted |
| Secondary seal | NA | NA | None |
| Deck type | NA | NA | Welded |
| Deck Fitting category | NA | NA | Typical |
| View/Add fittings | NA | NA | Automated by program |
| Vacuum setting | -0.03 | -0.03 | -0.03 |
| Pressure setting | 0.03 | 0.03 | 0.03 |

## TANKS data output for diesel storage tanks

### Table 18 Horizontal Fixed Roof Tanks – emissions of Total VOCs (kg).

| Throughput (kL/yr) | Capacity (kL) | | | |
|---|---|---|---|---|
| | **5** | **20** | **50** | **100** |
| 50 | 0.3375 | | | |
| 100 | 0.486 | | | |
| 150 | 0.63 | | | |
| 200 | 0.729 | 1.3545 | | |
| 250 | 0.7515 | | | |
| 393 | | 1.935 | | |
| 491.4 | 0.873 | | 3.375 | |
| 589 | | 2.52 | | |
| 786 | | 2.9115 | | |
| 982 | | 3.006 | 4.842 | 6.759 |
| 1474 | | | 6.3 | |
| 1965 | | 4.1355 | 7.2765 | 9.6795 |
| 2457 | | | 7.5195 | |
| 2949 | | | | 12.6 |
| 3931 | | | | 14.5485 |
| 4914 | | | 8.7345 | 15.0345 |
| 9828 | | | | 17.469 |

### Table 19 Vertical Fixed Roof Tanks – emissions of Total VOCs (kg).

| Throughput (kL/yr) | Capacity (kL) | | | |
|---|---|---|---|---|
| | **22** | **150** | **400** | **1300** |
| 220 | 1.3815 | | | |
| 440 | 2.025 | | | |
| 660 | 2.6685 | | | |
| 880 | 3.096 | | | |
| 1100 | 3.204 | | | |
| 1500 | | 9.045 | | |
| 2200 | 3.7395 | | | |
| 3000 | | 13.4235 | | |
| 4000 | | | 23.9445 | |
| 4500 | | 17.8065 | | |
| 6000 | | 20.727 | | |
| 7500 | | 21.456 | | |
| 8000 | | | 35.6265 | |
| 12000 | | | 47.304 | |
| 13000 | | | | 77.3775 |
| 15000 | | 25.1055 | | |
| 16000 | | | 55.09395 | |
| 20000 | | | 57.042 | |
| 26000 | | | | 115.344 |
| 39000 | | | | 153.3105 |
| 40000 | | | 66.7755 | |
| 52000 | | | | 178.6185 |
| 65000 | | | | 184.9455 |
| 130000 | | | | 216.5805 |

**Table 20 Internal Floating Roof Tanks – emissions of Total VOCs (kg).**

| Throughput (kL/yr) | Capacity (kL) | | | |
|---|---|---|---|---|
| | 22 | 150 | 400 | 1300 |
| 220 | 2.943 | | | |
| 440 | 3.618 | | | |
| 660 | 4.2975 | | | |
| 880 | 4.9725 | | | |
| 1100 | 5.6475 | | | |
| 1500 | | 5.49 | | |
| 2200 | 9.036 | | | |
| 3000 | | 8.4735 | | |
| 4000 | | | 8.6805 | |
| 4500 | | 11.457 | | |
| 6000 | | 14.445 | | |
| 7500 | | 17.4285 | | |
| 8000 | | | 14.5575 | |
| 12000 | | | 20.43 | |
| 13000 | | | | 15.93 |
| 15000 | | 32.3505 | | |
| 16000 | | | 26.307 | |
| 20000 | | | 32.1796 | 28.458 |
| 26000 | | | | |
| 39000 | | | | 40.986 |
| 40000 | | | 61.5555 | |
| 52000 | | | | 53.514 |
| 65000 | | | | 66.042 |
| 130000 | | | | 128.6775 |

**Table 21 Regression equations developed for calculation of emissions of Total VOCs using data in Tables 17-19.**

| Tank Type | Regression Equation | P | $R^2$ statistic (%) |
|---|---|---|---|
| Horizontal Fixed Roof | E = 4.7E-02 + 8.1E-02 * C + 1.1E-03 * T | > 95% | 96.43 |
| Vertical Fixed Roof | E = 1.2E-01 + 7.4E-02 * C + 1.1E-03 * T | > 95% | 96.83 |
| Internal Floating Roof | E = 8.0 – 3.3E-03 * C + 1.0E-03 * T | > 95% | 97.07 |

Notes:
1. E = emissions of Total VOCs (kg).
2. C = capacity of storage tank (kL).
3. T = throughput for period (kL).
4. P = probability of equation matching input data.
5. $R^2$ statistic = degree to which equation accounts for variability of input data.
6. Scientific notation is used: e.g. 7.38E-02 represents $7.38 \times 10^{-2}$ or 0.0738 and 7.38E+02 represents $7.38 \times 10^{+2}$ or 738.