National Pollutant Inventory

Emission Estimation Technique Manual

for
Airports

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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 Airports EET Manual (Version 1.1 – 17 May 2001).

Page	Outline of alteration
5	Table note e - Added the comment that engine test cell emission factors provided should only be used for Melbourne Airport.
6	Altered example 1 to use airside vehicles instead of test cells and used the correct Total Aircraft figure for Brisbane from Table 1 (152 118).
9	First paragraph in 4.2.7 highlighted that ICAO and other emission data in relation to aircraft and APUs are in the Aircraft AED manual.

EMISSION ESTIMATION TECHNIQUES FOR AIRPORTS

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LIST OF TABLES AND EXAMPLES

1.0 Introduction

The purpose of all Manuals in this series is to assist Australian manufacturing, industrial, and service facilities report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual describes the procedures and recommended approaches for estimating emissions from airports.

EET MANUAL:	Airports
HANDBOOK:	Airports
ANZSIC CODES :	2824, 6401, 6402, 6403, 8200 and all codes in the within the 640 and 820 ANZSIC code groups.

This Manual has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

2.0 Reporting Arrangements for Airports

This Airports Manual applies to facilities, either privately owned or leased from any Australian government, engaged in providing services related to domestic, international, and military transportation by air, as well as operating airports and all terminal services, including aircraft maintenance and engine testing activities. Australian airports vary in size from a few hectares to over a thousand hectares and their activities range from retail and tourist catering through to the refurbishment of large jet aircraft. Airport facilities also include infrastructure such as wastewater treatment plants, roads, vehicle maintenance and repair workshops. Much of the support activity associated with this infrastructure is commercial and industrial in nature and involves many individual tenants who are often quite discrete from the airport lessee company (ALC) responsible for overall airport management.

The purpose of this Manual is to provide guidance on the characterisation of emissions from those activities specifically associated with airports (see Section 3 for a complete list of the activities covered by this Manual). It is likely that there will be certain activities (eg wastewater treatment) which lead to emissions of NPI-listed substances but which are not covered by this Manual. In this situation, your State or Territory environment agency will provide advice on emission estimation techniques which may be used for these activities.

In the specific context of airports, the following issues must be noted:

- ALCs, as Airport Managers, are not directly responsible for individual tenant's NPI reporting obligations. It is the responsibility of the airport tenants to ensure that, if they trip any of the NPI reporting thresholds (see The NPI Guide for further information), they report to the NPI.
- This Manual does not address emissions from aircraft in flight. Emissions from aircraft in flight (including the landing and take-off cycle and taxiing) are considered as 'aggregated emissions' and will be calculated separately by the relevant State or Territory environmental agency.
- All activities on airports (excluding aircraft in flight and the landing and take-off cycle, including taxiing) such as contracted aircraft maintenance, servicing activities, retail activities within a terminal or any other facility activity on airport land, will need to be examined by the relevant facility manager/occupier (this, in most cases, will be the relevant tenant) to ascertain whether they trip an NPI threshold for any listed NPI substance. If they do trip any threshold, occupiers of these facilities will then need to report their emissions. The NPI Guide provides assistance in determining whether a threshold has been tripped. Where a threshold is not triggered reporting is not required (ie some tenants at airports may not be required to report to the NPI).

3.0 Airport Activities Covered by this Manual

This Manual provides guidance on estimating emissions from the following airport activities:

- Ground Support Equipment (airside vehicles and mobile plant);
- Paint and Solvent Usage;
- Fuel and Organic Liquid Storage;
- Boilers and Space Heaters;
- Emergency Generators;
- Fire Training and Emergency Simulations;
- Aircraft Engine Test Cells; and
- Re-fuelling Operations and General Engine Testing.

This list comprises those practices and activities which are likely to be the largest sources of NPI-listed pollutants at major Australian airports.

Emissions from aircraft while mobile (taxiing, landing, and take-off cycles) and stationary (idling, docked at gate, and during on-wing engine testing) are estimated by State and Territory environment authorities using the Emission Estimation Technique Manual for Aggregated Emissions from Aircraft. State and Territory environment authorities as part of their aggregated emissions programs will also estimate private motor vehicles on airport access roads and car parks.

It is likely that some tenants with NPI reporting requirements will have certain activities (eg wastewater treatment) which lead to emissions of NPI-listed substances but which are not covered by this Manual. In this situation, the respective State or Territory environment agency will provide advice on emission estimation techniques which may used for these activities.

4.0 Estimating Emissions

This section describes the techniques available, the data inputs required, and the likely sources of these data for estimating emissions of NPI-listed substances from the airport activities listed in Section 3 of this manual.

There are a number of techniques available for estimating emissions from airport activities. The specific techniques chosen depend on the available data, the available resources, the degree of accuracy sought and the source of emissions being quantified. Where site-specific data (eg direct emissions monitoring data) are available, these should be used in preference to the default emission factors provided in Sections 4.1 and 4.2 below. In the absence of such monitoring data, the use of the default emission factors presented in this Manual provides an acceptable degree of accuracy in emissions estimation for the purposes of NPI reporting.

Section 4.1 provides default emission factors which have been derived based on data from Melbourne Airport, where the emissions have been correlated with the number of aircraft movements at the airport. This is a very crude approach but suitable for use in situations where there is no site-specific information available on fuel consumption in specific activities. Section 4.2 is slightly more complex in that it requires that more site-specific data are available and that activities are considered individually. However, for the majority of airports, and for tenants' activities at airports, the site-specific data are likely to be readily available. The use of the approaches outlined in Section 4.2 is likely to provide significantly more accurate information than the use of the default emission factors in Section 4.1.

4.1 Emission Factors Based on LTO Data

An emission factor is the pollutant emission rate relative to the level of source activity and is usually expressed as the weight of a substance emitted multiplied by the unit weight, volume, distance, or duration of the activity emitting the substance. An example could be the number of kilograms of carbon monoxide emitted from each airside plant per year per aircraft movement (Landing and Take Off cycle (LTO)).

There is limited Australian data on emissions from airport activities. The emissions data which are available (from Melbourne Airport) have been correlated with aircraft movements (LTO cycles) at the airport (see Table 1). This correlation has been adopted based on the assumption that there is a direct correlation between aircraft movements and ground support activities. The emission factors presented in Table 2 are averages of available data collected from Melbourne airport only and that reliability of the emission factors will depend on the degree of similarity between the emission source at Melbourne airport and the emission source of interest.

Clearly, other activities such as airframe maintenance, engine overhaul and engine and APU test cell running are directly related to the location of an airline's maintenance, engine overhaul and engine and APU test facilities, the respective fleet numbers of aircraft and engine types, the normal test profile (power setting, duration and number of cycles) for engine and APU (not necessarily the same profile as the LTO cycle) and the airline's network which determines flight hours and cycles for activity to approved procedures and intervals. Therefore, it is not possible to relate the emissions from these activities to aircraft movements. For these activities, the emission estimation techniques provided in Section 4.2 should be utilised. Other techniques are available for estimating emissions to the NPI such as using the Combustion Engines and Combustion in Boilers EET manuals.

Table 1 Emission Factors for Airport Activitiesa

Auxiliary Activity	NO_x	CO	VOC[c]	SO_2
Airside Vehicles (kg/vehicle/LTO/yr) [b]	1.09×10^{-4}	1.46×10^{-3}	1.1×10^{-4}	
Airside Plant (kg/plant/LTO/yr) [d]	8.90×10^{-4}	1.26×10^{-3}	3.27×10^{-4}	
Space Heaters, Boilers, and Emergency Generators (kg/LTO/yr)	2.65×10^{-3}	1.67×10^{-3}	4.53×10^{-5}	1.54×10^{-3}
Aircraft Engine Test Cells[e] (kg/LTO/yr)	0.104	3.48×10^{-2}	1.46×10^{-2}	1.98×10^{-2}
Solvent and Paint Usage (kg/LTO/yr)			0.265	
Aircraft Refuelling *Jetfuel* (kg/LTO/yr) *Avgas* (kg/LTO/yr)			 6.82×10^{-3} 3.72×10^{-2}	
Fuel and Organic Liquid Storage Tanks (kg/LTO/yr)			6.71×10^{-2}	

Source: V & C Environment Consultants 1995.

[a] The emission factors contained in Table 1 have been calculated from information collected for the Melbourne Airport Air Emissions Inventory and Air Quality Management Plan. Aircraft movements data for Melbourne airport for base year 1995 were used to develop the emission factors provided.

[b] Based on a fleet breakdown of 61.5 percent petrol and 38.5 percent diesel vehicles.

[c] Hydrocarbon emissions converted to total volatile organic compound (VOC) emissions using conversion factor of 1.0947. Guidance on the speciation of VOC emissions is provided in the *Emission Estimation Technique Manual for Fugitive Emissions.*

[d] Based on a fleet breakdown of 27.4 percent petrol and 72.6 percent diesel vehicles.

[e] These data will be replaced by site specific data in a future revision of this handbook. This emission factor should only be used for Melbourne airport, and a more accurate estimate for Melbourne airport is attained using the techniques in Section 4.2.

The emission factors in Table 1 can be used to estimate emissions from a particular airport activity by application of Equation (1).

$$E_{kpy,i} = A * EF_i \qquad (1)$$

where :

$E_{kpy,i}$ = emissions of pollutant i, in kg/yr
A = activity rate in completed LTO/year
EF_i = emission factor of pollutant i, in kg/LTO

To calculate the total emissions in cases where the emission factor EF_i is considered per airside vehicle or plant, it will have to be multiplied by the number of vehicles or plants in use. Although emissions arising directly from operating aircraft are not required to be estimated by the airport lessee, the airport's annual aircraft activity nevertheless still needs to be determined by the individual facility operators/tenants as the first step in estimating emissions using emission factors. To ensure the accuracy of the emissions estimates, this information should be obtained from the ALC. In the event that such information is not available, the numbers presented in Table 2 can be used as a starting point for emissions estimation.

Example 1 – Using Emission Factors

This hypothetical example shows how carbon monoxide emissions can be estimated from Brisbane airport from Airside vehicles using Equation (1) and the appropriate emission factor from Table 1. There are 150 airside vehicles used at Brisbane airport.The following data are given:

EF_{CO} = 1.26×10^{-3} kg /LTO/vehicle
A = 152 118 aircraft movements at Brisbane (from Table 2)

E_{CO} = A * EF_{CO} * number of Airside vehicles
= 152 118 * 1.26×10^{-3} * 150
= 28 750 kg CO/yr

Table 2 Passenger Numbers and Aircraft Movements (LTO) at Major Australian Airports (1995/96)

Airport	Total Passengers	Scheduled & Commercial Movements	General Aviation Movements	Total Aircraft Movements
Sydney	20 520 822	245 268	23 640	268 908
Melbourne	13 184 830	141 768	9 320	151 088
Brisbane	9 761 529	131 764	20 354	152 118
Adelaide	3 666 752	63 940	45 190	109 130
Perth	4 275 000	61 184	28 172	89 356
Cairns	3 158 358	40 752	51 464	96 244
Canberra	1 777 802	35 518	73 278	108 796
Coolangatta	1 993 319	27 690	55 008	82 698
Hobart	860 756	12 422	3 472	15 894
Launceston	595 881	13 160	19 916	33 076
Alice Springs	864 727	15 190	30 096	45 286
Darwin	994 353	22 178	59 166	81 344
Townsville	662 976	18 828	39 042	57 370
Mt Isa	88 012	4 320	1 936	6 256
Essendon	0	0	57 686	57 686
Bankstown	0	0	610 502	610 502
Moorabbin	311 117	0	349 817	349 817
Jandakot	0	0	404 576	404 576

Source: Australian Academy of Technological Sciences and Engineering, 1997.

4.2 Using Site-Specific Emission Estimation Techniques

This section discusses the use of site-specific emissions estimation techniques and includes information on the data inputs and data sources required to apply these techniques. Although using site-specific information may require additional resources to the use of default emission factors based on LTO data (as described in Section 4.1), the resulting emission estimates should be more accurate. This section is divided as follows:

- Sections 4.2.1 to 4.2.8 provide emission estimation techniques for specific sources.
- Section 4.2.9 provides specific guidance on estimating emissions of sulfur dioxide and metals.

4.2.1 Emissions from Ground Support Equipment

Ground Support Equipment (GSE) includes airside vehicles and mobile plant. Emissions from GSE of NPI-listed substances include VOCs, CO, NO_x, PM_{10}, and SO_2. For diesel or other fossil-fuel powered GSE, the factors that determine the quantity of pollutants emitted are average rated brake horsepower, load factor, and period of usage throughout the reporting year. To estimate emissions from GSE refer to the *Emission Estimation Technique Manual for Combustion Engines.* This manual includes information on emissions of organic species and heavy metals which may also be required to be reported.

For electric powered GSE, the emissions of NPI substances can be taken as zero (ie these sources do not need to be considered for the purposes of NPI reporting).

4.2.2 Emissions from Paint and Solvent Usage

Volatile organic compounds (VOCs) are emitted to the atmosphere through evaporation of the paint vehicle, thinner, or solvent used to facilitate the application of the coatings. To estimate emissions from paint and solvent use refer to the *Emission Estimation Technique Manual for Surface Coating.*

4.2.3 Emissions from Storage Tanks

Three types of fuel storage tanks, fixed roof, external floating roof and internal floating roof, are commonly found at large airports.

To estimating emissions from fuel storage tanks refer to the *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage.* If there are difficulties in applying the estimation techniques provided in this Manual:

- Emissions from small tanks (ie less than 30 tonnes capacity) can be calculated using the EET for air displacement provided in Section 5.2 of the *Emission Estimation Technique Manual for Organic Chemical Processing Industries*. This is a relatively simple EET, requiring only vapour mole fraction, liquid mole fraction and vapour pressure data for each of the components being stored.
- Emissions from larger tanks may be estimated using the TANKS 4.0 software. TANKS 4.0 requires more detailed information such as the physical characteristics of the storage tanks, typical atmospheric conditions (such as wind speeds and temperatures), the contents of the tank and throughput.

4.2.4 Emissions from Boilers and Space Heaters

The E*mission Estimation Technique Manual for Combustion in Boilers* provides emission factors and other estimation techniques for a wide range of boilers and boiler fuel types and should be used to calculate emissions from boilers.

For space heaters, it can be assumed that the emission factors and emission estimation techniques provided in the *Emission Estimation Technique Manual for Combustion Engines* can be utilised.

These manuals also include information on emissions of organic species and heavy metals which may also be required to be reported.

4.2.5 Emissions from Emergency Generators

To estimate emissions from emergency generators refer to the *Emission Estimation Technique Manual for Combustion Engines.* This Manual provides default emission factors and other estimation techniques which can be utilised for the purposes of NPI reporting.

4.2.6 Emissions from Fire Training and Emergency Simulations

Fire training facilities are distinguished by the type of fuel burned in the simulations. The most commonly used fuels are propane, avtur, diesel and petrol. There has been a move in Australia in recent years to burn propane as the burning of avtur and other fuels tends to produce a column of smoke (particulate matter) that can extend for kilometres downwind. The air pollutants generated from the burning training fires include PM_{10}, NO_x, SO_2, CO and VOCs.

To calculate emissions from fire training requires that the total quantity of fuel burned in each fire is known. This quantity is multiplied by the relevant emission factors to calculate the total pollutant emissions to the atmosphere for each fire. The total emissions from one training fire are calculated using Equation (2).

$$E_i = Q_f * EF_i \qquad (2)$$

where:

E_i = total emissions of pollutant i, in kg
Q_f = quantity of fuel burned in training fire in 10^3 litres
EF_i = emission factor (kilograms of pollutant i emitted per 10^3 litres of fuel burned
i = pollutant

The total emissions of a specific pollutant in a reporting year are then calculated by summing the emissions of that pollutant from each individual training fire.

Table 3 provides emission factors for PM_{10}, NO_x, SO_2, CO, and VOCs arising from commonly used fuels. The emission factors are expressed in terms of kilograms of pollutant emitted per 1 000 litres of fuel burned.

Table 3 Emission Factors for Uncontrolled Fuel Burning in Training Fires

Fuel	Emission Factors (kg/10^3 litres of fuel)				
	CO	PM_{10}	NO_x	SO_2	VOCs
Propane (Liquified Petroleum Gas)	4.2	14.1	0.77	0.0024	3.8
Avtur JP-4	430	115	3.23	0.46	15.4
Avtur JP-8	538	121.7	4.04	0.82	16.2

Adapted from: Energy and Environmental Analysis Inc., September 1995.

4.2.7 Emissions from Aircraft Engine Test Cells

The emissions from aircraft engine testing can be calculated using emission factors from the *ICAO Engine Exhaust Emissions Data Bank* (for commercial aircraft only) in the case of jet engines and from *Energy and Environmental Analysis Inc.,* in the case of APUs. A lot of this information is in Tables in the Aircraft Aggregated Emission Data on the NPI Internet Site (www.npi.ea.gov.au). Alternatively, Appendix I provides emission factors for aircraft engines per LTO for a range of pollutants. The advantage of using these data to estimate emissions for NPI reporting is that engine manufacturers already calculate this value, based on default LTO times-in-mode, as part of the engine certification process. The emission factors are reported as Dp/Foo, where Dp is the mass of any gaseous pollutant emitted during the reference emissions landing and takeoff cycle and Foo is rated output, which is the maximum power/thrust available for take-off under normal operating conditions at sea level static conditions (without water injection). It is typically reported in grams/kiloNewton thrust.

Appendix II of this manual lists APUs by aircraft type and provides emission factors for a range of pollutants from APU engine cell testing. During testing, the engine or APU is taken through a sequence of power levels simulating actual flight conditions. Knowledge of the test times and fuel flow rates for each of these steps allows the calculation of emissions from each testing step using the emission factors provided at Appendix I (or the ICAO databank) for engines and at Appendix II for APUs. The technique for calculating overall emissions from aircraft engine testing (including emissions from APU testing) is expressed by Equation (3).

$$E_{kpy,i} = \Sigma (N * TM_j * FF_j / 1\,000 * EF_i) \qquad (3)$$

where:

$E_{kpy,i}$ = total emissions of pollutant i, kg/yr
N = number of test cycles performed per year, cycles/yr
TM_j = average test time, in seconds per test cycle, for mode j
FF_j = fuel flow rate while in testing mode j, kg/sec
EF_i = emission factor in grams emitted per kilogram of fuel burned, g/kg
i = pollutant species (VOCs, CO, PM_{10}, and NO_x)
j = testing mode
1 000 = conversion factor, grams to kilograms

The aircraft engine test time for each testing mode varies with the engine type, goals of the test, and the equipment used. Site-specific information on test times and the number of test cycles performed on each aircraft is required to apply Equation (4) is used for NPI reporting. If the engine fuel flow rate, in kilograms per second, is not known, then the average engine LTO emission default values given at Appendix I should be used. If site-specific engine data for engines tested is not available, then an appropriate default engine can be chosen based on the operator's national fleet. The following example illustrates the procedure for determining the pollutant emissions from engine test cells.

Example 2 - Emissions from Engine Test Cells

An engine test cell operator ran 48 complete tests of Boeing B737-300 aircraft CFM56-3C-1 engines during the reporting year. Emissions are calculated by applying Equation (4) and the emission factors from the *ICAO Data Bank*. A copy of the *ICAO Data Bank* is in the Aircraft AED manual.

Pollutant (x)		Number of Cycles (cyc/yr)		Time in Mode (sec)		Fuel Flow (kg/sec)		Emission Factor (g/kg)		Conversion Factor (g/kg)		Total Emissions (kg/yr)
Take-Off												
VOCs		48	*	43 200	*	1.154	*	0.03	/	10^3	=	72
CO		48	*	43 200	*	1.154	*	0.90	/	10^3	=	2 200
NO_x		48	*	43 200	*	1.154	*	20.70	/	10^3	=	50 000
Climb-Out Mode												
VOCs		48	*	129 600	*	0.954	*	0.04	/	10^3	=	240
CO		48	*	129 600	*	0.954	*	0.90	/	10^3	=	5 300
NO_x		48	*	129 600	*	0.954	*	17.80	/	10^3	=	110 000
Approach Mode												
VOCs		48	*	115 200	*	0.336	*	0.06	/	10^3	=	110
CO		48	*	115 200	*	0.336	*	3.10	/	10^3	=	5 800
NO_x		48	*	115 200	*	0.336	*	9.10	/	10^3	=	17 000
Idle Mode												
VOCs		48	*	72 000	*	0.124	*	1.3	/	10^3	=	560
CO		48	*	72 000	*	0.124	*	26.8	/	10^3	=	11 000
NO_x		48	*	72 000	*	0.124	*	4.3	/	10^3	=	1 800

Total Emissions (Take-Off + Climbout + Approach + Idle)

VOCs	72	+	240	+	110	+	560	=	980 kg/yr
CO	2 200	+	5 300	+	5 800	+	11 000	=	24 000 kg/yr
NO_x	50 0000	+	110 000	+	17 000	+	1 800	=	180 000 kg/yr

Note: All calculated quantities have been rounded to 2 significant figures.

4.2.8 Emissions from General Aviation

This section discusses the procedures for calculating exhaust emissions from general aviation and air taxi aircraft as well as general aviation aircraft evaporative emissions. The only general aviation emissions which must be reported are those arising from engine testing routines and refuelling operations. Emissions occurring while the aircraft are mobile, including pre-flight safety checks and during the LTO cycle, are not attributable to the airport reporting facility and are estimated by the relevant State or Territory environment authority as aggregated emissions.

Most general aviation aircraft are powered by piston engines, which are fuelled by avgas. Aviation gasoline has a much higher volatility than avtur and the fuel tanks are vented to the atmosphere resulting in significant VOC evaporation. Evaporative emissions are associated with refuelling, pre-flight safety procedures, and fuel venting due to diurnal temperature changes. The following equations should be used for estimating VOC emissions from general aviation aircraft pre-flight safety procedures and fuel venting. These equations are not suitable for estimating emissions from turbine engines. Equation (4) is for calculating emissions of VOCs from off-wing engine testing (exhaust emissions).

$$E_{VOC} = 0.088 \text{ kg} * LTO_L \quad (4)$$

where:

E_{VOC} = total VOC emissions, in kilograms, resulting from pre-flight safety checks

LTO_L = number of landing and take off cycles by piston-engine aircraft during NPI reporting year

Equation (5) is for estimating VOC emissions occurring from diurnal temperature changes (evaporative emissions).

$$E_{VOC} = 0.066 \text{ kg/day/based aircraft} * A_b * 365 \quad (5)$$

where:

E_{VOC} = total VOC emissions, in kilograms, resulting from diurnal temperature changes

A_b = number of aircraft based at the reporting airport

365 = number of days in the reporting year

4.2.9 Emissions of Sulfur Dioxide

The techniques provided above for estimating exhaust emissions from aircraft are generally not adequate for estimating sulfur dioxide (SO_2) emissions. The most accurate and easiest method for estimating emissions of SO_2 from aircraft exhaust is through analysis of the avtur and avgas fuels used.

Fuel analysis can be used to estimate emissions based on the application of conservation laws. The presence of certain NPI-listed elements in fuels may be used to predict their presence in emission streams. This includes sulfur, which is converted into the listed substance sulfur dioxide (SO_2) during the combustion process.

Equation (6) can be used for fuel analysis emission calculations.

$$E_i = Q_f * C_i/100 * (EW_p / MW_f) \quad (6)$$

where:

E_i = emissions of pollutant i, kg/sec
Q_f = fuel flow rate (kg/sec)
C_i = concentration of substance i within fuel that leads to pollutant release, weight percent, %
EW_p = elemental weight of substance in fuel, g/mole
MW_f = molecular weight of substance in fuel, g/mole

For example, SO_2 emissions from fuel combustion can be calculated based on the known concentration of sulfur in the fuel consumed, assuming complete conversion of sulfur to SO_2 and an EW_p / MW_f ratio of 2 (ie 64/32). The application of this estimation technique is shown in the following example.

Example 3 - Estimating SO_2 Emissions from Engine Test Cells

An engine test cell facility estimates the SO_2 emissions from an APU model GTCP85-129 using Equation (7) where the fuel flow rate of the APU model undergoing the test is known (from Appendix II).

$$Q_f = 2.971 * 10^{-2} \text{ kg/sec}$$

$$\text{Percent sulfur in avtur} = 0.021$$

$$E_{SO2} = Q_f * C_i/100 * (EW_p / MW_f)$$
$$= (2.971 * 10^{-2}) * (0.021 / 100) * (64 / 32)$$
$$= 1.247 * 10^{-5} \text{ kg } SO_2\text{/sec}$$

5.0 Emission Estimation Techniques: Acceptable Reliability and Uncertainty

This section is intended to give a general overview of some of the inaccuracies associated with each of the techniques. Although the National Pollutant Inventory does not favour one emission estimation technique over another, this section does attempt to evaluate the available emission estimation techniques with regards to accuracy.

Several techniques are available for calculating emissions from airport facilities. The technique chosen is dependent on available data, and available resources, and the degree of accuracy sought by the facility in undertaking the estimate. In general, site-specific data that is representative of normal operations is more accurate than industry-averaged data such as the emission factors.

5.1 Direct Measurement

NPI emissions data collected via sampling or direct measurement procedures should meet quality objectives. Sampling data should be reviewed to ensure that the sampling was conducted under normal operating conditions and that data were generated according to acceptable methods. On certain occasions, State and Territory licensing conditions may require that stack tests and sampling be conducted under maximum or specific loading or emission flow conditions. Utilising these data alone may overestimate the annual average emissions data required by the NPI, where only representative sampling data should be used.

Use of sampling data, such as workplace health and safety data, is likely to be a relatively accurate method of estimating air emissions from both point and fugitive sources. However, collection and analysis of air samples can be very expensive and especially complicated where a variety of NPI-listed VOCs are emitted and where most of these emissions are fugitive in nature. Sampling data from one specific process may not be representative of the entire operation and may provide only one example of the facility's emissions. To be representative, sampling data used for NPI reporting purposes would need to be collected over a period of time covering representative activities.

5.2 Mass Balance

The mass balance approach to emissions estimation at an airport or airport manufacturing facility considers the facility as a *black box* where the total quantity of listed substances in the raw materials consumed versus amounts of listed substances leaving the facility as product and waste is compared and analysed. NPI-listed pollutants can be contained in wastes, such as spent solvent or still bottoms, cutting fluid sludges, metal wastes, polishing sludges, drum residue, and wastewater.

Calculating emissions from any manufacturing activity or process using mass balance appears on the surface to be a straightforward approach to emissions estimations. However, few Australian airports facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method, and inaccuracies associated with individual material tracking or other activities inherent in each material handling stage often accumulate into large deviations of total facility emissions. Because emissions from specific materials are typically below 2 percent of gross consumption, an error of only ± 5 percent in any one step of the operation can significantly skew emissions estimations.

5.3 Engineering Calculations

Theoretical and complex equations, or *models*, can be used for estimating emissions from airport facilities.

Use of emission equations to estimate emissions from airport facilities is a more complex and time-consuming process than the use of emission factors. Emission equations require more detailed inputs than the use of emission factors but they do provide an emission estimate that is based on facility-specific conditions

5.4 Emission Factors

Emission factors are available for many sources and processes across an airport facility and are based on the results of source tests performed at an individual airport facility or at one or more common facilities at an airport. Basically, an emission factor is the pollutant emission rate relative to the level of source activity. The user should recognise that, in most cases, emission factors adopted for the NPI are averages of available industry-wide data, usually US or European and seldom Australian, with varying degrees of quality. For airport activities, only the emission factors presented in Section 4.1 of this Manual have been derived entirely from activities at Australian airports. Emission factors are, however, an acceptable method for estimating emissions from all industry sectors and source categories for the National Pollutant Inventory where estimations of emissions are required to quantify medium to long-term emission trends.

The use and application of emission factors for NPI reporting is fairly straightforward where the relationship between process data and emissions is direct and relatively uncomplicated. Emission factors given in this Manual are defined for specific processes at airports. For some Inventory-listed substances, the variability in emissions among this population may be high. Emission factors given in this Manual are a mean only and could equally overestimate or underestimate emissions for any single unit or process in the population. What is more, the data on which these factors are based are limited to Melbourne airport.

6.0 References

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USEPA. October 1996. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, *Fifth edition, AP-42. Section(s) 3.3 Stationary Internal Combustion Sources - Gasoline and Diesel Industrial Engines.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

USEPA. October 1996. *Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources*, *Fifth edition, AP-42. Section(s) 3.4 Stationary Internal Combustion Sources - Large Stationary Diesel and Dual Fuel Industrial Engines.* United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.

V & C Environmental Consultants. December 1995. *Air Emissions Inventory and Air Quality Management Plan. Prepared for: Federal Airports Corporation Melbourne Airport November 1995.* Oak Park, VIC.

The following EET Manuals are available at the NPI Homepage (http://www.npi.gov.au), and from your local Environmental Protection Authority:

Emission Estimation Technique Manual for Combustion in Boilers;
Emission Estimation Technique Manual for Combustion Engines;
Emission Estimation Technique Manual for Fuel and Organic Liquid Storage;
Emission Estimation Technique Manual for Organic Chemicals Processing Industries;
Emission Estimation Technique Manual for Surface Coating
Emission Estimation Technique Manual for Fugitive Emissions; and
Emission Estimation Technique Manual for Aggregated Emissions from Aircraft.

The latest version of TANKS software may be downloaded from:

http://www.epa.gov/ttn/chief/tanks.html

Appendix I - Aircraft Engine Emission Factors (ranked by DP/Foo)

Table 4 Aircraft emission factors per LTO cycle.

Aircraft Name	Aircraft Manufacturer	Engine Name	Number of Engines	Class	Emissions Per LTO Aircraft g/(kg fuel burnt)			
					CO	NOx	VOC	VOC + NOx
A-310-200	AIRBUS	PW4152	2	2	17.000	46.700	1.423	48.123
A-320-100	AIRBUS	CFM56-5-A1	2	1	27.900	40.500	2.600	42.600
A-320-200	AIRBUS	IAE V2500	2	1	14.800	69.300	0.650	69.950
A-321	AIRBUS	CFM56-5-A1	2	2	27.900	40.500	2.600	42.600
A-330	AIRBUS	CF6-80C2A1	2	3	53.040	48.120	12.392	60.512
A-330	AIRBUS	CF6-880C2A1	2	3	53.040	48.120	12.392	60.512
A-330	AIRBUS	CF6-90C2A1	2	3	53.040	48.120	12.392	60.512
A-330	AIRBUS	PW4158	2	3	28.700	50.200	2.627	52.827
A-330B	AIRBUS	CF6-50C2	2	2	93.700	61.800	36.672	98.472
A-340	AIRBUS	CFM56-5-A1	2	3	27.900	40.500	2.600	42.600
B-727-200	BOEING	JT8D-15	3	1	130.600	57.900	43.022	100.922
B-727-200	BOEING	JT8D-17	3	1	112.500	60.200	40.723	100.923
B-727-200	BOEING	JT8D-17A	3	1	43.800	55.100	7.225	62.325
B-727-200	BOEING	JT8D-7B	3	1	130.900	49.500	40.723	90.223
B-737-300	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-737-300	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-737-300	BOEING	CFM56-3C	2	1	59.100	48.200	3.240	51.440
B-737-400	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-737-400	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-737-400	BOEING	CFM56-3C	2	1	59.100	48.200	3.240	51.440
B-737-500	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-737-500	BOEING	CFM56-3B	2	1	59.170	48.210	3.240	51.450
B-747-200	BOEING	JT9D-7Q	4	3	87.700	54.400	21.894	76.294
B-747-400	BOEING	PW4056	4	3	14.200	51.700	1.314	53.014
B-767-200	BOEING	CF6-80C2B2	2	2	64.670	38.080	16.147	54.227
B-767-200	BOEING	CF6-80A	2	2	35.500	53.100	8.582	61.682
B-767-200	BOEING	CF6-80A2	2	2	34.200	55.500	8.298	63.798
B-767-200	BOEING	CF6-80C2B2	2	2	64.670	38.080	16.147	54.227
B-767-200	BOEING	JT9D-7R4D	2	2	15.300	61.900	2.408	64.308
B-767-300	BOEING	CF6-80A2	2	3	34.200	55.500	8.298	63.798
B-767-300	BOEING	CF6-80C2B6	2	3	52.360	46.260	12.173	58.433
B-767-300	BOEING	CF6-8OA2	2	3	34.200	55.500	8.298	63.798
B-767-300	BOEING	PW4460	2	3	27.100	52.700	2.408	55.108
B-777-200	BOEING	PW4056	2	3	14.200	51.700	1.314	53.014
BAE 146-200	BAE	ALF 502R-5	4	1	97.800	34.800	14.888	49.688
F-28	FOKKER	SPEY MK555	2	1	388.000	50.750	429.122	479.872

NOTE: The emission factor units are grams of substance per kilogram of fuel burnt.

Appendix II - Auxiliary Power Unit (APU) Emission Factors

Table 5 Auxiliary Power Units and Commercial Aircraft Models[1]

Auxiliary Power Unit	Aircraft Model
Allied Signal Inc. GTP 30 Series [2]	Fairchild F-27 [3]
GTCP 30 Series [2]	Dassault-Bregue Falcon 20 Jet Commander [3]
GTCP 35-300 [2]	Airbus A-321 [4]
GTCP 36 Series [5] 59.66 kW (80 HP)	Airbus A320 Airbus A-320-100 [6] Airbus A-320-200 [6] Airbus A-321 [6] Aerospatiale ATR-42 [3] Beechcraft Beech 18 [7] British Aerospace BAe 146 British Aerospace BAe 146-100 [6] British Aerospace BAe 146-200 [6] British Aerospace Jetstream 31 [7] British Aerospace Super 31 [7] Canadair CL600/CL601 [3] Cessna C-208 [7] Dessault-Bregue Falcon 50 [3] DeHavilland Dash 7 [7] DeHavilland DHC-6/300 [7] DeHavilland DHC-8 [7] DeHavilland DHC-8-100 [7] Embraer EMB-110 [6] Embraer EMB-120 [3] Embraer EMB-145 [6] Fokker F-27 Series [6] Fokker F-28 Saab Fairchild 340 [3] Saab Fairchild 340A [6] Short Brothers SHT-360 [7] Swearingen SA227 [7]
GTCP 85 Series [8] 149.14 kW (200 HP)	Boeing B-707 Boeing B-707-300 [6] Boeing B-727 Boeing B-727-100 [6] Boeing B-727-200 [6] Boeing B-737 [9] Boeing B-737-300 [10] Boeing B-737-400 [10] Boeing B-737-500 [10] Lockheed L-100 [3] McDonnell Douglas DC-8 McDonnell Douglas DC-8-62 [6]

Table 5 Auxiliary Power Units and Commercial Aircraft Models1 (cont'd)

Auxiliary Power Unit	Aircraft Model
	McDonnell Douglas MD-80 [6]
GTCP 331 Series [11] 106.64 kW (143 HP)	Airbus A-330 [4] Airbus A-340 [4] Boeing B-767 [12] Boeing B-767-200 [12] Boeing B-767-200ER [12] Boeing B-767-300 [6, 12] Boeing B-767-300ER [6, 12] Boeing B-777 [4, 13] Boeing B-777-200 [6, 13]
GTCP 660 [14] 223.71 kW (300 HP)	Boeing B-747 Boeing B-747-200 [6] Boeing B-747-300 [6]
Pratt & Whitney	
PW 901A	Boeing B-747 Boeing B-747-400 [6] Boeing B-747-SP [6]

[1] Federal Express Aviation Services, Inc., January 1991. *Federal Express Fleet Guide*, unless otherwise noted.
[2] No emission factor available
[3] Garrett Turbine Engine Company. *Reference Guide - Auxiliary Power Systems*. Phoenix, AZ, USA.
[4] New aircraft scheduled to enter production.
[5] Emission factors for the GTCP36-300 series can be used for calculation purposes as representative of all series of the APU model.
[6] APU for a particular aircraft model assumed to be the same as other aircraft in that series or for similar aircraft.
[7] GTCP 36 series assumed to be representative for this aircraft.
[8] Emission factors for the GTCP85-98ck series can be used for calculation purposes as representative of all series of the APU model, unless otherwise noted.
[9] Emission factors for the GTCP85-129 series should be used for calculation purposes.
[10] Emission factors for the GTCP85-129ck series should be used for calculation purposes.
[11] Emission factors for the GTCP331-200/250 series can be used for calculation purposes as representative of all series of the APU model, unless otherwise noted.
[12] Emission factors for the GTCP331-200ER series should be used for calculation purposes.
[13] Emission factors for the GTCP331-500 series should be used for calculation purposes.
[14] Emission factors for the GTCP660-4 series should be used for calculation purposes as representative of all series of the APU model.
[15] Emission factors for the TSCP700-4B series can be used for calculation purposes as representative of all series of the APU model.
[16] Emission factors for the ST-6 L-73 series can be used for calculation purposes as representative of all series of the APU model.

Table 6 Auxiliary Power Units Model Emission Factors[1]

Model -Series (shaft HP)	Mode	Fuel Flow (kg/hr)	Emission Factors (kg/tonne)			
			VOCs	CO	NO_x	SO_2
GTC85-72 149.15 kW (200)	Load	95.45	0.14	14.83	3.88	0.54
GTCP100-544 298.28 kW (400)	Load	187.64	0.17	5.89	5.95	0.54
GTCP30-300		128.27	0.22		10.10	
GTCP331-200/250 106.64 kW (143)		121.78	0.47		9.51	
GTCP331-200ER 106.64 kW (143)		121.78	0.47	4.13	9.51	
GTCP331-500 106.64 kW (143)		243.64	0.14	0.09	14.67	
GTCP36-300 59.66 kW (80)		128.27	0.22	2.05	10.10	
GTCP660-4 223.71 kW (300)		392.24	0.31	8.65	5.33	
GTCP85 149.14 kW (200)		106.95	1.03		4.75	
GTCP85-129 149.14 kW (200)		106.95	1.13	17.99	4.75	
GTCP85-129ck 149.14 kW (200)		106.95	1.13	17.99	4.75	
GTCP85-98ck 149.14 kW (200)		106.95	1.13	17.99	4.75	
GTCP95-2 223.71 kW (300)	Load	133.09	0.39	3.20	5.65	0.54
PWC 901A	No Load	231.82	2.19	20.50	1.80	
PWC 901A	Max. Load	408.64	0.00	5.60	6.50	
PWC 901A		392.24	1.64	16.78	3.15	
ST6/ST6 L-73		200.00	0.02	0.05	8.90	
T-62T-47C1		106.95	0.18	40.20	4.30	
TSCP 700 105.89 kW (142)		147.13	0.28		8.55	
TSCP 700-4B 105.89 kW (142)		147.13	0.28	1.48	8.55	
WR27-1 63.38 kW (85)	Load	63.55	0.23	5.66	4.63	0.54

[1] Energy and Environmental Analysis Inc. September 1995. *Technical Data to Support FAA's Advisory Circular on Reducing Emissions from Commercial Aviation.* Arlington, VA, USA.