National Pollutant Inventory

Emission Estimation Technique Manual

for

Non-Metallic Mineral Product Manufacture

First published in December 1999

EMISSION ESTIMATION TECHNIQUES
FOR
NON-METALLIC MINERAL PRODUCT MANUFACTURE

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1.0 Introduction

The purpose of all Emission Estimation Technique (EET) Manuals in this series is to assist Australian manufacturing, industrial and service facilities to report emissions of listed substances to the National Pollutant Inventory (NPI). This Manual will deal with the activities outlined under the ANZSIC Code 2640 - Non-Metallic Mineral Product Manufacture n.e.c. ie. to the manufacture or processing of mineral products. This Manual also includes certain mineral processing activities that have been identified as not being classified elsewhere. The relevant activities are listed below the 'Scope of activities in Manual'. Certain activities under ANZSIC Code 2640 are already covered under other NPI Manuals as indicated in Table 1.

EET MANUAL: Non-Metallic Mineral Product Manufacture

HANDBOOK: Non-Metallic Mineral Product Manufacture

ANZSIC CODE: 2640

Pacific Air & Environment Pty Ltd drafted this Manual on behalf of Environment Australia. The Manual has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

Scope of Activities Covered by this Manual

This Manual is intended to cover the following activities;

- Abrasives Manufacturing
- Acoustic Tiles Manufacturing
- Asbestos/Cement Boards
- Carbon/Graphite Products
- Chalk Products Manufacturing
- Diamond Powder Manufacturing
- Dry Mix Mortar Manufacturing
- Feldspar Manufacturing
- Foundry Cores Manufacturing
- Frit Manufacturing
- Fullers Earth Manufacturing
- Headstones Manufacturing
- Imitation Brick/Stone Building Boards
- Insulation/Glass Fibre
- Manganese Dioxide Processing
- Magnesite/Flooring materials
- Mica Production
- Mineral Earth Manufacturing
- Mineral Wool and Products
- Monuments Making
- Resin Coated Sand
- Rock Wool
- Silica Lime Bricks
- Silicon Carbide Abrasive
- Slag Crushing
- Stone Products
- Stone Working
- Talc Processing
- Cassiterite Ore Processing

Certain activities under ANZSIC Code 2640 are already covered under other NPI Manuals as indicated in Table 1.

Table 1 - Existing NPI Coverage of Non-Metallic Mineral Product and Associated Processes

Process	Emission Estimation Technique Manual
Glass Fibre Manufacture	*Emission Estimation Technique Manual for Glass & Glass Fibre Manufacturing.*
Lime Manufacture	*Emission Estimation Technique Manual for Lime & Dolomite Manufacturing.*
Refractory Products Manufacture (except fused ceramic products)	*Emission Estimation Technique Manual for Bricks, Ceramics & Clay Product Manufacturing.*
Gypsum & Plaster product manufacture	*Emission Estimation Technique Manual for Gypsum & Plaster Product Manufacture.*
Phosphate Rock Processing	*Emission Estimation Technique Manual for Mining & Processing of Non-Metallic Minerals*; and *Emission Estimation Technique Manual for Phosphate Manufacturing.*
Alumina & Bauxite Processing	*Emission Estimation Technique Manual for Alumina Refining.*
Clays (Bentonite, Kaolin, Fullers Earth, Ball Clay, Fire Clay, Common Clay & Shale etc)	*Emission Estimation Technique Manual for Mining & Processing of Non-Metallic Minerals;* and *Emission Estimation Technique Manual for Brick, Ceramic and Clay Product Manufacture.*
Wastewater Treatment	*Emission Estimation Technique Manual for Sewage & Wastewater Treatment.*
Liquid Spills	*Emission Estimation Technique Manual for Organic Chemical Processing Industries.*
Storage Vessels	*Emission Estimation Technique Manual for Organic Chemical Processing Industries;* and *Emission Estimation Technique Manual for Alumina Refining.*
Combustion Activities & Thermal Processes	*Emission Estimation Technique Manual for Combustion Engines;* and *Emission Estimation Technique Manual for Combustion in Boilers.*

1.1 Manual Structure

Due to the fact that this Manual covers a wide range of industries, it would not be feasible to individually cover each of the primary activities that are involved. Therefore this Manual has been structured as a list of unit processes, with the intent to encompass all of the unit processes in the industries that are listed under the ANZSIC Code for this Manual.

The following list outlines the content of this Manual.

- **Section 2.0** provides an overview of NPI reporting thresholds and how they apply to the industry. **Section 2.1** discusses the issue of transfers while **Sections 2.2, 2.3** and **2.4** discuss the specific NPI reporting thresholds. Emissions to air, water and land are then discussed in **Sections 2.5, 2.6** and **2.7** respectively.
- **Section 3** discusses likely emissions from unit processes and operations covered by this Manual.
- **Section 4** provides general guidance on the characterisation of emissions of PM_{10} while **Section 5** provides guidance on characterising VOC emissions.
- **Section 6** provides a glossary of the technical terms and abbreviations used in this Manual.
- **Section 7** provides a list of the references used in the development of this Manual.
- **Appendix A** provides an overview of the four general types of emission estimation techniques: sampling or direct measurement; mass balance; engineering calculations and emission factors, as well as example calculations to illustrate their use. Reference to relevant sections of this appendix is recommended in understanding the application of these techniques with particular respect to the non-metallic mineral product manufacturing industry.
- **Appendix B** provides a discussion of the reliability and uncertainty involved with each of the techniques presented in **Appendix A.**
- **Appendix C** provides a list of the variables and symbols used throughout this Manual.

1.2 Manual Application

Context and use of this Manual

To effectively utilise this Manual for the purposes of NPI reporting, you should, first of all determine whether reporting under the NPI is required for your facility and identify those substance(s) for which reporting is required (see the *NPI Guide* and **Section 2** of this Manual). If reporting is required, you should:

1. Identify all of the process units at your facility. A process flow diagram would provide a useful starting point for this activity. In addition, you will need to identify other potential sources of emissions (eg. combustion, wastewater treatment systems, ancillary processes);

2. Identify the relevant section(s) of this Manual that correspond to each of your processes (see **Section 3.1** of this Manual);

3. Select the estimation technique that best suits your facility's current methods of measuring or estimating emissions or flows; and

4. Apply the emission estimation technique to your activities/operations.

This NPI Manual provides a 'how to' guide for the application of various methods to estimate emissions as required by the NPI. It is recognised that the data that is generated in this process will have varying degrees of accuracy with respect to the actual emissions from equipment manufacturing facilities. In some cases there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs) and/or a lack of available information of chemical processes.

EETs should be considered as 'points of reference'

The EETs and generic emission factors presented in this Manual should be seen as 'points of reference' for guidance purposes only. Each has associated error bands that are potentially quite large. **Appendix B** discusses the general reliability associated with the various methods. The potential errors associated with the different EETs should be considered on a case-by-case basis as to their suitability for a particular facility. Facilities may use EETs that are not outlined in this document. They must, however, seek the consent of their relevant environmental authority to determine whether any 'in house' EETs are suitable for meeting their NPI reporting requirements.

Hierarchical approach recommended in applying EETs

This Manual presents a number of different EETs, each of which could be applied to the estimation of NPI substances. The range of available methods should be viewed as a hierarchy of available techniques in terms of the error associated with the estimate. Each substance needs to be considered in terms of the level of error that is acceptable or appropriate with the use of the various estimation techniques. Also, the availability of pre-existing data and the effort required to decrease the error associated with the estimate will need to be considered. For example, if emissions of a substance are clearly very small no matter which EET is applied, there would be little gained by applying an EET that required significant additional sampling.

The steps in meeting the reporting requirements of the NPI can be summarised as follows:

- For Category 1 and 1a substances, identify which reportable NPI substances are used, produced or stored, if any, and determine whether the amounts used or handled are above the 'threshold' values and therefore trigger reporting requirements;

- For Category 2a and 2b substances, determine the amount and rate of fuel (or waste) burnt each year, the annual power consumption and the maximum potential power consumption, and assess whether the threshold limits are exceeded;

- For Category 3 substances, determine the annual emissions to water and assess whether the threshold limits are exceeded; and

- For those substances above the threshold values, examine the available range of EETs and determine emission estimates using the most appropriate EET.

Generally it will be appropriate to consider various EETs as alternative options whose suitability should be evaluated in terms of:

- The associated reliability or error bands; and
- The cost/benefit of using a more reliable method.

The accuracy of particular EETs is discussed in **Appendix B**.

NPI emissions in the environmental context

It should be noted that the NPI reporting process generates emission estimates only. It does not attempt to relate emissions to potential environmental impacts, bioavailability of emissions or natural background levels.

2.0 NPI Reporting Requirements

2.1 Transfers

Under the NPI, the following are classed as transfers and are not required to be reported:

- Discharges of substances to sewer or tailings dam;
- Deposit of substances to landfill; and,
- Removal of substances from a facility for destruction, treatment, recycling, reprocessing, recovery, or purification.

The definition of transfer has been clarified by the NPI Implementation Working Group as: 'All emissions of listed substances, except those that are directed to, and contained by, purpose built facilities, are to be reported to the NPI. This applies irrespective of whether the substances' fate is within or outside a reporting facility boundary. With respect to receipt of NPI-listed substances, such receiving facilities are to be operating in accordance with any applicable State or Territory government requirements.'

2.2 Category 1

The reporting threshold for Category 1 substances is exceeded if the activities of a facility involve the use (eg. handling) of 10 tonnes or more of the substance. Therefore the total amount of Category 1 substances used, must be estimated in order to determine whether the threshold is exceeded. If the threshold is exceeded, then the facility must report emissions from all sources, but only for the substances for which reporting is triggered. If reporting is triggered for a substance, then emissions of that substance must be reported for all processes and operations relating to the facility, even if actual emissions are very low or zero. Note: 'usage' is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances (see the *NPI Guide*).

Due to the wide range of activities that are involved in the Non-Metallic Mineral Product Manufacturing industry, it is possible that almost any of the NPI Category 1 substances may trigger the reporting threshold. The total amount of each Category 1 substance 'used' must be estimated in order to determine whether the threshold is exceeded. For all NPI substances, consideration of whether or not reporting is triggered depends upon the concentration of each substance in the feedstock materials.

Example 1 shows a calculation that can be performed to determine if a Category 1 substance triggers a reporting threshold.

Example 1 - Category 1 Substance Reporting Threshold

An abrasives manufacturing facility consumes 100 000 litres of solvent per annum. The solvent contains 96% methyl ethyl ketone (MEK). Is the Category 1 threshold exceeded?

Total amount of solvent used = $1 * 10^5$ L/yr
Concentration of MEK = 96%

Volume of MEK consumed = $0.96 * 1 * 10^5$ L/yr
= 96 000 L/yr

Density of MEK = 0.805 kg/L

Mass of MEK consumed = Density * Volume consumed
= 0.805 kg/L * 96 000 L/yr
= 77 280 kg/yr

So, in this case, the Category 1 threshold for MEK of 10 tonnes per annum has been exceeded and the facility is required to report all emissions of MEK to the NPI.

2.3 Category 2

The Category 2 threshold is based on energy consumption or fuel usage. The Category 2a threshold for fuel usage is either:

- A facility burns 400 tonnes or more of fuel or waste per year; or
- A facility burns 1 tonne or more of fuel or waste per hour.

The Category 2b threshold is triggered if:

- A facility burns 2000 tonnes or more of fuel or waste per year; or
- A facility uses 60 000 megawatt hours (MWh) or more of energy; or
- A facility's maximum potential power consumption is rated at 20 megawatts (MW) or more at any time during the year.

"Potential Power Consumption" includes heat and steam. Based on these thresholds, the amount of fuel usage required to trigger these thresholds may be calculated (as shown in Table 2). It should be noted that Category 2 threshold calculations should be performed for total fuel usage. If a number of different fuels are used at one facility, the sum of each individual fuel use needs to be calculated to determine whether or not the Category 2 threshold is triggered.

The fuel consumption required to trigger the Category 2 thresholds is found in Table 2.

Table 2 - Approximate Fuel Usage Required to Trigger Category 2 Thresholds

Fuel Type	Category 2a	Category 2b
Natural Gas[a]	$2.06 * 10^7$ MJ per reporting year, or at least $5.14 * 10^4$ MJ in any one hour in the reporting year	$1.03 * 10^8$ MJ per reporting year
Simulated Natural Gas (SNG)[b]	$2.55 * 10^5$ m^3 per reporting year, or at least $6.37 * 10^2$ m^3 in any one hour in the reporting year	$1.27 * 10^6$ m^3 per reporting year
Liquefied Petroleum Gas (LPG)[c]	$7.87 * 10^5$ L per reporting year, or at least $1.97 * 10^3$ L in any one hour in the reporting year	$3.94 * 10^6$ L per reporting year
Liquefied Natural Gas (LNG)[d]	$9.47 * 10^5$ L per reporting year, or at least $2.37 * 10^3$ L in any one hour in the reporting year	$4.73 * 10^6$ L per reporting year
Diesel[e]	$4.44 * 10^5$ L per reporting year, or at least $1.11 * 10^3$ L in any one hour in the reporting year	$2.22 * 10^6$ L per reporting year
Propane[f]	$2.15 * 10^5$ m^3 per reporting year, or at least $5.38 * 10^2$ m^3 in any one hour in the reporting year	$1.08 * 10^6$ m^3 per reporting year
Butane[g]	$1.63 * 10^5$ m^3 per reporting year, or at least $4.08 * 10^2$ m^3 in any one hour in the reporting year	$8.16 * 10^5$ m^3 per reporting year

[a] Assuming natural gas with a gross heating value of 51.4 MJ/kg. Natural gas (NSW) data from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995).

[b] Assuming ideal gas with a density of 1.57 kg/m^3 at 15°C and 101.325 kPa from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995)

[c] Assuming ideal gas with a density of 508 kg/m^3 at 15°C under pressure from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995)

[d] Assuming 100% methane ideal gas with a density of 422.4 kg/m^3 at 15°C at its boiling point from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995)

[e] Assuming a density of 900 kg/m^3 at 15°C for fuel oil for commercial use (Perry, et al., 1997)

[f] Assuming a density of 1.86 kg/m^3 at at 15°C and 101.325 kPa.

[g] Assuming a density of 2.45 kg/m^3 at at 15°C and 101.325 kPa.

If a facility triggers the Category 2a threshold, all Category 2a pollutants need to be reported. If a facility triggers the Category 2b threshold, Category 2a and Category 2b pollutants need to be reported. Category 2 substances are listed in Table 3.

Table 3 - NPI-listed Category 2 Substances

Category 2a Substances	Category 2b Substances
Carbon Monoxide Fluoride Compounds Hydrochloric Acid Oxides of Nitrogen Particulate Matter (PM_{10}) Polycyclic Aromatic Hydrocarbons Sulfur Dioxide Total Volatile Organic Compounds	Arsenic & compounds Beryllium & compounds Cadmium & compounds Chromium (III) compounds Chromium (VI) compounds Copper & compounds Lead & compounds Magnesium Oxide Fume Manganese & compounds Mercury & compounds Nickel & compounds Nickel Carbonyl Nickel Subsulfide Polychlorinated Dioxins & Furans **PLUS all Category 2a substances**

2.4 Category 3

Under Clause 13 of the *NPI NEPM*, the reporting threshold for a Category 3 substance is exceeded in a reporting period if the activities of the facility involve the emission to water (excluding groundwater) of:

- 15 tonnes or more per year of Total Nitrogen; or
- 3 tonnes per year or more of Total Phosphorus.

For Non-Metallic Mineral Product Manufacturing facilities, it is extremely unlikely there will be licensed discharges to surface waters. The one exception may be stormwater run-off, although it is unlikely that this run-off would contain levels of nitrogen or phosphorus that would lead to the triggering of the Category 3 threshold. If however, your facility has a significant, or potentially significant, release of aqueous nitrogen or phosphorus, you need to determine whether or not Category 3 reporting requirements are triggered for your facility.

2.5 Emissions to Air

Emissions to air are likely to be the major NPI reporting issue for most facilities covered by this Manual. **Section 3** provides detailed guidance on the characterisation of emissions to air while **Sections 4** and **5** provide additional guidance on characterising PM_{10} emissions and VOCs.

2.6 Emissions to Water

For Non-Metallic Mineral Manufacturing facilities, it is expected that all the process liquid effluent and waste streams will be:

- Sent to sewer;
- Sent off-site for treatment, recycling or recovery; or
- Recycled through the process.

If wastewater treatment occurs on-site (and the effluent is released to a surface water body), it needs to be examined for potential emissions. Please refer to the *Emission Estimation Technique Manual for Sewage and Wastewater Treatment* for guidance on how to estimate these emissions.

Stormwater run-off may present an issue in terms of NPI reporting. If stormwater contains NPI-listed substances, most facilities are likely to be required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This sampling data can be used to calculate annual emissions. Refer to **Appendix A.1.1** for guidance on the use of sampling data to calculate emissions.

2.7 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids. Such emissions may contain listed substances. It is expected that all of these substances will be sent to sewer, sent off-site for treatment or recycling or sent to landfill. As these are classed as transfers, there will be no requirement to report on these emissions. It is likely that the only reporting requirements for the industry will relates to the following releases to land:

- Spills or accidental releases to land (if spills occur, see the *Emission Estimation Technique Manual for Organic Chemical Processing Industries* (Section 9.2) for guidance on how to estimate these releases);
- Releases to groundwater (see the *Emission Estimation Technique Manual for Organic Chemical Processing Industries* (Section 9.1) for guidance on how to estimate these releases); and
- On-site disposal where the on-site disposal does not meet the definition of transfer provided above.

3.0 Unit Sources/Operations

3.1 Introduction

This Manual is intended to be applicable to a wide range of industry sectors. However, these sectors have common unit processes and activities. Therefore, this Manual has been subdivided into the unit processing operations that are common to many Non-Metallic Mineral Product Processes. The user of this Manual can then simply identify the processing units that are used in their plant, find the necessary EET from those subsections of this Manual and proceed to estimate their emissions if required.

Processing operations covered by this Manual

1. Raw Material/Product Handling Operations (**Section 3.2**);
2. Crushing/Grinding Processes (**Section 3.3**);
3. Classifying/Separating Processes (**Section 3.4**);
4. Wet/Dry Product Mixing/Blending Processes (**Section 3.5**);
5. Firing/Curing/Cooling Processes (**Section 3.6**);
6. Melted Products Manufacture (**Section 3.7**);
7. Resin Coated Sand & Foundry Cores (**Section 3.8**);
8. Stone & Monument Working (**Section 3.9**);
9. Cassiterite Ore Processing (**Section 3.10**);
10. Manganese Dioxide Production (**Section 3.11**); and
11. Miscellaneous Sources (**Section 3.12**).

3.2 Raw Material/Product Handling Operations

3.2.1 General Description

Raw material and product handling operations include the transfer of materials from stockpiles, kilns, crushers, etc. on conveyors, rail cars or other transportable devices. These operations can cause fugitive particulate emissions, particularly when handling crushed or ground products.

3.2.2 Emissions

The only major NPI-listed emissions from handling operations for Non-Metallic Mineral Products are likely to be particulate matter. Emission factors for PM_{10} from the bulk material handling of talc and vermiculite processing are given in Table 4.

Table 4 - PM_{10} Emission Factors from Talc & Vermiculite Transfer & Loading Operations

Process	PM_{10} Emissions		Emission Factor Rating
	Emission Factor	Units	
Vermiculite Vermiculite concentrate conveyor transfer, with cyclone	0.011[a,b]	kg/tonne of production	D
Talc Pneumatic conveyer venting, with fabric filter	0.00765[b]	kg/tonne of material conveyed	D
Packaging, with fabric filter	0.0044[c]	kg/tonne of production	D
Crushed talc railcar loading	0.00049[b]	kg/tonne of production	D
Crushed talc storage bin loading, with fabric filter	0.00176[c]	kg/tonne of material loaded into the storage bin	D
Ground talc storage bin loading, with fabric filter	0.00078[c]	kg/tonne of material loaded into the storage bin	D
Final product storage bin loading, with fabric filter	0.00171[c]	kg/tonne of material loaded into the storage bin	D

Source: USEPA 1995b (talc); 1995c (vermiculite).

[a] Factors represent emissions for low moisture ore without control technology unless noted. Low moisture ore is considered to be ore that has been processed through a dryer or that has moisture content of less than 4 percent by weight.

[b] PM_{10} emission factors have been calculated using particulate data provided in USEPA AP-42, Chapter 11.26, Table 11.26-1 and the default cumulative percent (85%) of PM_{10} in Total PM from USEPA AP-42, Appendix B.2 Generalized Particle Size Distributions, Table B.2.2 category 4.

[c] PM_{10} emission factors have been calculated using the total PM emission factor (USEPA, 1995b Table 11.26-1) and multiplying by the cumulative percent of particulate matter under 10.0μm, that is 48.9%. The cumulative percent of particulate matter under 10.0 μm was calculated by interpolating data in USEPA, 1995b Table 11.26-2

There is limited data available on emissions from the handling operations of other Non-Metallic Mineral Products. However, emissions of PM_{10} from certain non-metallic mineral processes could be estimated using the emission factors for metallic minerals processing. Section 7.1.2 of the *Emission Estimation Technique Manual for Mining and Processing of Non-Metallic Minerals* discusses this approach to estimating PM_{10} emissions. Table 5 below provides emission factors for transferring metallic mineral ore with high and low moisture contents. High moisture content is defined as ore that has moisture content of 4 percent by weight or greater. Low moisture ore is considered to be ore that has been processed through a dryer or that has a moisture content of less than 4 percent by weight. Each facility should evaluate whether it is fair to assume that their product behaves in a similar manner to a metallic mineral product. This assumption could be valid for dust emissions from a crushed or ground substance.

Table 5 - Emission Factors for PM_{10} from Material Handling of Metallic Minerals

Process	PM_{10} emissions[b] (kg/tonne of material processed)	Emission Factor Rating
Low Moisture Ore[d] Material handling and transfer[c]	0.03[a]	C
Moisture Ore[e] Material handling and transfer[c]	0.002[a]	C

Source: USEPA, 1995d.

[a] Emission factors represent emissions without control technology.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput. If control technology is used, refer to Sections 4 and 5 of this Manual for guidance on how to calculate these emissions.

[c] The emission factor should be applied to each loading or unloading operation and to each conveyor belt transfer point.

[d] Low moisture ore is defined as an ore that has been processed through a dryer or that has a moisture content of less than 4 percent by weight.

[e] High moisture content is defined as ore that has moisture content of 4 percent by weight or greater.

Bulk material handling operations and loading/unloading of vehicles have been addressed in Section 4.4 of the *Emission Estimation Technique Manual for Mining.* While the information is given for metalliferous and coal mining operations, the emission factors are also likely to apply to the handling of non-metallic mineral products. It is likely that many facilities will be able to justify a correlation between these operations and their own process in terms of dust emissions.

In the absence of suitable emission factors, other options for estimating emissions are provided in **Appendix A** of this Manual. In-house methods of estimating emissions may also be available, that would serve the purpose of NPI reporting.

3.3 Crushing/Grinding Processes

3.3.1 General Description

Crushing, grinding and milling operations are part of many mineral processes. Crushing can consist of primary, secondary and tertiary processes, which can be followed by wet or dry grinding and milling. These operations are commonly used for reducing the particle size of ores for further processing downstream. They are also performed in processes where the final product is a powder, or before mixing and moulding operations. Irrespective of the purpose, the issues related with NPI emissions are similar.

The main factor that influences emissions from these operations is the condition under which the size reduction process is performed. The main difference is between wet and dry processes and the target size of the product material.

3.3.2 Emissions

For NPI reporting, the primary emission of concern resulting from crushing, grinding and milling operations, is PM_{10}.

Table 6 provides emission factors for crushing and grinding operations for talc and vermiculite.

Table 6 - Emission Factors for PM_{10} from Crushing, Grinding and Milling Operations

Process	Total PM_{10} emissions (kg/tonne of production)	Emission Factor Rating
Vermiculite Product grinding, with fabric filter	0.153[a]	D
Talc Primary crushing, with fabric filter	0.00026[b]	D
Grinding, with fabric filter	0.0185[b]	D
Grinding with heated makeup air, with fabric filter	0.0185[b]	D

Source: USEPA 1995b (talc); 1995c (vermiculite).

[a] PM_{10} emission factors have been calculated using particulate data provided in USEPA AP-42, Chapter 11.26, Table 11.26-1 and the default cumulative percent of PM_{10} in Total PM from USEPA AP-42, Appendix B.2 Generalized Particle Size Distributions, Table B.2.2 category 4.

[b] The total PM emission factor multiplied by the cumulative percent of particulate matter less than 10.0µm (USEPA, 1995b). The cumulative percent of particulate matter less than 10.0µm was calculated by interpolating the data from Table 11.26-2 for primary crushing and grinding.

However, many of the processes producing Non-Metallic Mineral Products have limited publicly available emissions information. The estimation techniques provided in Section 7.1.2 of the *Emission Estimation Manual for Mining and Processing of Non-Metallic Minerals* may be used as a basis for emissions estimation in the absence of other information.

Table 7 below provides emission factors for crushing and grinding metallic mineral ore with high and low moisture contents. High moisture content is defined as ore, which has moisture of 4 weight percent or greater. Low moisture ore is considered to be ore that has been processed through a dryer or that has moisture content of less than 4 weight percent. Each facility should evaluate whether it is fair to assume that their product behaves in a similar manner to a metallic mineral product. This assumption could be valid for dust emissions from a crushed or ground substance.

The metals fraction of PM_{10} may be assumed to be the same as that for unprocessed ore, in the absence of more suitable site-specific data. In the absence of site specific data, typical concentrations of various NPI-listed substances are presented in Table B2 (Appendix B1) of the *Emission Estimation Technique Manual for Mining*.

Table 7 - Emission Factors for PM_{10} from Crushing & Grinding of Metallic Minerals

Process	PM_{10} emissions[a b] (kg/tonne of material processed)	Emission Factor Rating
Low Moisture Ore[c]		
Primary Crushing[e]	0.02	C
Secondary Crushing[e]	ND	NA
Tertiary Crushing[e]	0.08	E
Wet grinding	Negligible	
Dry grinding with air conveying and/or air classification[f]	13.0	C
Dry grinding without air conveying and/or air classification[f]	0.16	D
High Moisture Ore[d]		
Primary Crushing[e]	0.004	C
Secondary Crushing[e]	0.012	D
Tertiary Crushing[e]	0.01	E
Wet grinding	Negligible	
Dry grinding with air conveying and/or air classification[f]	13.0	C
Dry grinding without air conveying and/or air classification[f]	0.16	D

Source: USEPA 1995d

[a] Emission factors represent emissions without control technology.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput. If control technology is used, refer to Sections 4 and 5 of this Manual for guidance on how to calculate these emissions.

[c] Low moisture ore is considered to be ore that has a dryer preceding the operation or that has moisture content of less than 4 percent by weight

[d] High moisture content is defined as ore that has moisture content of 4 percent by weight or greater.

[e] Based on weight of material entering primary crusher.

[f] Based on weight of material entering grinder; emission factors are the same for high and low moisture ores because the ore is usually dried before entering the grinder.

3.4 Classifying/Separating/Screening Processes

3.4.1 General Description

Separation processes for solid particulate systems include screening, wet classification, jigging, tabling, spirals, dense-media separation, magnetic separation, electrostatic separation and flotation. These processes are used extensively across the non-metallic mineral product manufacturing industry to separate or concentrate particles of minerals.

3.4.2 Emissions

As with transferring operations and size reduction processes, the main emission from these operations would be PM_{10}. Wet processes should have negligible emissions.

Table 8 provides emission factors for screening and classifying operations in talc and vermiculite processing.

Table 8 - Emission Factors for Screening & Classifying Operations in Talc & Vermiculite Processing

Process	PM_{10} emissions (kg/tonne of production)	Emission Factor Rating
Vermiculite Concentrate screening, with cyclone	0.255[a]	D
Talc Screening, with fabric filter[b]	0.0037[a]	D
Classifying, with fabric filter[c]	0.00037[a]	D

Source: USEPA 1995b (talc); 1995c (vermiculite).

[a] PM_{10} emission factors have been calculated using particulate data as represented in USEPA AP-42, Chapter 11.26, Table 11.26-1 and the default cumulative percent of PM_{10} in Total PM from USEPA AP-42, Appendix B.2 Generalized Particle Size Distributions, Table B.2.2 category 4.

[b] For crushed talc ore.

[c] For ground talc ore.

There are, at present, no emission factors available for screening and classifying operations for other Non-Metallic Mineral Products is very limited. **Appendix A** of this Manual provides general guidance on other EETs that could be used to characterise these emissions.

3.5 Wet/Dry Product Mixing/Blending Processes

3.5.1 General Description

The mixing and blending of raw materials is quite common when minerals are involved as raw materials in any process. There is a large variety of mixing equipment and there are also a number of different types of mixing. Mixing types are usually defined by the mechanism used for agitation and the conditions under which the mixture is treated.

3.5.2 Emissions

Emissions from mixing operations depend mainly on the properties of the materials being mixed. Dry mixing almost always produces dust emissions. However, under wet conditions, mixing should not lead to significant emissions.

There are, at present, no emission factors available for mixing operations. **Appendix A** of this Manual provides general guidance on other EETs that could be used to characterise these emissions.

3.6 Firing/Curing/Drying/Cooling Processes

3.6.1 General Description

These processes involve heating by equipment such as kilns or ovens. Dehydrogenation or dealkylation processes are used to remove moisture from the contents of the kiln/oven.

3.6.2 Emissions

The purpose of drying is usually to drive off excess moisture. However, other emissions such as PM_{10} and products of combustion are also produced. Emission factors for PM_{10} emissions from drying, curing and cooling operations are provided in Table 9.

Table 10 provides emission factors for the drying of metallic minerals. There are, at present, no other emission factors available for drying operations. In the absence of other information the emission estimation techniques presented in Section 7.1.2 of the *Emission Estimation Manual for Mining and Processing of Non-Metallic Minerals* may be used as a basis for characterising emissions. Each facility should evaluate whether it is fair to assume that their product behaves in a similar manner to a metallic mineral product. This assumption could be valid for dust emissions from a crushed or ground substance.

Table 9 - Emission Factors for PM_{10} from Drying, Curing and Cooling Operations.

Process	**PM_{10} emissions**		**Emission Factor Rating**
	Emission Factors	**Units**	
Talc Natural gas-fired crude ore drying with fabric filter	0.0011[a]	kg/tonne of production	D
Pellet drying with fabric filter	0.017[a]	kg/tonne of production	E
Vermiculite Rotary dryer, with wet collector	0.29[b]	kg/tonne of material feed to dryer	D
Exfoliation - gas-fired vertical furnace, with fabric filter	0.50[a]	kg/tonne of material feed to dryer	D
Feldspar Dryer with scrubber and demisters	0.60[b]	kg/tonne of material feed to dryer	D
Dryer with mechanical collector and scrubber	0.041[b]	kg/tonne of material feed to dryer	D
Perlite Expansion furnace	ND	ND	NA
Expansion furnace with wet cyclone	1.1[b]	kg/tonne of perlite leaving furnace	D
Expansion furnace with cyclone and baghouse	0.15[b]	kg/tonne of perlite leaving furnace	D
Dryer	ND	kg/tonne of perlite leaving furnace	NA
Dryer with baghouse	0.64[b]	kg/tonne of perlite leaving furnace	D
Dryer with cyclones and baghouses	0.139[b]	kg/tonne of perlite leaving furnace	D

Source: USEPA 1995b (talc); 1995c (vermiculite).

[a] PM_{10} emission factors have been calculated using particulate data presented in USEPA AP-42, Chapter 11.26, Table 11.26-1 and the default cumulative percent of PM_{10} in Total PM from USEPA AP-42, Appendix B.2 Generalized Particle Size Distributions, Table B.2.2 category 5.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput. If control equipment is used, the emission factor represents emissions from the control equipment to the environment.

Table 10 - Emission factors for PM_{10} from Drying Metallic Minerals

Process	PM_{10} emissions [a b] (kg/tonne of exiting dryer)	Emission Factor Rating
Drying - all minerals except titanium/zirconium sands	5.9	C

Source: USEPA 1995d

[a] Emission factors represent emissions without control technology.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput.

3.7 Melted Products Manufacture

Many Non-Metallic Mineral Products processes involve the use of a furnace to bring raw materials to the molten state. Molten material may be moulded into specific forms that will resolidify or can be quenched and reground.

Emissions from melting processes and furnaces can be extremely diverse and the specific emissions will depend on the materials that are in the furnace. Table 11 and Table 12 below provide emission factors for the melting operations during frit manufacture.

The best option for analysing emissions from furnaces is to use site-specific data. Most facilities will already gather to meet regulatory requirements). Guidance on the use of these site-specific data to estimate emissions may be found in **Appendix A.1.1** of this Manual.

Table 11 - Emission Factors from Melting Operations for the Manufacturing of Frit

Source	Emission Factors (kg/tonne of feed material)			Emission Factor Rating
	PM_{10} [a, b]	CO[a]	NO_x [a]	
Melting Furnace	8	2.4	8	E
Melting Furnace, with Venturi Scrubber	0.9	2.4	8	D
Melting Furnace, with Fabric Filter	0.01	2.4	8	E

Source: USEPA 1997

[a] Factors represent emissions without control technology, unless otherwise noted.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput.

Table 12 - Emission Factors for Fluoride and Metals from Frit Melting Operations

Source	Pollutant	Emission Factor (kg/tonne of material feed)	Emission Factor Rating
Melting Furnace with Fabric Filter	Fluorides	0.44	E
	Chromium	$7.0 * 10^{-6}$	E
	Cobalt	$2.2 * 10^{-6}$	E
	Copper	$9.5 * 10^{-6}$	E
	Lead	$4.8 * 10^{-6}$	E
	Manganese	$7.0 * 10^{-6}$	E
	Nickel	$8.0 * 10^{-6}$	E
	Zinc	$6.0 * 10^{-5}$	E

Source: USEPA 1997

3.7.1 Abrasive Products Manufacture

3.7.1.1 General Description

Abrasive products manufacturing can be broken down into three categories, namely abrasive grain manufacturing, bonded abrasive products, and coated abrasive products.

The most commonly used abrasive grains are silicon carbide and aluminium oxide, although other materials such as cubic boron nitride, synthetic diamond and naturally occurring garnet and emery can also be used.

Synthetic abrasive grains are manufactured by reacting or fusing the raw materials in furnaces at very high temperatures and, usually, at very high pressures. The fused material then undergoes crushing and sizing until the final abrasive grain product is formed.

Bonded abrasives are held together by a number of bonding agents. Each process varies slightly, although the basic process involves the wet mixing of an abrasive grain with a porosity media followed by moulding, heating/firing, cooling and final machining.

Coated Abrasive products start as a backing, which is printed and has an adhesive material (the ‘make’ coat) applied. The abrasive grains are then applied by mechanical application or electrostatic precipitation. After curing, the ‘size’ coat of adhesive is applied and final curing takes place. The product is then in its marketable form.

There is limited information available regarding emissions from the abrasives manufacturing industry. There are some published emission factors and these are provided in **Section 3.7.1.2** of this Manual.

3.7.1.2 Emissions

NPI-listed emissions from the production of synthetic abrasives such as silicon carbide and aluminium oxide are most likely to consist of combustion products and metals from the furnaces. Salt and sawdust from silicon carbide production are likely to result in emissions of chlorides and VOCs. The aluminium oxide process may also produce fluorides, sulfides and metal constituents may also be released if they are present in the feed material. If the Solgel method is used, then NO_x may also be emitted.

Emissions from the crushing, screening, classifying and drying processes associated with abrasive grain manufacture consist mainly of $PM_{10.}$ Table 13 provides emission factors for drying operations. It also provides some data on emissions of metals in the abrasives manufacturing industry. Metals analyses conducted on a rotary dryer controlled by a wet scrubber are also shown in Table 13.

Table 13 - Emission Factors for Grain Drying Operations in Abrasives Manufacturing

Process	Pollutant	Emission Factor (kg/tonne of feed into dryer)	Emission Factor Rating
Rotary dryer, sand blasting grit, with fabric filter.	PM_{10} [a]	0.0073	E
Rotary dryer, sand blasting grit, with wet scrubber.	PM_{10} [a]	ND	NA
	Antimony	0.00004	E
	Arsenic	0.00012	E
	Beryllium	0.0000041	E
	Lead	0.0022	E
	Cadmium	0.00048	E
	Chromium	0.00023	E
	Manganese	0.000031	E
	Mercury	0.00000085	E
	Nickel	0.0013	E

Source: USEPA 1995

[a] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput.

Small amounts of PM_{10} may be released from the bonded abrasive products. However, VOCs are most likely to be released from heating ovens, kilns, dryers and curing ovens by the bonding agent during curing. The volatisation of grinding aids such as chloride and sulfur based materials may also occur to a minor degree. Combustion products from the heating ovens or kilns will also be released.

3.7.2 Cast/Fused Ceramics Manufacture

3.7.2.1 General Description

Cast ceramic products utilise an electric arc furnace to melt raw ceramic materials, which are then formed in a sand-forming mould. The process is similar to the metal foundry industry except that the raw materials are non-metallic.

3.7.2.2 Emissions

Emissions of particulate matter will result from electric arc furnace melting operations. However, there are no emission factors presently available. The best option for analysing the emissions from furnaces in the cast ceramic industry is to use site-specific data. Most facilities will already gather this information to meet regulatory requirements. Guidance on the use of site-specific data to estimate emissions is provided in **Appendix A.1.1** of this Manual.

When pouring into sand moulds is the method used to form cast ceramics, there will be VOC emissions from the binding materials. In the absence of other information, it may be assumed that the emission factors for VOC losses for the metal casting industry apply to the emissions from binder use in the cast ceramics industry. These emission factors are provided in Table 5, Section 6 of the *Emission Estimation Technique Manual for Ferrous Foundries.* However, each facility will need to determine the validity of this assumption for their operations.

3.7.3 Mineral Wool and Ceramic Fibre Manufacture

3.7.3.1 General Description

Any fibrous substance produced from melting natural rock or mineral slags can be classed as mineral wool. The process involves melting of the raw materials in a cupola. The product is then formed into fibres and finally formed into products. Mineral wools are primarily used as insulation or in products such as fire resistant material or structural strengtheners. Mineral wool usually becomes one of:

1. Blowing/Pouring wool - used in structural spaces of buildings.
2. Batts - covered with papers or foils to create a vapour barrier. These fit between structural members of buildings.
3. Industrial/Commercial products - high density belts and fibres for the insulation of process equipment.
4. Bulk fibre - raw material for manufacturing products such as ceiling tile, wall board, spray-on insulation, cement and mortar.

Ceramic fibre is produced in a similar method to mineral wool, except that the raw material (calcined kaolin) is melted in an arc furnace, before being formed into fibrous strands and undergoing the curing process.

3.7.3.2 Emissions

The two major sources of emissions from mineral wool manufacture are from the cupola and the blow chamber. Other sources include the binder, storage, mixing and application, the curing oven, mineral wool cooler, materials handling and bagging and wastewater treatment.

The cupola emits a significant amount of particulate matter. In addition, emissions from cupolas include metals and products of combustion such as CO, NO_x and SO_2. The blow chamber also leads to emissions of particulate matter.

The oils and binders used and the processes of batt application, oven curing and wastewater treatment may also result in VOC emissions.

Table 14 provides the PM_{10}, CO and SO_2 emission factors for the manufacture of mineral wool. Emission factors for NO_x, N_2O, H_2S and fluorides are presented in Table 15.

Table 14 - Emission Factors for PM_{10}, CO & SO_2 from Mineral Wool Manufacturing

Process	PM_{10} [a,b]		CO [a]		SO_2 [a]	
	Emission Factor (kg/tonne of product)	Emission Factor Rating	Emission Factor (kg/tonne of total feed charged)	Emission Factor Rating	Emission Factor (kg/tonne of total feed charged)	Emission Factor Rating
Cupola	8.2	E	125	D	4.0	D
Cupola with fabric filter	0.051	D	NA	NA	NA	NA
Reverberatory furnace	2.4	E	ND	NA	ND	NA
Batt curing oven	1.8	E	ND	NA	0.58	E
Batt curing oven, with ESP	0.36	D	ND	NA	ND	NA
Blow Chamber	6.0	E	ND	NA	0.43	E
Blow Chamber, with wire mesh filter	0.45	D	ND	NA	ND	NA
Cooler	1.2	E	ND	NA	0.034	E

Source: USEPA 1995h

[a] Emission Factors show emissions without control technology, unless otherwise indicated.

[b] Weight of total filterable (captured by a filter) PM_{10} per unit weight of material throughput.

Table 15 - NO_x, N_2O, H_2S & Fluoride Emission Factors for Mineral Wool Manufacturing

Process	NO_x [a] or N_2O [a]		H_2S [a]		Fluorides	
	Emission Factor (kg/tonne of feed charged)	Emission Factor Rating	Emission Factor (kg/tonne of feed charged)	Emission Factor Rating	Emission Factor (kg/tonne of feed charged)	Emission Factor Rating
Cupola	0.8 [c]	E	1.5	E	ND	NA
Cupola with fabric filter	ND	NA	ND	NA	0.019 [d]	D
Cupola with fabric filter	ND	NA	ND	NA	0.19 [e]	D
Batt curing oven	0.079 [b]	E	ND	NA	ND	NA

Source: USEPA 1995h

[a] Emission Factors represent emissions without control technology unless otherwise noted.

[b] N_2O emission factor. No data available for NO_x.

[c] NO_x emission factor. No data available for N_2O.

[d] Coke only used as fuel.

[e] Fuel combination of coke and aluminium smelting by-products.

Emissions from electric arc furnaces are not directly addressed by any published emission estimation techniques. These emissions are highly site-specific and depend on the materials that are being handled and the reactions that occur in the furnace. The best method for analysing the emissions from furnaces would be to use site-specific data (that most facilities already gather to meet regulatory requirements). Guidance on the use of site-specific data to estimate emissions may be found in **Appendix A.1.1** of this Manual.

3.8 Resin Coated Sand & Foundry Cores

3.8.1 General Description

Resin Coated Sand

The resin used to coat resin coated sand may contain a number of NPI-listed substances, including phenol, formaldehyde, methanol and sulfuric acid. The processes involved for coating the sand vary. However a heating and mixing stage is common to most processes. The heating and mixing process is likely to cause the volatilisation of some of the substances in the resins and this may lead to the emission of NPI-listed substances.

Foundry Cores

The manufacture of foundry cores can be classified into hot box and the cold box processes. During hot box core making, the sand binder mix is generally blown into a heated mould. The heat from the mould cures the resin binder to produce a core with sufficient strength to withstand subsequent handling and pouring operations. Cold box operations involve curing the sand binder mix at ambient temperatures. Due to the higher temperature involved, hot box processes will generally result in greater VOC emissions.

Some core making processes also use gases such as Methyl Ethyl Formate to assist in the curing process. There may be NPI reporting issues associated with releases of these gases.

PM_{10} emissions for shakeout, cleaning and finishing, sand handling and core making are provided in Table 6, Section 6 of the *Emission Estimation Technique Manual for Ferrous Foundries*.

3.8.2 Emissions

There are no emission factors presently available for the resin coated sand manufacturing industry. **Appendix A** provides generic guidance on emissions estimation to assist facilities reporting emissions to the NPI.

Foundry cores have had some previous coverage under the NPI, in Section 6.1 of the *Emission Estimation Technique Manual for Ferrous Foundries*. The chemical constituents of the various binders used are listed in Tables 7-9. It is important to recognise that the emission factors presented in the *Emission Estimation Technique Manual for Ferrous Foundries* are for the estimation of total emissions from resin usage, including emissions due to casting, and are not valid for core making alone.

3.9 Stone and Monument Working

3.9.1 General Description

Stone and monument making activities consist mainly of cutting, grinding, polishing and similar dressing operations on stone such as marble, granite and sandstone. These operations are generally performed under wet conditions.

3.9.2 Emissions

The only NPI-listed substance that the stone working and monument making industries are likely to emit in significant amounts would be PM_{10}. In most situations, these emissions are expected to be minimal as a consequence of the wet nature of the process. It is important to recognise that reporting on these emissions is only required in situations where reporting is triggered on Category 2 substances.

3.10 Cassiterite Ore Processing

3.10.1 General Description

Note: This is the process description for the Renison Bell Ltd facility, Bell Bay, Tasmania.

The processing of the ore to extract the target cassiterite mineralisation (SnO_2) requires a complex process circuit.

Crushing and wet grinding is broadly similar to other base metal circuits. Dusty air is extracted and passed through a water spray system. The cleaned air is discharged to atmosphere and the spray water is discharged to sedimentation ponds. The ore then undergoes sulfide flotation. About 50% of the ore is usually pyrrhotite and flotation is used to separate the pyrrhotite as a waste product. This waste stream is combined with other process waste streams and is transferred to the tailings storage facility. The flotation process uses an activator, a collector, a pH modifier and sometimes a depressant. The collector is a xanthate and most of the xanthate reports, with the pyrrhotite, to the tailings facility.

The recovery of cassiterite from the sands left behind from the flotation process is accomplished using either gravity concentration or cassiterite flotation concentration. Gravity concentration is most effective for coarse particles whereas cassiterite flotation is most effective with fine particles. The classification circuit deslimes the slurry, which then forms part of the process tailings stream. The gravity separation involves the use of spirals, shaking tables and Kelsey jigs to produce a cassiterite concentrate. No chemicals are used in the process. The tailings from the gravity process are reground to liberate the fine grain cassiterite that has not been recovered. The reground slurry is treated in the cassiterite flotation section. The same principles are used in the cassiterite flotation process as in the sulfide flotation process. This process uses a collector, pH modifier and depressant (although the chemical reagents used are different to sulfide flotation). Tailings from this process are combined with the other tailings streams for transfer to the tailings storage facilities.

The concentrates from the gravity and cassiterite flotation circuits contain acid soluble carbonates. The concentrates are combined and leached with sulfuric acid. Any acid mist or hydrogen sulfide arising from the leaching process is collected by a sodium hydroxide scrubbing system. All effluent (including the tailing streams) from the processing plant are treated with lime to a pH of 8.5 before being discharged to the tailings storage facility.

A number of thickeners are also used in the process. Flocculants are added to these to aid in the settling of solids.

3.10.2 Emissions

There are no emission factors presently available for cassiterite ore processing.
Appendix A of this Manual provides guidance on EETs that may be used to characterise emissions for the purposes of NPI reporting.

Particulate emissions from crushing, grinding, material handling and drying operations may be estimated using the emission factors provided in Table 9 and Table 10 of this Manual. Section 4.4.2 of the *Emission Estimation Technique Manual for Mining* provides additional guidance on estimating these emissions.

The metals fraction of PM_{10} may be assumed to be the same as that for unprocessed ore, in the absence of more suitable site-specific data. In the absence of site specific data, typical concentrations of various NPI-listed substances are presented in Table B2 (Appendix B1) of the *Emission Estimation Technique Manual for Mining*.

If sodium ethyl xanthate is used in the flotation process to concentrate sulfide ores, then the possibility of carbon disulfide emissions will arise. Carbon disulfide is a Category 1 NPI-listed substance. Section 4.9 of the *Emission Estimation Technique Manual for Mining* outlines a procedure that can be adopted for calculating carbon disulfide emissions.

See **Section 3.12** of this Manual for a discussion of general sources of emissions (eg. motor vehicles) associated with cassiterite ore processing.

3.11 Manganese Dioxide Processing

3.11.1 General Description

Note: This is a process description of the Delta EMD facility, Mayfield, NSW.

Electrolytic Manganese Dioxide Process

The primary raw materials for the process are manganese ore and coal. These are roasted together in a kiln to reduce the MnO_2 to MnO. The MnO is then ground in a ball mill. The ground MnO undergoes a sulfuric acid leaching stage, producing a liquid manganese sulfate. The gangue and other unwanted ore remain solid and are retained in the leaching tanks. Trace metals such as cobalt, nickel and molybdenum, are removed by reacting with NaHS. The gases produced during this stage are processed through a caustic scrubber to remove H_2S.

The pure manganese sulfate solution then undergoes electrolysis, where pure manganese dioxide is formed on a titanium anode. Hydrogen gas is produced at the graphite cathode. Dilute sulfuric acid is a by-product of the process and is redirected back into the leaching tanks. When the plating cycle is complete, the anodes are removed from the cell and pneumatic hammers are used to remove the manganese dioxide chips. The cathodes are cleaned by dipping them into sodium carbonate and hydrochloric acid solutions to remove the calcium sulfate. These cleaning solutions are periodically returned to the wastewater treatment plant.

The electrolytic manganese dioxide chips are then crushed and washed in hot water. They are dewatered on a vibrating screen and screw classifier before they are stored in a surge bin for grinding in a ring roller mill. The ground material is washed, dewatered and dried in a hot air drying system. The dry manganese dioxide is then blended and bagged.

Effluent Treatment and Solid Waste Management

Zinc, copper, cobalt, and nickel sulfides are produced in the filter cake of the sulfidation process. These are removed by a thickener and transported to landfill with other solid wastes. The effluent is neutralised with lime to precipitate metal hydroxides. After the solids have been filtered, the remaining effluent is pH adjusted before being discharged to a river. The filters from the leaching process, the sulfide process and the filters from the wastewater ponds are dosed with lime slurry to ensure manganese is fully precipitated before being sent to landfill.

Reagents Tank Farm

Reagents such as caustic soda, hydrochloric acid, sodium hydrosulfide, sulfuric acid and ferric sulfate are stored on site. If accidental spills occur, there is the potential for NPI substances to be produced.

3.11.2 Emissions

There is a range of possible emission sources from this process. In practice, many of the potential emissions are redirected into the process. NPI issues. For example the separation by precipitation of the metallic hydroxides and subsequent transfer to landfill sites account for a number of potential emissions. All solid waste is transported to landfill and hence is classed as a transfer. The effluent leaving the wastewater ponds is strictly monitored to prevent license limits being exceeded. These monitoring data may be used as a basis for characterising emissions.

Emissions to air are reduced by control equipment. However certain pollutants are emitted to the atmosphere from the process. These are shown in Table 16. The emissions shown are also a general indication of the types of pollutant that can be emitted from the electrolytic manganese dioxide process. Any facility producing manganese dioxide should analyse their facility to determine the amounts of each substance that is emitted. There are no emission factors presently available for the manganese dioxide production process. **Appendix A** of this Manual provides guidance on EETs that may be used to characterise emissions for the purposes of NPI reporting.

See **Section 3.12** of this Manual for a discussion of general sources of emissions (eg. motor vehicles) associated with the manganese dioxide production process.

Table 16 - Summary of Possible Emissions from Electrolytic Manganese Dioxide Process

Possible NPI-listed Emissions	Likely to Trigger NPI Threshold (for approx 25 000 tpa product MnO_2)
Nitrogen Oxides (NO_x)	Yes
Carbon Monoxide (CO)	Possible
Sulfur Dioxide (SO_2)	Unlikely
Particulate Matter (PM_{10})	Yes
Arsenic (As)	No
Cadmium & compounds (Cd)	No
Chromium & compounds (Cr)	No
Fluorides (F)	No
Lead & compounds (Pb)	No
Manganese & compounds (Mn)	Unlikely
Nickel & compounds (Ni)	No
Total Volatile Organic Compounds (VOCs)	No
- Acrylinitrile	No
- Benzene	No
- 1,3-Butadiene	No
- 1,4-Dichlorobenzene	No
- Dioxins	No
- Formaldehyde	No
- Methyl Ethyl Ketone	No
- Methyl Isobutyl Ketone	No
- Polycyclic Aromatic Hydrocarbons (PAH's)	No
- Styrene	No
- Tetrachloroethylene	No
- Toluene	No
- Toluene di-isocyanate	No
- Vinyl Chloride	No
- Xylenes	No

Source: Delta EMD Australia P/L

3.12 General Sources of Emissions

There is a number of common sources of emissions which are potentially associated with the activities and industries covered by this Manual. These sources and details of where EETs may be found are presented in Table 17.

Table 17- EETs for Various Emission Sources

Source	Location of EETs
Combustion	*Emission Estimation Technique Manual for Combustion in Boilers* *Emission Estimation Technique Manual for Combustion in Engines*
Vehicles	*Emission Estimation Technique Manual for Mining*
Workshops	*Emission Estimation Technique Manual for Mining*
Wastewater Treatment	*Emission Estimation Technique Manual for Sewage and Wastewater Treatment*
Fuel Storage	*Emission Estimation Technique Manual for Fuel and Organic Liquid Storage*

4.0 General Estimation Technique for Estimating PM_{10} and VOC Emissions

PM_{10} & VOC emissions can be estimated via a facility-wide approach if individual process emissions are unavailable. To adopt this approach the following parameters are required:

- Type of pollution control equipment used;
- Collection efficiency of each piece of equipment;
- Total mass of particulates/VOCs collected;
- Size distribution of collected particulates; or
- Actual VOC composition data for the stream; and/or, limited speciation data in the form of weight fractions developed by USEPA.

Step 1
Identify the types of pollution control equipment used (eg. baghouse, cyclone, scrubber etc).

Step 2
Identify which process streams lead into the equipment identified in Step 1. This may be useful for identifying stream composition or size distribution data.

Step 3
Estimate the total mass of pollutants collected in each piece of equipment. Waste disposal records may already provide this information.

Step 4
Estimate the total mass of PM_{10} and/or VOCs collected. The size distribution of the collected particulates will provide a breakdown of PM_{10} content. The stream compositions or speciation data can be used to provide a breakdown of VOCs.

Step 5
Specify the collection efficiency of the control equipment. The efficiency may be manufacturer supplied or default values (refer to Table 18, of this Manual, for default control efficiencies on pollution control equipment for PM_{10}) may be assigned if no other data source is available.

Step 6
Calculate the mass of PM_{10}/VOC released. This can be done by using the following formula:

$$\text{Pollutant released} = \text{Pollutant flow into control device} * \{1 - (\text{collection efficiency}/100)\}$$

NB: Speciation of the emissions may also be required for other reportable NPI substances. Assays of the collected particulates will supply composition data if speciation is required.

For further information on the speciation of VOCs and PM_{10}, refer to Section 5 of the *Emission Estimation Technique Manual for Fugitive Emissions*.

5.0 Control Technologies

Abatement equipment and control technologies, such as baghouses, cyclones and afterburners, are often used to reduce emissions in many facilities. If you have installed these types of control technologies or other abatement equipment at your facility, or if you have implemented work practices that reduce emissions, you should multiply the uncontrolled emission total by the control efficiency of the technology or practice adopted.

Table 18 and Table 19 provide expected control efficiencies for emissions to air on commonly used abatement equipment. If control equipment is used, the emission should be multiplied by the emission reduction factor of the equipment (1-CE/100), where CE (the control efficiency is in per cent (%)). Default control efficiencies (CE) are provided in Table 18.

Table 18 - Default VOC Collection Efficiencies for Pollution Control Equipment

Control Equipment	**Controlled Emissions** [a]		**Efficiency** [b] **(%)**
	Organic Vapours	**Inorganic Vapours**	
Wet Scrubbers	Yes[c]	Yes	95
Carbon adsorption	Yes[d]	Yes	75
Fluidised-bed systems	Yes[e]	No	ND
Absorption	Yes[f]	No	95
Condensation	Yes	Yes[g]	50-95[h]
Thermal incineration	Yes	No	>99
Catalytic incineration	Yes	No	97

Source: *Emission Estimation Technique Manual for Ferrous Foundries*

[a] 'Yes' in the table indicates that the control equipment (on the corresponding row) is used to reduce emissions of the substance (in the corresponding column). Conversely 'No' indicates that the equipment is not used to reduce emissions of specific substance.

[b] Where a range was given in original table, the midpoint has been taken.

[c] Depends on material, should be miscible in water.

[d] Carbon adsorption or fired-bed systems.

[e] Not widely used.

[f] Material must be readily soluble in water or other solvents.

[g] Depends on vaporisation point of material.

[h] Highly dependent on the emission stream characteristics.

ND = no data.

Table 19 - Default PM_{10} Collection Efficiency Values for Pollution Control Equipment

Control Equipment	Collection Efficiency (%)
Wet scrubber - hi-efficiency	99
Wet scrubber - med-efficiency	95
Wet scrubber - low-efficiency	90
Gravity collector - hi-efficiency	6
Gravity collector - med-efficiency	4.8
Gravity collector - low-efficiency	3.7
Centrifugal collector - hi-efficiency	95
Centrifugal collector - med-efficiency	85
Centrifugal collector - low-efficiency	50
Electrostatic precipitator - hi-efficiency	99.5
Electrostatic precipitator - med-efficiency	
Boilers	94
Other	97
Electrostatic precipitator - low-efficiency	
Boilers	90
Other	90
Mist eliminator - high velocity >250 FPM	90
Mist eliminator - low velocity <250 FPM	75
Fabric filter - high temperature	99.5
Fabric filter - med temperature	99.5
Fabric filter - low temperature	99.5
Process change	NA
Liquid filtration system	85
Packed-gas absorption column	99
Tray-type gas absorption column	95
Spray tower	90
Venturi scrubber	99
Process enclosed	3.7
Impingement plate scrubber	99
Dynamic separator (dry)	99
Dynamic separator (wet)	85
Mat or panel filter - mist collector	97
Metal fabric filter screen	20
Dust suppression by water sprays	90
Dust suppression by chemical stabilizer or wetting agents	90
Gravel bed filter	80
Annular ring filter	97
Fluid bed dry scrubber	90
Single cyclone	50
Multiple cyclone w/o fly ash reinjection	95
Multiple cyclone w/fly ash reinjection	85
Wet cyclonic separator	85
Water curtain	90

Source: USEPA 1995a

6.0 Glossary of Technical Terms and Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
CO	Carbon Monoxide
EEA	European Environment Agency
EET	Emission Estimation Technique
EFR	Emission Factor Rating
NEPM	National Environment Protection Measure
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
PM	Particulate Matter
PM_{10}	Particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less (ie. $\leq 10\mu m$)
SO_2	Sulfur Dioxide
Transfer	Transfers consist of a deposit of a substance into landfill, or discharge of a substance to a sewer or tailings dam, or removal of a substance from a facility for destruction, treatment, recycling, reprocessing, recovery or purification. Emissions classed as transfers are not required to be reported under the NPI.
TSP	Total Suspended Particulate
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compounds

7.0 References

AGL Gas Company (NSW) Limited, 1995, *Natural Gas Technical Data Book*, Industrial Applications Department - AGL Gas Company (NSW) Limited, Five Dock, Australia.

ANZSIC: Australian and New Zealand Standard Industrial Classification Australian Bureau of Statistics & NZ Dept of Statistics 1993 ABS Catalogue No 1292.0

Kerr, I., 1999, Delta EMD Australia Pty Ltd, pers. comm., 02/09/99.

Laszczyk, H., 1999, Renison Bell Ltd, pers. comm., 02/09/99.

Lide, D., 1994, *CRC Handbook of Chemistry and Physics*, CRC Press, London.

Perry, R. and D. Green, 1997, *Perry's Chemical Engineers' Handbook*, (7th ed), Mcgraw-Hill, New York, USA.

USEPA. January 1995a. *Emission Factor Documentation for AP-42, Appendix B.2 Generalized Particle Size Distributions*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/appb-2.pdf

USEPA. November 1995b. *Emission Factor Documentation for AP-42, Section 11.26 Talc Processing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s26.pdf

USEPA. November 1995c. *Emission Factor Documentation for AP-42, Section 11.28 Vermiculite Processing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s28.pdf

USEPA. November 1995d. *Emission Factor Documentation for AP-42, Section 11.24 Metallic Minerals Processing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s24.pdf

USEPA. January 1995e. *Emission Factor Documentation for AP-42, Section 11.27 Feldspar Processing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s27.pdf

USEPA. January 1995f. *Emission Factor Documentation for AP-42, Section 11.30 Perlite Processing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s30.pdf

USEPA. June 1997. *Emission Factor Documentation for AP-42, Section 11.14 Frit Manufacturing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s14.pdf

USEPA. January 1995g. *Emission Factor Documentation for AP-42, Section 11.31 Abrasives Manufacturing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s31.pdf

USEPA. January 1995h. *Emission Factor Documentation for AP-42, Section 11.18 Mineral Wool Manufacturing*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c11s18.pdf

The following EET Manuals are available at the NPI Homepage (http://www.environment.gov.au/npi/home.html), and from your local environmental protection agency or:

- *Emission Estimation Technique Manual for Alumina Refining;*
- *Emission Estimation Technique Manual for Bricks, Ceramics & Clay Product Manufacturing;*
- *Emission Estimation Technique Manual for Combustion Engines*;
- *Emission Estimation Technique Manual for Combustion in Boilers;*
- *Emission Estimation Technique Manual for Ferrous Foundries;*
- *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage;*
- *Emission Estimation Technique Manual for Fugitive Emissions*;
- *Emission Estimation Technique Manual for Glass & Glass Fibre Manufacturing;*
- *Emission Estimation Technique Manual for Gypsum & Plaster Product Manufacture;*
- *Emission Estimation Technique Manual for Lime & Dolomite Manufacturing;*
- *Emission Estimation Technique Manual for Mining;*
- *Emission Estimation Technique Manual for Mining & Processing of Non-Metallic Minerals;*
- *Emission Estimation Technique Manual for Organic Chemical Processing Industries;*
- *Emission Estimation Technique Manual for Phosphate Manufacturing;* and
- *Emission Estimation Technique Manual for Sewage & Wastewater Treatment.*

Appendix A - Emission Estimation Techniques

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 thresholds are contained in the *NPI Guide* at the front of this Handbook.

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 EETs (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 EETs that are not outlined in this handbook, your data will also be displayed as being of 'acceptable reliability'.

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

You are able to use emission estimation techniques that are not outlined in this document. 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.

You should note that the EETs presented or referenced 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, ie. the quantity of the NPI reportable substance spilled, less the quantity recovered or consumed during clean up operations.

A.1 Direct Measurement

You may wish to undertake direct measurement in order to report to the NPI, particularly if you already do so in order to meet other regulatory requirements. However, the NPI does not require you to undertake additional sampling and measurement. For the sampling data to be adequate and able to be used for NPI reporting purposes, it would need to be collected over a period of time, and to be representative of operations for the whole year.

A.1.1 Sampling Data

Stack sampling test reports often provide emissions data in terms of kg per hour or grams per cubic metre (dry). Annual emissions for NPI reporting can be calculated from this data. Stack tests for NPI reporting should be performed under representative (ie. normal) operating conditions. You should be aware that some tests undertaken for a State or Territory license condition may require the test be taken under maximum emissions rating, where emissions are likely to be higher than when operating under normal operating conditions.

An example of test results is summarised in Table 20. The table shows the results of three different sampling runs conducted during one test event. The source parameters measured as part of the test run include gas velocity and moisture content, which are used to determine exhaust gas flow rates in m^3/s. The filter weight gain is determined gravimetrically and divided by the volume of gas sampled, as shown in Equation 1 to determine the PM concentration in grams per m^3. Note that this example does not present the condensable PM emissions.

Pollutant concentration is then multiplied by the volumetric flow rate to determine the emission rate in kilograms per hour, as shown in Equation 2 and Example 2.

Equation 1

$$C_{PM} = C_f / V_{m,STP}$$

where:

C_{PM} = concentration of PM or gram loading, g/m^3
C_f = filter catch, g
$V_{m,STP}$ = metered volume of sample at STP, m^3

Equation 2

$$E_{PM} = C_{PM} * Q_d * 3.6 * [273 / (273 + T)]$$

where:

E_{PM} = hourly emissions of PM, kg/hr
C_{PM} = concentration of PM or gram loading, g/m^3
Q_d = actual stack gas volumetric flow rate, m^3/s, dry
3.6 = 3600 seconds per hour multiplied by 0.001 kilograms per gram
T = temperature of the gas sample, °C

Table 20 - Stack Sample Test Results

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (sec)		7200	7200	7200
Moisture collected (g)	g_{MOIST}	395.6	372.6	341.4
Filter catch (g)	C_f	0.0851	0.0449	0.0625
Average sampling rate (m^3/s)		$1.67 * 10^{-4}$	$1.67 * 10^{-4}$	$1.67 * 10^{-4}$
Standard metered volume (m^3)	$V_{m, STP}$	1.185	1.160	1.163
Volumetric flow rate (m^3/s), dry	Q_d	8.48	8.43	8.45
Concentration of particulate (g/m^3)	C_{PM}	0.0718	0.0387	0.0537

Example 2 - Using Stack Sampling Data

PM emissions calculated using Equation 1 and Equation 2 (above) and the stack sampling data for Test 1 (presented in Table 20, and an exhaust gas temperature of 150°C (423 K)). This is shown below:

$$\begin{aligned} C_{PM} &= C_f / V_{m, STP} \\ &= 0.0851 / 1.185 \\ &= 0.072 \text{ g/m}^3 \end{aligned}$$

$$\begin{aligned} E_{PM} &= C_{PM} * Q_d * 3.6 * [273/(273 + T)] \\ &= 0.072 * 8.48 * 3.6 * (273/423 \text{ K}) \\ &= 1.42 \text{ kg/hr} \end{aligned}$$

The information from some stack tests may be reported in grams of particulate per cubic metre of exhaust gas (wet). Use Equation 3 below to calculate the dry particulate emissions in kg/hr.

Equation 3

$$E_{PM} = Q_a * C_{PM} * 3.6 * (1 - moist_R/100) * [273 / (273 + T)]$$

where:

E_{PM} = hourly emissions of PM in kilograms per hour, kg/hr
Q_a = actual (ie. wet) cubic metres of exhaust gas per second, m^3/s
C_{PM} = concentration of PM or gram loading, g/m^3
3.6 = 3600 seconds per hour multiplied by 0.001 kilograms per gram
$moist_R$ = moisture content, %
273 = 273 K (0°C)
T = stack gas temperature, °C

Total suspended particulates (TSP) are also referred to as total particulate matter (total PM). To determine PM_{10} from total PM emissions, a size analysis may need to be undertaken. The weight PM_{10} fraction can then be multiplied by the total PM emission rate to produce PM_{10} emissions. Alternatively, it can be assumed that 100% of PM emissions are PM_{10}; ie assume that all particulate matter emitted to air has an equivalent aerodynamic diameter of 10 micrometres or less ie. ≤10µm. In most situations, this is likely to be a conservative assumption, but may it be a suitable technique to obtain a reasonable characterisation of emissions for the purposes of NPI reporting.

To calculate moisture content use Equation 4

Equation 4

Moisture percentage = 100 * weight of water vapour per specific volume of stack gas/ total weight of the stack gas in that volume.

$$moist_R = \frac{100 * \frac{g_{moist}}{(1000 * V_{m,STP})}}{\frac{g_{moist}}{(1000 * V_{m,STP})} + \rho_{STP}}$$

where:

$moist_R$ = moisture content, %
g_{moist} = moisture collected, g
$V_{m,STP}$ = metered volume of sample at STP, m^3
ρ_{STP} = dry density of stack gas sample, kg/m^3 at STP
{if the density is not known a default value of 1.62 kg/m^3 may be used. This assumes a dry gas composition of 50% air, 50% CO_2}

Example 3 - Calculating Moisture Percentage

A 1.2m^3 sample (at STP) of gas contains 410g of water. To calculate the moisture percentage use Equation 4.

$$moist_R = {100 * \frac{g_{moist}}{(1000 * V_{m,STP})}} \Big/ {\frac{g_{moist}}{(1000 * V_{m,STP})} + \rho_{STP}}$$

$g_{MOIST}/1000 * V_{m,STP}$ = 410 / (1000 * 1.2)
= 0.342
$moist_R$ = 100 * 0.342 / (0.342 + 1.62)
= 17.4%

A.1.2 Continuous Emission Monitoring System (CEMS) Data

A continuous emission monitoring system (CEMS) provides a continuous record of emissions over time, usually by reporting pollutant concentration. Once the pollutant concentration is known, emission rates are obtained by multiplying the pollutant concentration by the volumetric gas or liquid flow rate of that pollutant.

Although CEMS can report real-time hourly emissions automatically, it may be necessary to estimate annual emissions from hourly concentration data Manually. This Section describes how to calculate emissions for the NPI from CEMS concentration data. The selected CEMS data should be representative of operating conditions. When possible, data collected over longer periods should be used.

It is important to note that, prior to using CEMS to estimate emissions, you should develop a protocol for collecting and averaging the data in order that the estimate satisfies the local environmental authority's requirement for NPI emission estimations.

To monitor SO_2, NO_x, VOC, and CO emissions using a CEMS, you use a pollutant concentration monitor that measures the concentration in parts per million by volume dry air (ppm_{vd} = volume of pollutant gas/10^6 volumes of dry air). Flow rates should be measured using a volumetric flow rate monitor. Flow rates estimated based on heat input using fuel factors may be inaccurate because these systems typically run with high excess air to remove the moisture out of the kiln. Emission rates (kg/hr) are then calculated by multiplying the stack gas concentrations by the stack gas flow rates.

The output includes pollutant concentrations in parts per million dry basis (ppm_{vd}), Table 21 presents example CEMS data output for three periods for a hypothetical furnace. diluent (O_2 or CO_2) concentrations in percent by volume dry basis (%v, d) and gas flow rates; and may include emission rates in kilograms per hour (kg/hr). This data represents a snapshot of a hypothetical boiler operation. While it is possible to determine total emissions of an individual pollutant over a given time period from this data, assuming the CEMS operates properly all year long, an accurate emission estimate can be made by adding the hourly emission estimates if the CEMS data is representative of typical operating conditions.

Table 21 - Example CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil

Time	O_2 content	Concentration				Gas Flow Rate (Q)	Production Rate of Product (A)
	% by volume	SO_2 (ppm_{vd})	NO_x (ppm_{vd})	CO (ppm_{vd})	VOC (ppm_{vd})	m^3/s	tonnes/hour
1	10.3	150.9	142.9	42.9	554.2	8.52	290
2	10.1	144.0	145.7	41.8	582.9	8.48	293
3	11.8	123.0	112.7	128.4	515.1	8.85	270

Hourly emissions can be based on concentration measurements as shown in Equation 5.

Equation 5

$$E_i = (C * MW * Q * 3600) / [22.4 * ((T + 273)/273) * 10^6]$$

where:

E_i = emissions of pollutant i, kg/hr
C = pollutant concentration, $ppm_{v,d}$
MW = molecular weight of the pollutant, kg/kg-mole
Q = actual stack gas volumetric flow rate, m^3/s
3600 = conversion factor, s/hr
22.4 = volume occupied by one mole of gas at standard temperature and pressure (0°C and 101.3 kPa), m^3/kg-mole
T = temperature of gas sample, °C

Actual annual emissions can be calculated by multiplying the emission rate in kg/hr by the number of actual operating hours per year (OpHrs) as shown in Equation 6 for each typical time period and adding the results.

Equation 6

$$E_{kpy,i} = \Sigma (E_i * OpHrs)$$

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr
E_i = emissions of pollutant i, kg/hr (from Equation 5)
OpHrs = operating hours, hr/yr

Emissions in kilograms of pollutant per tonne of product produced can be calculated by dividing the emission rate in kg/hr by the activity rate (production rate tonnes/hr) during the same period. This is shown in Equation 7 below.

It should be noted that the emission factor calculated below assumes that the selected time period (ie. hourly) is representative of annual operating conditions and longer time periods should be used for NPI reporting where they are available. Use of the calculation is shown in Example 4.

Equation 7

$$E_{kpt,i} = E_i / A$$

where:

$E_{kpt,i}$ = emissions of pollutant i per tonne of product produced, kg/t
E_i = hourly emissions of pollutant i, kg/hr
A = production, t/hr

Example 4 illustrates the application of Equation 5, Equation 6 and Equation 7.

Example 4 - Using CEMS Data

This example shows how SO_2 emissions can be calculated using Equation 5 based on the CEMS data for Time Period 1 shown in Table 21, and an exhaust gas temperature of 150°C (423 K).

$$\begin{aligned} E_{SO2,1} &= (C * W * Q * 3600) / [(22.4 * (T + 273/273) * 10^6] \\ &= (150.9 * 64 * 8.52 * 3600) / [22.4 * (423/273) * 10^6] \\ &= 296\ 217\ 907 / 34\ 707\ 692 \\ &= 8.53 \text{ kg/hr} \end{aligned}$$

For Time Period 2, also at 150°C

$$E_{SO2,2} = 8.11 \text{ kg/hr}$$

For Time Period 3, also at 150°C

$$E_{SO2,3} = 7.23 \text{ kg/hr}$$

Say representative operating conditions for the year are:

Period 1 = 1500 hr
Period 2 = 2000 hr
Period 3 = 1800 hr

Total emissions for the year are calculated by adding the results of the three Time Periods using Equation 6:

$$\begin{aligned} E_{kpy,SO2} &= E_{SO2,1} * OpHrs + E_{SO2,2} * OpHrs + E_{SO2,3} * OpHrs \\ &= (8.53 * 1500) + (8.11 * 2000) + (7.23 * 1800) \text{ kg} \\ &= 42\ 021 \text{ kg/yr} \end{aligned}$$

Emissions, in terms of kg/tonne of product produced when operating in the same mode as time period 1, can be calculated using Equation 7

$$\begin{aligned} E_{kpt,SO2} &= E_{SO2} / A \\ &= 8.53 / 290 \\ &= 2.94 * 10^{-2} \text{ kg } SO_2 \text{ emitted per tonne of product produced} \end{aligned}$$

When the furnace is operating as in time periods 2 or 3, similar calculations can be undertaken for emissions per tonne.

A.2 Using Mass Balance

A mass balance identifies the quantity of substance going in and out of an entire facility, process, or piece of equipment. Emissions can be calculated as the difference between input and output of each listed substance. Accumulation or depletion of the substance within the equipment should be accounted for in your calculation.

Mass balance calculations for estimating emissions to air of NPI-listed substances can be represented conceptually by Equation 8.

Equation 8

$$E_{kpy,i} = \text{Amount in}_i - \text{Amount out}_i$$

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr
Amount in_i = amount of pollutant i entering the process, kg/yr
Amount out_i = amount of pollutant i leaving the process as a waste stream, article or product, kg/yr

The term "Amount out_i" may actually involve several different fates for an individual pollutant. This could include the amount recovered or recycled, the amount leaving the process in the manufactured product, the amount leaving the process in wastewater, the amount emitted to the atmosphere, or the amount of material transferred off-site as hazardous waste or to landfill. A thorough knowledge of the different fates for the pollutant of interest is necessary for an accurate emission estimate to be made using the mass balance approach.

The amount of a particular substance entering or leaving a facility is often mixed within a solution as a formulation component or as a trace element within the raw material. To determine the total weight of the substance entering or leaving the process, the concentration of the substance within the material is required. Using this concentration data, Equation 9 can be applied as a practical extension of Equation 8.

Equation 9

$$E_{kpy,i} = [(Q_{in} * C_{in}) - (Q_{pr} * C_{pr}) - (Q_{rec} * C_{rec}) - (Q_{waste} * C_{waste})] / 10^6$$

where:

$E_{kpy,i}$ = emissions of pollutant i, kg/yr
$Q_{in}, Q_{pr}, Q_{rec}, Q_{waste}$ = quantity of raw material, product, recycled material or waste respectively, that is processed (generally expressed in kg for solids, L for liquids)
$C_{in}, C_{pr}, C_{rec}, C_{waste}$ = concentration of substance i in the raw material, product, recycled material or waste respectively, that is processed annually (usually mg/kg for solids, mg/L for liquids)
10^6 = conversion from milligrams to kilograms.

Wastewater treatment may precipitate the reportable chemical in a sludge. Facilities are often required to obtain data on the concentration of metals or other substances in sludge as part of their licensing requirement and this data can be used to calculate the emissions as kilograms of sludge multiplied by the concentrations of the substance in the sludge. Although listed substances in sludge transferred off-site do not require reporting, determining this loss can assist with determining other process losses or may require reporting if the sludge is disposed of on-site.

For many chemicals used and emitted during chemical processes, some degradation in treatment may occur so that the entire chemical is not transferred to the sludge. Facilities can estimate the amount of reportable compounds in the sludge by using measured data, or by subtracting the amount biodegraded from the total amount removed in treatment. The amount of removal can be determined from operating data, and the extent of biodegradation might be obtained from published studies. If the biodegradability of the chemical cannot be measured or is not known, reporting facilities should assume that all removal is due to absorption to sludge.

A.3 Engineering Calculations

An engineering calculation is an estimation method based on physical/chemical properties (eg. vapour pressure) of the substance and mathematical relationships (eg. ideal gas law).

A.3.1 Fuel Analysis

Fuel analysis is an example of an engineering calculation and can be used to predict SO_2, metals, and other emissions based on application of conservation laws, if fuel rate is measured. The presence of certain elements in fuels may be used to predict their presence in emission streams. This includes elements such as sulfur that may be converted into other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is the following:

Equation 10

$$E_{kpy,i} = Q_f * C_i/100 * (MW_p / EW_f) * OpHrs$$

where:

$E_{kpy,i}$ = annual emissions of pollutant i, kg/yr
Q_f = fuel use, kg/hr
OpHrs = operating hours, hr/yr
MW_p = molecular weight of pollutant emitted, kg/kg-mole
EW_f = elemental weight of pollutant in fuel, kg/kg-mole
C_i = concentration of pollutant i in fuel, weight percent, %

For instance, SO_2 emissions from fuel oil combustion can be calculated based on the concentration of sulfur in the fuel oil. This approach assumes complete conversion of sulfur to SO_2. Therefore, for every kilogram of sulfur (EW = 32) burned, two kilograms of SO_2 (MW = 64) are emitted. The application of this EET is shown in Example 5.

Example 5 - Using Fuel Analysis Data

This example shows how SO_2 emissions can be calculated from fuel combustion based on fuel analysis results, and the known fuel flow of the engine. $E_{kpy,SO2}$ may be calculated using Equation 10 and given the following:

Fuel flow (Q_f) = 20 900 kg/hr
Weight percent sulfur in fuel = 1.17 %
Operating hours = 1500 hr/yr

$$
\begin{aligned}
E_{kpy,SO2} &= Q_f * C_i/100 * (MW_p / EW_f) * OpHrs \\
&= (20\ 900) * (1.17/100) * (64 / 32) * 1500 \\
&= 733\ 590 \text{ kg/yr}
\end{aligned}
$$

A.4 Emission Factors

In the absence of other information, default emission factors can be used to provide an estimate of emissions. Emission factors are generally derived through the testing of a general source population (eg. boilers using a particular fuel type). This information is used to relate the quantity of material emitted to some general measure of the scale of activity (eg. for boilers, emission factors are generally based on the quantity of fuel consumed or the heat output of the boiler).

Emission factors require 'activity data', that is combined with the factor to generate the emission estimates. The generic formula is:

$$\text{Emission Factor}\left(\frac{\text{mass}}{\text{unit of activity}}\right) * \text{Activity Data}\left(\frac{\text{unit of activity}}{\text{time}}\right) = \text{Emission Rate}\left(\frac{\text{mass}}{\text{time}}\right)$$

For example, if the emission factor has units of '*kg pollutant/*m^3 *of fuel burned*', then the activity data required would be in terms of 'm^3 *fuel burned/hr*', thereby generating an emission estimate of '*kg pollutant/hr*'.

An emission factor is a tool used to estimate emissions to the environment. In this Manual, it relates the quantity of substances emitted from a source, to some common activity associated with those emissions. Emission factors are obtained from US, European, and Australian sources and are usually expressed as the weight of a substance emitted, divided by the unit weight, volume, distance, or duration of the activity emitting the substance.

Emission factors are used to estimate a facility's emissions by the general equation:

Equation 11

$$E_{kpy,i} = [A * OpHrs] * EF_i * [1 - (CE_i/100)]$$

where :

$E_{kpy,i}$ = emission rate of pollutant i, kg/yr
A = activity rate, t/hr
$OpHrs$ = operating hours, hr/yr
EF_i = uncontrolled emission factor of pollutant i, kg/t
CE_i = overall control efficiency of pollutant i, %.

Emission factors developed from measurements for a specific process may sometimes be used to estimate emissions at other sites. Should a company have several processes of similar operation and size, and emissions are measured from one process source, an emission factor can be developed and applied to similar sources. It is necessary to have the site-specific emission factor reviewed and approved by State or Territory environment agencies prior to its use for NPI estimations.

Appendix B - 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 equipment manufacturing 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.

B.1 Direct Measurement

Use of stack and/or workplace health and safety sampling data is likely to be a relatively accurate method of estimating air emissions from equipment manufacturing facilities. However, collection and analysis of samples from facilities can be very expensive and especially complicated where a variety of NPI-listed substances are emitted, and where most of these emissions are fugitive in nature. Sampling data from a specific process may not be representative of the entire manufacturing operation, and may provide only one example of the facility’s emissions.

To be representative, sampling data used for NPI reporting purposes needs to be collected over a period of time, and to cover all aspects of production.

In the case of CEMS, instrument calibration drift can be problematic and uncaptured data can create long-term incomplete data sets. However, it may be misleading to assert that a snapshot (stack sampling) can better predict long-term emission characteristics. It is the responsibility of the facility operator to properly calibrate and maintain monitoring equipment and the corresponding emissions data.

B.2 Mass Balance

Calculating emissions from equipment manufacturing facilities using mass balance appears to be a straightforward approach to emission estimation. However, it is likely that few Australian facilities consistently track material usage and waste generation with the overall accuracy needed for application of this method. Inaccuracies associated with individual material tracking, or other activities inherent in each material handling stage, can result in large deviations for 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 emission estimations.

B.3 Engineering Calculations

Theoretical and complex equations, or models, can be used for estimating emissions from equipment manufacturing production processes. EET equations are available for the following types of emissions common to equipment manufacturing facilities.

Use of emission equations to estimate emissions from equipment manufacturing 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

B.4 Emission Factors

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 Handbooks. 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 that the factor was derived.

The EFR system is as follows:

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

Appendix C - List of Variables and Symbols

Variable	Symbol	Units
Conversion from kilograms to tonnes	10^3	kg/tonne
Conversion from milligrams to kilograms	10^6	mg/kg
Density of air	ρ_a	kg/m^3
Density of material	ρ_m	kg/L
Dry density of stack gas sample	ρ_{STP}	kg/m^3 at STP
Activity rate	A	units/hr, eg t/hr
Surface area	area	m^2
Overall control efficiency	CE_i	% reduction in emissions of pollutant i
Filter Catch	C_f	grams
Concentration of pollutant i	C_i	kg/L
Concentration of pollutant i in material	C_i	kg/L
Concentration of substance i in the raw material, product, recycled material or waste respectively, that is processed annually	C_{in}, C_{pr}, C_{rec}, C_{waste}	(usually mg/kg for solids, mg/L for liquids)
Concentration of PM_{10}	C_{PM10}	$grams/m^3$
Uncontrolled emission factor for pollutant i	EF_i	kg of pollutant/tonne
Total emissions of pollutant i per hour	E_i	kg/hr
Emissions per tonne	$E_{kpt,i}$	kg of pollutant i per tonne of fuel consumed
Annual emissions of pollutant i	$E_{kpy,i}$	kg/yr
Elemental weight of pollutant in fuel	EW_f	kg/kg-mole
Molecular Weight of pollutant i	MW_i	kg/kg-mole
Operating hours	OpHrs	hr/yr
Pollutant concentration	ppm_{vd}	volume of pollutant gas/10^6 volume of dry air
Saturation vapour pressure of pollutant i	$P_{sat,i}$	kilopascals (kPa)
Total pressure	P_t	kPa
Vapour pressure of pollutant i	$P_{vap,i}$	kPa
Volumetric flow rate,	Q	m^3/s
Volumetric flow rate of stack gas	Q_a	actual cubic metres per second (m^3/s)
Volumetric flow rate of stack gas	Q_d	dry cubic metres per second (m^3/s)
Fuel used	Q_f	t/hr
Material entering the process	Q_{in} or Amount in_i	kg/hr
Material leaving the process	Q_{out} or Amount out_i	kg/hr
Ideal gas constant	R	kPa.m^3 /(kgmol).K
Standard Temperature & Pressure	STP	0°C (273 K) and 1 atmosphere 101.3 kPa
Temperature	T	°Celsius (°C) or Kelvin (K)

Appendix C - List of Variables and Symbols cont'

Total suspended particulates or Total particulate matter (total PM)	TSP or PM	mg/m^3
Metered volume at STP	$V_{m,STP}$	m^3
Total VOC emissions	E_{VOC}	kg/L
Moisture collected	g_{moist}	grams
Moisture content	$moist_R$	%
Percentage weight of pollutant i	$Wt\%_i$	%