National Pollutant Inventory

Emission Estimation Technique Manual

for

Appliance, Machinery and Electrical Equipment Manufacture

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EMISSION ESTIMATION TECHNIQUES
FOR
APPLIANCE, MACHINERY AND ELECTRICAL EQUIPMENT MANUFACTURE

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APPLIANCE, MACHINERY AND ELECTRICAL EQUIPMENT MANUFACTURE

LIST OF TABLES AND EXAMPLES

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 describes the procedures and recommended approaches for estimating emissions from facilities engaged in the manufacture of a range of equipment from scientific, medical & photographic equipment to appliances & electrical equipment and larger industrial machinery. This Manual deals, primarily, with assembly line-type activities and associated processes.

EET MANUAL: Appliance, Machinery and Electrical Equipment Manufacture

HANDBOOK: Appliance, Machinery and Electrical Equipment Manufacture

ANZSIC CODES: 283 series Photographic and Scientific Equipment Manufacturing
    2831 Photographic and Optical Good Manufacturing
    2832 Medical and Surgical Equipment Manufacturing
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    285 series Electrical Equipment and Appliance Manufacturing
    2851 Household Appliance Manufacturing
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    2867 Commercial Space Heating and Cooling Equipment Manufacturing
    2869 Industrial Machinery and Equipment Manufacturing n.e.c.

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

1.1 Manual Structure

This Manual applies to a broad cross-section of industry. Therefore, rather than considering each manufacturing process separately, the scope of this Manual has been defined as a series of unit processes. That is, each of the manufacturing processes covered by this Manual can be considered (for the purposes of emissions estimation) as being a combination of one or more of the unit processes presented in this Manual (see **Section 3.0** of this Manual).

Other EET Manuals cover a number of appliance, machinery and electrical equipment manufacturing processes. These Manuals are listed in Table 1.

Table 1 - Previous Coverage under the NPI

Industrial Activity	NPI Manual That Relates to this Activity
Glass Product Processes	*Emission Estimation Technique Manual for Glass & Glass Fibre Manufacturing*
Battery Manufacture	*Emission Estimation Technique Manual for Lead Acid Battery Manufacturing*
Metal Machining/Working	*Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture* *Emission Estimation Technique Manual for Ferrous Foundries* *Emission Estimation Technique Manual for Non Ferrous Foundries* *Emission Estimation Technique Manual for Motor Vehicle Manufacturing*
Welding & Soldering	*Emission Estimation Technique Manual for Fugitive Emissions* *Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture*
Cleaning Operations	*Emission Estimation Technique Manual for Surface Coating* *Emission Estimation Technique Manual for Fugitive Emissions*
Surface Coating & Painting	*Emission Estimation Technique Manual for Surface Coating* *Emission Estimation Technique Manual for Electroplating and Anodising* *Emission Estimation Technique Manual for Galvanising* *Emission Estimation Technique Manual for Motor Vehicle Manufacturing* *Emission Estimation Technique Manual for Fugitive Emissions*
Liquid Spills	*Emission Estimation Technique Manual for Organic Chemical Processing Industries*
Storage Vessels	*Emission Estimation Technique Manual for Organic Chemical Processing Industries* *Emission Estimation Technique Manual for Alumina Refining*
Wastewater Treatment	*Emission Estimation Technique Manual for Sewage and Wastewater Treatment*
Combustion Activities & Thermal Processes	*Emission Estimation Technique Manual for Combustion Engines* *Emission Estimation Technique Manual for Combustion in Boilers*

This Manual is structured as follows:

- **Section 2** discusses likely emissions from unit processes and those elements of the environment (air, water or land) to which emissions may be released. Relevant emissions of substances for each of the NPI threshold categories are discussed in **Sections 2.1, 2.2** and **2.3**. Emissions to air, water and land are discussed in **Sections 2.4, 2.5** and **2.6** respectively.

- **Section 3** describes the unit processes and activities covered by this Manual.

- **Section 4** provides a glossary of the technical terms and abbreviations used in this Manual.

- **Section 5** provides a list of 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 appliance, machinery and electrical equipment manufacturing industry.

- **Appendix B** provides a discussion of the reliability and uncertainty associated with each of the techniques presented in **Appendix A.**

- **Appendix C** provides a list of variables and symbols used in 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 could 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).
2. (Recognising that the order in which the unit processes are presented in this Manual may not be the same as at your facility). Identify the relevant section(s) of Table 4 of this Manual, which correspond to each unit process.
3. Select the estimation techniques that best suit your facility's current methods of measuring or estimating emissions or flows.
4. Apply the emission estimation technique that is most appropriate 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 regarding 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 EET options 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, then there would be little gained by applying an EET which 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, if any, and determine whether the amounts used 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   Reportable Emission Sources

2.1   Category 1

The reporting threshold for Category 1 substances is exceeded if the activities involve the use (eg. handling) of 10 tonnes or more of the substance in a year. A facility is only required to report on those substances for which reporting thresholds have been exceeded. If the threshold is exceeded for a particular substance, then the facility must report emissions of that substance all some operations/processes relating to the facility, even if actual emissions are very low or zero.

Due to the wide range of activities in the appliance, machinery and electrical equipment manufacturing industry, many of which involve the use of cutting oils, degreasing and cleaning solvents, acids, alkalis and metals, it is possible that reporting could be triggered for any of the NPI Category 1 substances. The total amount of each Category 1 substance used must be estimated in order to determine whether the threshold is exceeded. For some NPI substances, the assessment of whether or not reporting is triggered depends on the concentration of each substance in the materials used and the total amount of materials used in the process.

Example 1 shows a calculation that can be performed to determine if a Category 1 substance triggers the threshold for an appliance manufacturing facility.

Example 1 - Category 1 Substance Reporting Threshold

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

Total amount of solvent used =   100 000 L/yr
Concentration of MEK   =   96%

Volume of MEK consumed   =   0.96 * 100 000 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
                                =   77.28 tonnes/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.

2.2   Category 2

The Category 2 threshold is based on energy consumption or fuel use. 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.

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.

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]	$1.25 * 10^7$ MJ per reporting year, or at least $3.13 * 10^4$ MJ in any one hour in the reporting year	$6.24 * 10^7$ MJ 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]	$2.02 * 10^7$ MJ per reporting year, or at least $5.04 * 10^4$ MJ in any one hour in the reporting year	$1.01 * 10^8$ MJ per reporting year
Butane[g]	$1.98 * 10^7$ MJ per reporting year, or at least $4.96 * 10^4$ MJ in any one hour in the reporting year	$9.92 * 10^7$ MJ 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 natural gas with a gross heating value of 31.27 MJ/kg. Natural gas (NSW) data from the *Natural Gas Technical Data Handbook* (AGL Gas Company (NSW) Limited, 1995).
[c] Assuming ideal gas with a density of 508 kg/m³ 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/m³ 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/m³ at 15°C for fuel oil for commercial use (Perry, et al., 1997)
[f] Assuming a gross heating value of 50.4 MJ/kg at 25°C and 101.325 kPa (Lide, 1994).
[g] Assuming a gross heating value of 49.6 MJ/kg at 25°C and 101.325 kPa (Lide, 1994).

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

Table 3 - NPI-listed Category 2 Substances

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

2.3   Category 3

It is highly unlikely that the Category 3 threshold will be triggered for the industries that are covered in this Manual. As stated in the *NPI Guide*, the Category 3 threshold will only be triggered if emissions to water (excluding groundwater) exceed:

- 15 tonnes or more per year of total nitrogen; or,
- 3 tonnes per year or more of total phosphorus.

For appliance, machinery and electrical equipment manufacturing facilities, it is extremely unlikely there will be licensed discharges to surface or ground waters. The one exception may be stormwater run-off, although it is unlikely that this run-off would contain levels of nitrogen or phosphorus, which 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 will need to go through the process of determining whether or not Category 3 reporting requirements are triggered for your facility.

2.4   Emissions to Air

The emissions to air from appliance, machinery and electrical equipment manufacture are listed in Table 4.

Table 4 - Emissions to Air from Appliance, Machinery and Electrical Equipment Manufacturing Facilities

Activities	Potential NPI Emissions	Sources of Information
Glass Product Processes	PM_{10} Fluorides Sulfur dioxide Oxides of nitrogen Carbon monoxide Category 1 listed solvents	The *Emission Estimation Technique Manual for Glass & Glass Fibre Manufacturing* provides emission estimation techniques for the glass manufacturing industry. See also **Section 3.1** of this Manual for further information.
Copper Wire Products Optical Fibre Products	No data presently available	It is likely that most of the emissions associated with these activities will occur indoors. A number of techniques for estimating fugitive emissions from inside buildings are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions*.

Battery Manufacture	Lead Acid Battery
	  Lead
	  Sulfuric acid
	  PM_{10}
	
	Leclanche Dry Cells
	  No data presently available
		The manufacture of lead acid batteries is covered in the *Emission Estimation Technique Manual for Lead Acid Battery Manufacturing*.
		
		Refer to **Section 3.4** of this Manual for further information on the manufacture of Leclanche (Dry Cell) batteries.
		
		It is likely that most of the emissions associated with these activities will occur indoors. A number of techniques for estimating fugitive emissions from inside buildings are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions*.

Table 4 - Emissions to Air from Appliance, Machinery and Electrical Equipment Manufacturing Facilities cont'

Emission Source	Potential NPI Emissions	Sources of Information
Metal Machining/Working	The emissions from these processes may include a range of NPI-listed substances due to the use of lubricant oils and solvents etc. However, it is unlikely that the use of these substances will, of itself, be sufficient to trigger reporting. Particulate matter (PM_{10}) is probably the main substance of concern in the context of NPI reporting. Reporting of PM_{10} could be triggered in industries that use energy for furnaces and heating operations.	Refer to **Section 3.5** of this Manual for further information on metal machining and working operations
Welding & Soldering	PM_{10} Carbon monoxide Manganese & compounds Nickel & compounds Chromium (III) compounds Chromium (VI) compounds Cobalt & compounds Lead & compounds	Refer to **Section 3.6** of this Manual for further information on emissions to air from welding and soldering processes. It is likely that most of the emissions associated with these activities will occur indoors. A number of techniques for estimating fugitive emissions from inside buildings are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions*.
Cleaning Operations	NPI-listed substances contained in cleaning agents	Refer to **Section 3.7** of this Manual for further information on emissions to air from cleaning operations.
Surface Coating and Painting Operations	NPI-listed substances contained in surface coating agents	Refer to **Section 3.8** of this Manual for further information on the estimation of air emissions from surface coating and painting operations.

Table 4 - Emissions to Air from Appliance, Machinery and Electrical Equipment Manufacturing Facilities cont'

Emission Source	Potential NPI Emissions		Sources of Information
Combustion Activities and Thermal Processes	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	Guidance on the estimation of emissions from combustion processes is provided in the *Emission Estimation Technique Manual for Combustion in Boilers*. Guidance on the estimation of emissions from petrol and diesel engines and stand-by generators is provided in the *Emission Estimation Technique Manual for Combustion Engines*.
Storage Vessels	Any NPI-listed substances that are contained in bulk storage facilities.		Refer to **Section 3.10** of this Manual for further information regarding emissions to air from storage vessels.
Liquid Spills	Any accidental releases of NPI-listed substances.		Refer to **Section 3.11** of this Manual for further information regarding emissions to air from liquid spills.
Fugitive Emissions	Potentially all substances listed above.		It is likely that most of the emissions associated with these activities will occur indoors. A number of techniques for estimating fugitive emissions from inside buildings are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions*.

2.5   Emissions to Water

Liquid effluent containing NPI-listed substances to water are usually sent off-site for treatment or disposal. In this situation, the effluent is classed as a transfer (see **Section 2.6** below) under the NPI (and is therefore not required to be reported).   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.

There may be NPI reporting issues associated with stormwater run-off. 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. These sampling data can be used to calculate annual emissions.

2.6   Emissions to Land

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 which 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."

Emissions of substances to land on-site include solid wastes, slurries, sediments, 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 a consequence, there will be no requirement to report on these emissions. The only possible reporting requirements for the industry 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 provided above.

3.0   Process Descriptions & Emissions

The following potential sources of NPI emissions are covered in this Section:

- Glass product processes (**Section 3.1**);
- Copper wire products (**Section 3.2**);
- Optical fibre products (**Section 3.3**);
- Battery manufacture (**Section 3.4**);
- Metal machining/working (**Section 3.5**);
- Welding and soldering (**Section 3.6**);
- Cleaning operations (**Section 3.7**);
- Surface coating and painting (**Section 3.8**);
- Combustion activities and thermal processes (**Section 3.9**);
- Storage vessels (**Section 3.10**); and
- Liquid spills (**Section 3.11**).

3.1   Glass Product Processes

3.1.1   Description

Glass working may be carried out in facilities that require glass componentry. Glass product manufacture has the potential to emit particulates (PM_{10}), fluorides, sulfur dioxide, oxides of nitrogen, carbon monoxide and a number of Category 1 listed solvents.

3.1.2   Emissions Estimation Coverage under the NPI

The *Emission Estimation Manual for Glass & Glass Fibre Manufacturing* provides emission estimation techniques for the glass manufacturing industry. The glass and glass product manufacturing facilities covered by the Manual include facilities engaged in the manufacture of glass containers, motor vehicle glass, domestic glassware, glass and glass products, glass wool and associated insulation products and industrial glass.

Glass grinding and cutting operations are not presently covered by any of the NPI Manuals. However, these operations are generally performed using lubricants, which should ensure that emissions of PM_{10} are negligible.

3.2   Copper Wire Products

3.2.1   Description

The process of producing wire involves drawing a metal rod through successively smaller conical holes in tungsten carbide or industrial diamond dies, until the desired diameter is obtained.

3.2.2 Emissions Estimation Coverage under the NPI

The drawing of wire should not result in any emissions of PM_{10}, due to the fact that solid metal is being manipulated. It is also expected that no chemical substances or particulate metal materials would be produced from this process. In the event that there are emissions, **Appendix A** of this Manual provides guidance on EETs that may be used.

Copper wire production operations generally occur within buildings. Therefore, for the purposes of characterising emissions for NPI reporting, emissions from activities and processes that are not recovered by a local exhaust ventilation system may be considered as fugitive emissions. A number of methods for estimating fugitive emissions are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.3 Optical Fibre Products

3.3.1 Description

The manufacture of fibre optic cable involves the drawing of high-grade silica glass (SiO_2) to produce a fibre. SiO_2 is produced by reducing silica with carbon then reacting with chlorine gas to form a liquid silicon tetrachloride ($SiCl_4$), which undergoes purification. SiO_2 is recovered from the vapourisable liquid silicon chloride by gas phase deposition. Other chlorides such as germanium chloride can be added to the silicon chloride for doping of the SiO_2 glasses. The chloride mixture is hydrolised in a gas flame, where the soot particles condense out and are collected as a soot preform. The preform is converted to a glass in a furnace where residual water is removed as hydrogen chloride gas via an exhaust system. Submicron silica particles are removed and the gas is absorbed into water to form hydrochloric acid, which is neutralised with caustic soda. The silica glass then enters the drawing furnace and the resulting fibre is coated and wound before proof testing is performed. Cable manufacturers apply a low-density polyethylene over the core on conventional sheathing lines. A layer of Nylon 12 may also be applied to protect the cable.

3.3.2 Emissions Estimation Coverage under the NPI

The fibre optics manufacturing industry may have NPI reporting requirements as a consequence of the production of HCl gas from the drying process and the use of chlorine throughout the process. These substances are both Category 1 substances (and will trigger reporting if 10 tonnes or more are used). The fuel usage for a facility as a whole would also need to be less than 400 tonnes/year or 1 tonne/hour or the Category 2a threshold would be triggered. If this is the case, particulate matter from combustion and SiO_2 soot production will also need to be reported.

There are, at present, no publicly available emission factors for the fibre optics manufacturing industry. Therefore, some of the other EETs outlined in **Appendix A** could be applied for emissions estimation.

Optical fibre production operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions from processes and activities that are not recovered by a local exhaust ventilation system may be considered as fugitive emissions. A number of methods for estimating fugitive emissions may be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.4   Battery Manufacture

3.4.1   Description

The manufacture of lead acid batteries is covered in the *Emission Estimation Technique Manual for Lead Acid Battery Manufacturing*.

The one major type of battery manufacture not covered by that Manual is the manufacture of Leclanche (Dry Cells) batteries. The manufacturing process comprises six main stages, as follows:

Zinc Can or Container

The zinc can or container can be manufactured by a number of standard metal shaping techniques such as:

- Rolling a zinc strip into a cylinder with the can bottom (punched out of a zinc plate) soldered into place;
- Deep drawing processes; or
- An impact extrusion process which produces a complete can of uniform dimension.

Bobbin

The bobbin is a mixture of cathode material (manganese dioxide) carbon, (acetylene black) and electrolyte (typically zinc chloride solution with or without ammonium chloride) which is mixed in a blender or similar device to obtain a homogenous mixture. Note that the cathode material (a manganese compound) and the electrolyte (a zinc compound and ammonia) are Category 1 listed substances under the NPI and may trigger NPI reporting requirements.

Carbon Rod

Carbon rods are produced from high purity petroleum coke which is calcined (removal of volatile material), mixed with coal tar pitch and extruded into long thin rods. The rods are then baked and allowed to cool. The carbon rods may be waterproofed with oil or paraffin before application.

Separator

The separator may be a gel electrolyte (zinc chloride, ammonium chloride, water and gelling agent mixture) or gelling agent coated paper. Note that zinc chloride (a zinc compound) and ammonium chloride (ammonia (total)) are listed as Category 1 substances under the NPI.

Wrap

The insulating sleeve is a laminated cardboard or plastic tube that may be asphalt-lined. The top seal can be asphalt pitch, wax or plastic (polyethylene or polypropylene).

Assembly Process

The insulating paper liner and bottom washer are installed, the bobbin mix and carbon rod is inserted and the tops are sealed in one continuous operation.

3.4.2 Emissions Estimation Coverage under the NPI

Guidance on the estimation of emissions from metal shaping techniques is provided in the *Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture.*

Spills of Category 1 listed substances may present an issue in terms of NPI reporting. Refer to **Section 2.6** of this Manual for further guidance.

Battery manufacturing operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions that are not recovered by a local exhaust ventilation system may be considered as fugitive emissions. A number of methods for estimating fugitive emissions may be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions*

3.5 Metal Machining/Working

3.5.1 Description

The metal working operations covered by this Manual are extremely diverse. Basic fabrication activities can include cutting, grinding, drilling, turning, milling, forming, shearing and forging. Other operations for metal componentry can include heat treating, melting and die casting and foundry casting operations. The emissions from these processes can potentially include a range of NPI-listed substances, due to the lubricant oils and solvents used. Particulate matter (PM_{10}) is probably the main substance of concern in the context of NPI reporting and could be triggered in industries that use energy for furnaces and heating operations.

3.5.2 Emissions Estimation Coverage under the NPI

The *Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture* provides emission estimation techniques for metal fabrication processes. The main activities covered by this Manual are melting, die casting, cutting, shearing and forming, welding and soldering, grinding, heat treatment, forging and machining.

Emissions from foundry operations are covered by the *Emission Estimation Technique Manual for Ferrous Foundries* and the *Emission Estimation Technique Manual for Non-Ferrous Foundries.* These Manuals cover the casting, die casting and machining of iron and steel and also non-ferrous metal materials.

The *Emission Estimation Technique Manual for Motor Vehicle Manufacturing* addresses the foundry operations, metal machining and shaping, metal coating and assembly as these activities relate to the motor vehicle manufacturing industry. Many of these estimation techniques may be applied to the various processes that are considered here.

Metal machining and working operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions that are not recovered by a local exhaust ventilation system may be considered as fugitive emissions. A number of methods for estimating fugitive emissions may be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.6 Welding and Soldering

3.6.1 Description

Welding is the process of joining two metallic pieces together by melting the areas of contact and forming a join from that molten metal or a consumable electrode. Heat is generated most frequently by electric arc or gas-oxygen flame. Emissions from welding processes consist mainly of particulate matter and particulate phase hazardous air pollutants. The emitted fumes may contain the following NPI-listed pollutants:

- Carbon monoxide;
- Manganese;
- Nickel;
- Chromium;
- Cobalt; and
- Lead.

Electric arc welding is the only major source of these emissions (USEPA, 1995).

Soldering is a common process in electrical equipment manufacture. It is the process of joining two metallic pieces together by melting an alloy of metals, traditionally lead and tin, along the joining edge. Emissions will consist of gaseous flux material and particulate fumes, which will contain traces of the metals of which the solder is composed.

3.6.2 Emissions Estimation Coverage under the NPI

Emissions from welding can be estimated by using the emission estimation techniques presented in Section 3.18.1 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

There are, at present, no emission factors available for soldering processes. Soldering operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions that are not recovered by a local exhaust ventilation system may be considered as fugitive emissions. A number of methods for estimating fugitive emissions may be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.7 Cleaning Operations

3.7.1 Description

Solvent degreasing is the process whereby solvents are used to remove greases, fats, oils, wax or soil from materials such as metals, plastics and glass. These cleaning solvents include petroleum distillates, chlorinated hydrocarbons, ketones and alcohols. The emissions from these processes are mainly VOCs.

3.7.2 Emissions Estimation Coverage under the NPI

VOC emissions from cleaning processes are covered by Section 3.3 of the *Emission Estimation Technique Manual for Surface Coating.* Guidance on the speciation of VOC emissions is provided in Section 5.1 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

Cleaning operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions may be considered as fugitive emissions. A number of methods for estimating fugitive emissions can be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.8 Surface Coating & Painting

3.8.1 Description

Surface coating processes such as anodising, chemical conversion coating, electroplating, galvanising and painting are widely used within the appliance, machinery and electrical equipment industries. These processes will produce VOCs, metal and particulate fumes. There may also be NPI-listed metals in fumes (if metals are contained within the surface coating agents or paints). Most of these processes will also involve surface degreasing or cleaning. These activities are potential sources of VOC emissions.

3.8.2 Emissions Estimation Coverage under the NPI

Surface coating processes and the associated pre-treatment steps are addressed by the *Emission Estimation Technique Manual for Surface Coating,* the *Emission Estimation Technique Manual for Electroplating and Anodising* and the *Emission Estimation Technique Manual for Galvanising*.

The *Emission Estimation Technique Manual for Motor Vehicle Manufacturing* covers the surface coating of motor vehicles, light duty surface vehicles and commercial vehicles.

Guidance on the speciation of VOC emissions is provided in Section 5.1 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

Surface coating and painting operations generally occur within buildings. Therefore, for the purposes of NPI reporting, emissions may be considered as fugitive emissions. A number of methods for estimating fugitive emissions may be found in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

3.9 Combustion Activities & Thermal Processes

3.9.1 Description

These activities include combustion of fuels in boilers, furnace emissions and combustion products from engines.

3.9.2 Emissions Estimation Coverage under the NPI

The *Emission Estimation Technique Manual for Combustion Engines* can be used to estimate emissions from fuel combustion for a range of engine types. These engines include petrol and diesel industrial engines, petrol and diesel motor vehicles, commercial vehicles, and trucks, large stationary diesel and dual-fuel engines and heavy-duty natural gas fired pipeline compressor engines and turbines.

Emissions from fuel combustion in boilers can be estimated by using the emission estimation techniques provided in the *Emission Estimation Technique Manual for Combustion in Boilers.* The Manual covers the combustion of coal, gas, oil, wood and bagasse.

Furnace emissions are highly site-specific and depend on the materials that are being handled and the reactions that occur in the furnace. The best option for analysing the emissions from furnaces would be to use site-specific data (which most facilities will 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.

3.10 Storage Vessels

3.10.1 Description

Storage vessels include fixed roof tanks, floating roof tanks and variable vapour space tanks. The emissions of concern from storage vessels include losses from filling and transfer operations and standing losses.

3.10.2 Emissions Estimation Coverage under the NPI

It is recommended that the emissions from small tanks (ie. less than 30 tonnes capacity) are calculated using the emission estimation technique for air displacement provided in Section 5.2 of the *Emission Estimation Technique Manual for Organic Chemical Processing Industries.* This is a relatively simple emission estimation technique, requiring only vapour mole fraction, liquid mole fraction and vapour pressure data for each of the components

being stored. Alternatively, the TANKS 4.0 software may be used for estimating emissions from small tanks. TANKS 4.0 is a software package that requires more detailed information such as the physical characteristics of the storage tanks, typical atmospheric conditions (such as wind speeds and temperatures), the contents of the tank and throughput.

For large tanks (ie. greater than 30 tonnes capacity) the TANKS 4.0 model should be used for emissions estimation.

The *Emission Estimation Technique Manual for Alumina Refining* (Section 6.5.1) provides emission estimation techniques for fugitive emissions from the storage of acids.

3.11   Liquid Spills

3.11.1 Description

Liquid spills can occur in any facility using liquids. For volatile liquids these spills can be separated into air emissions (light end evaporation losses) and land releases (remaining heavy ends).

3.11.2 Emissions Estimation Coverage under the NPI

The *Emission Estimation Technique Manual for Organic Chemical Processing Industries* (Section 9.2) provides emission estimation techniques for liquid spills.

4.0 Glossary of Technical Terms and Abbreviations

ANZSIC   Australian and New Zealand Standard Industrial Classification

CEMS   Continuous Emission Monitoring System

CO   Carbon Monoxide

Dry Cell   A primary cell in which the electrolyte exists in the form of a paste or is absorbed in a porous medium, or is otherwise restrained from flowing from its original position.

EEA   European Environment Agency

EET   Emission Estimation Technique

EFR   Emission Factor Rating

n.e.c.   Not elsewhere classified

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

STP   Standard Temperature and Pressure (0°C and $101.3 * 10^3$ Pa)

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 Particulates

USEPA   United States Environmental Protection Agency

VOC   Volatile Organic Compound

5.0   References

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The following Emission Estimation Technique Manuals referred to in this Manual are available at the NPI Homepage (www.npi.gov.au), and from your local environmental protection agency:

- *Emission Estimation Technique Manual for Alumina Refining;*
- *Emission Estimation Technique Manual for Combustion Engines;*
- *Emission Estimation Technique Manual for Combustion in Boilers;*
- *Emission Estimation Technique Manual for Electroplating and Anodising;*
- *Emission Estimation Technique Manual for Ferrous Foundries;*
- *Emission Estimation Technique Manual for Fugitive Emissions;*
- *Emission Estimation Technique Manual for Galvanising;*
- *Emission Estimation Technique Manual for Glass & Glass Fibre Manufacturing*;
- *Emission Estimation Technique Manual for Motor Vehicle Manufacturing;*
- *Emission Estimation Technique Manual for Non Ferrous Foundries;*
- *Emission Estimation Technique Manual for Organic Chemical Processing Industries*;
- *Emission Estimation Technique Manual for Petroleum Refining;*
- *Emission Estimation Technique Manual for Sewage and Wastewater Treatment;*
- *Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture;* and
- *Emission Estimation Technique Manual for Surface Coating.*

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*.

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.

The **usage**[a] of each of the substances listed as Category 1 and 1a under the NPI must be estimated to determine whether the 10 tonnes (or 25 tonnes for VOCs) reporting threshold is exceeded. If the threshold is exceeded, **emissions** of these Category 1 and 1a substances must be reported for all operations/processes relating to the facility, even if the actual emissions of the substances are very low or zero.

[a] Usage is defined as meaning the handling, manufacture, import, processing, coincidental production or other uses of the substances.

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 5. 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

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

where:

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

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	=	stack gas volumetric flow rate at actual conditions, 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 5 - Stack Sample Test Results

Parameter	Symbol	Test 1	Test 2	Test 3
Total sampling time (s)		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 5, and an exhaust gas temperature of 150°C (423 K)).

C_{PM}	=	$C_f / V_{m, STP}$
	=	0.0851 / 1.185
	=	0.072 g/m^3

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

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 it may 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.

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

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.

Table 6 presents an example of CEMS data output for three periods for a hypothetical furnace. The output includes pollutant concentrations in parts per million dry basis (ppm$_{vd}$), diluent (O_2) concentrations in percent by volume dry basis (%v, d) and gas flow rates; and includes 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 6 - Example of CEMS Output for a Hypothetical Furnace Firing Waste Fuel Oil

Time	O₂ content	Concentration				Gas Flow Rate (Q)	Production Rate of Product (A)
	% by volume	SO₂ (ppm$_{vd}$)	NO$_x$ (ppm$_{vd}$)	CO (ppm$_{vd}$)	VOC (ppm$_{vd}$)	m³/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	=	stack gas volumetric flow rate at actual conditions, m³/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), m³/kg-mole
T	=	temperature of gas sample, °C
10^6	=	conversion factor, ppm.kg/kg

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 summing 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 5.

Equation 7

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

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	=	clinker 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 6, and an exhaust gas temperature of 150°C (423 K).

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

For Time Period 2, also at 150°C

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

For Time Period 3, also at 150°C

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

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:

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

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

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

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/yr for solids, L/yr 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 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 bio degraded 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

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

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/m³ of fuel burned*', then the activity data required would be in terms of '*m³ 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 $\pm$ 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 which the factor was derived.

The EFR system is as follows:

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

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	$E_{kpt,i}$	kilograms 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	^{o}Celsius (^{o}C) or Kelvin (K)
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%	%