National Pollutant Inventory

Emission Estimation Technique Manual

for

Non-Ferrous Metal Manufacture
Version 1.1

Environment Australia

First published December 1999
Version 1.1 – 9 October 2001

ISBN: 0 6425 46983

www.npi.gov.au

This manual may be reproduced in whole or part for study or training purposes subject to the inclusion of an acknowledgment of the source. It may be reproduced in whole or part by those involved in estimating the emissions of substances for the purpose of National Pollutant Inventory (NPI) reporting. The manual may be updated at any time. Reproduction for other purposes requires the written permission of Environment Australia, GPO Box 787, Canberra, ACT 2601, e-mail npi@ea.gov.au, internet address www.npi.gov.au or phone 1800 657 945.

Disclaimer

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

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

Erratum for Non-ferrous Metal Manufacture EET Manual (Version 1.1 – October 2001).

Page	Outline of alteration
1	Reformatted cover page to include EA logo, corrected header and footer info throughout the document (to make document consistent with other Version 1.1 EET Manuals).

EMISSION ESTIMATION TECHNIQUES
FOR
NON-FERROUS METAL MANUFACTURING

TABLE OF CONTENTS

NON-FERROUS METAL MANUFACTURE

LIST OF FIGURES, 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 Non-Ferrous Metal Manufacturing.

EET MANUAL: Non-Ferrous Metal Manufacture

HANDBOOK: Basic Non-Ferrous Metal Manufacture

ANZSIC CODES: 2729

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

Industry Sectors covered by this Manual

This Manual applies to facilities involved in the following activities:

- Tin Smelting;
- Silicon Smelting;
- Non-Ferrous Metals recovery from waste materials;
    - Secondary Aluminium Processing
    - Secondary Copper Smelting & Copper Alloys (Brass & Bronze) Manufacturing
    - Secondary Lead Processing
    - Secondary Magnesium Smelting
    - Secondary Zinc Processing
- Non-Ferrous Alloy Manufacture;
- Solder Manufacture;
- Non-Ferrous Welding Rod Manufacture;

Exclusions from this Manual

The following non-ferrous have not been included in this Manual:

- Antimony Refining
- Gold Refining
- Bismuth Smelting/Refining
- Magnesium Smelting
- Molybdenum Metal Powder Manufacture
- Tantalum Metal Powder Manufacture

Nickel smelting has been previously covered by the NPI in the *Emission Estimation Technique Manual for Nickel Concentration, Smelting and Refining*.

This Manual does not include activities involving the pouring of metals into sand moulds as these are covered in the *Emission Estimation Technique Manual for Ferrous Foundries* and *Emission Estimation Technique Manual for Non-Ferrous Foundries.*

1.1 Manual Structure

This Manual is structured as follows:

- **Section 2.0** summarises the NPI-listed substances, which trigger, or are likely to trigger reporting for the non-ferrous metal manufacturing industry. Category 1, 2 and 3 substances are discussed in **Sections 2.1.1, 2.1.2** and **2.1.3** respectively.
- **Section 3.0** provides a brief introduction to the non-ferrous metal manufacturing industry. This section also details the expected emissions to air, water and land respectively from the non-ferrous metal manufacturing process, the sources of these emissions and where emission estimation techniques for each of these sources are to be found.
- **Section 4.0** provides a glossary of technical terms and abbreviations used in this Manual.
- **Section 5.0** 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 non-ferrous metal 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 throughout this Manual.

1.2 Manual Application

Context and use of this Manual

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 non-ferrous metal manufacturing facilities. In some cases there will necessarily be a large potential error due to inherent assumptions in the various emissions estimation techniques (EETs).

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:

Category 1 and 1a Substances:

Identify which reportable NPI substances are used (or handled by way of their incidental presence in ore or materials, or exceeds the bulk storage capacity for Category 1a substances), and determine whether the amounts used or handled are above the 'threshold' values and therefore trigger reporting requirements. See **Section 2.1.1** of this Manual for guidance on which Category 1 substances are likely to require reporting for the non-ferrous metal manufacturing industry.

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. See **Section 2.1.2** of this Manual for a discussion which Category 2 substances are likely to be triggered for the non-ferrous metal manufacturing industry.

Category 3 Substances:

Determine the annual emissions to water and assess whether the threshold limits are exceeded. It is unlikely that this NPI Category will require reporting for the non-ferrous metal manufacturing industry.

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 Reporting Thresholds

2.1.1 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 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 substance, then the facility must report emissions from all operations/processes relating to the facility, even if actual emissions are very low or zero.

The triggering of the Category 1 threshold is a highly site-specific issue for the non-ferrous metal manufacturing industry. Each facility needs to carefully examine:

- The amount of Category 1 substances used or produced at a facility; and
- The amount of Category 1 substances (particularly metals) contained within raw materials and substances used at a facility.

If a facility has information regarding the composition of its raw materials, the procedure outlined in Example 1 may be followed to determine whether the Category 1 threshold is triggered.

Example 1 - Category 1 Threshold

An analysis of the coal used at a silicon smelting facility shows that there is 0.0006 % by weight of lead present in the coal. The facility uses approximately 15 000 tonnes of coal per year. Is the Category 1 threshold for lead exceeded?

The total lead input from the coal is:

$$\frac{0.0006\text{ kg lead}}{100\text{ kg coal}} * \frac{1000\text{ kg coal}}{\text{t coal}} * \frac{15\,000\text{ t coal}}{\text{yr}} = \frac{90\text{ kg lead}}{\text{yr}}$$

This is significantly lower than the Category 1 reporting threshold of 10 tonnes per year. However, it should be noted that this analysis has only been performed on the coal which is input into the process. Other raw materials input to the process may also contain lead and, therefore, these ores should be analysed for lead in a similar manner, to determine whether the threshold is exceeded for the facility.

2.1.2 Category 2

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

- 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 in a year; 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 1). 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 may be found in Table 1.

Table 1 - 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/m^3 at 15^{o}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^{o}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^{o}C for fuel oil for commercial use (Perry, et al., 1997)

[f] Assuming a gross heating value of 50.4 MJ/kg at 25^{o}C and 101.325 kPa (Lide, 1994).

[g] Assuming a gross heating value of 49.6 MJ/kg at 25^{o}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, then all Category 2a and Category 2b pollutants need to be reported. The Category 2 substances are listed in Table 2.

Table 2 - 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 (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 & Furans
	PLUS all Category 2a substances

2.1.3 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-ferrous metal 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.

3.0 Processes and Emissions

3.1 Primary Smelting/Refining Operations

3.1.1 Tin Smelting

Tin smelting and refining processes commonly consist of the following components:

- Tin concentrate handling;
- Roasting (where removal of impurities is required);
- Primary furnace;
- Secondary furnace (if primary dross is remelted);
- Refining kettles; and
- Kettle dross liquator.

Figure 1 provides an overview of the various components in the tin smelting/refining process. Some variations on this general overview are likely to exist (eg some facilities may not have secondary furnaces).

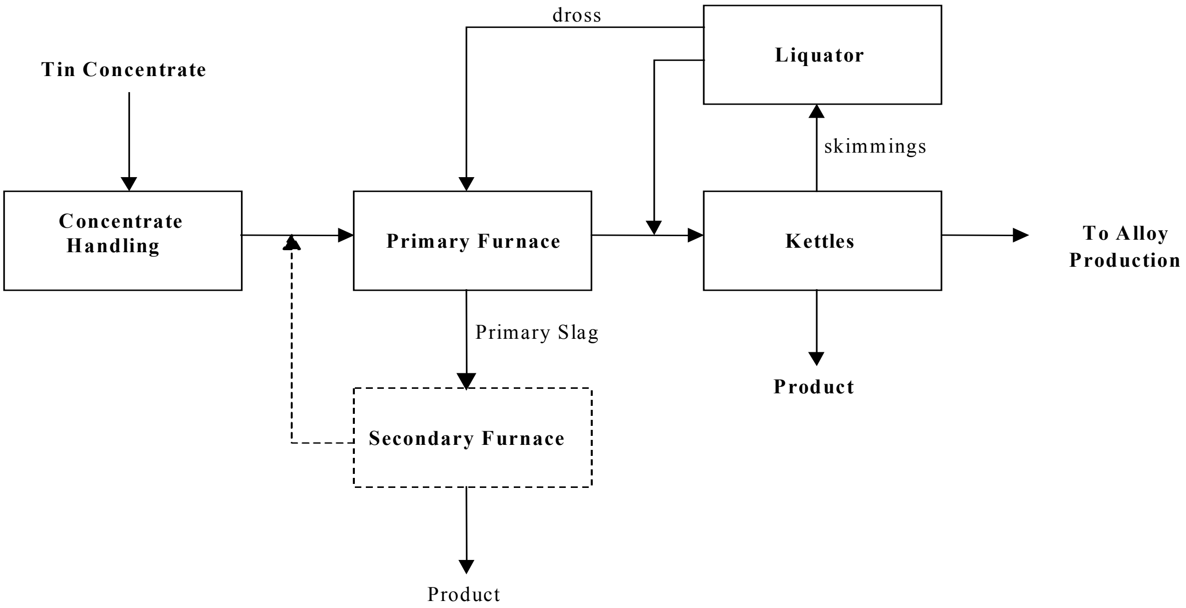

Figure 1 - Overview of the Tin Smelting Process

3.1.2 Silicon Smelting

Silicon smelting and refining typically involves the addition of silica (in the form of quartz or quartzite) and carbon (in the form of coal, charcoal, coke and/or wood chips) to a submerged electric arc furnace. The molten silicon is then refined in the ladle by the addition of air and oxygen to the ladle resulting in high grade (>98.5%) silicon. An overview of the process is presented in Figure 2. Some variations on this general overview are likely to exist.

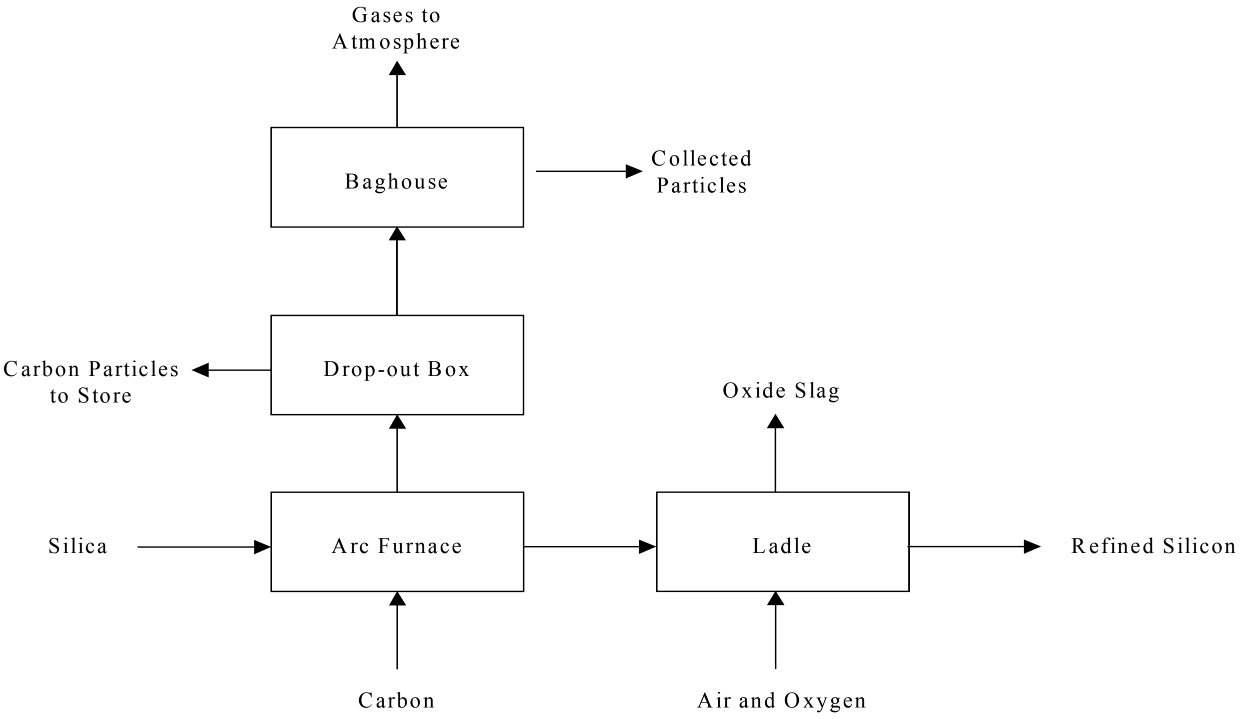

Figure 2 - Overview of the Silicon Smelting Process

3.1.3 Emissions to Air and Estimation Techniques

Table 3 identifies the various potential sources of emissions to air associated with the tin and silicon smelting/refining industries and provides guidance on the emission estimation techniques, which can be utilised to characterise emissions. It should be noted that the table provides a complete listing of the units that may be used in these processes. You should only use the parts of the table that are relevant to your process.

The processes that are most likely to trigger and emit NPI substances are the incineration and furnace operations.

Table 3 - Potential Emissions to Air from Primary Smelting/Refining Operations for Tin & Silicon

Process	Potential NPI Emission	Recommended Emission Estimation Techniques
Materials Handling • Bulldozers • Trucks • Wheel generated dust • Scrapers • Truck loading/unloading of stockpiles • Shaping of stockpiles by excavators • Front end loader operation • Delivery to dump hopper • Conveyer to screens, crusher and storage bins • Miscellaneous transfer points • Wind erosion from stockpiles • General handling	PM_{10} CO NO_x SO_x VOCs Boron & compounds Cobalt & compounds Manganese & compounds Zinc & compounds **Plus Category 2b substances**	The *Emission Estimation Technique Manual for Mining* (Section 4.4) provides emission estimation techniques for PM_{10} emissions from these activities. Note that there are also motor vehicles exhaust emissions associated with materials receipt and handling. The *Emission Estimation Technique Manual for Mining* (Section 4.6) discusses these emissions. Appendix B of the *Emission Estimation Technique Manual for Mining* provides guidance on the speciation of particulate emissions and provides default speciation profiles, which can be used in the absence of other information.

Table 3 - Potential Emissions to Air from Primary Smelting/Refining Operations for Tin & Silicon cont'

Process	Potential NPI Emission	Recommended Emission Estimation Techniques
Smelting & Refining Furnace Operations • Electric arc furnaces • Roasting furnaces • Sweating furnaces/Liquator • Reverberatory furnaces • Retort furnaces • Incinerators • Refining kettles/pots	PM_{10} CO NO_x SO_x VOCs Boron & compounds Cobalt & compounds Manganese & compounds Zinc & compounds **Plus Category 2b substances**	Direct sampling or continuous emission monitoring data will provide the most accurate data for emissions estimation from point sources. It is likely that, for many facilities, such sampling will already be required as part of license conditions or other regulatory requirements. Guidance on the use of monitoring data for NPI reporting is provided in **Appendix A.1** of this Manual. Emissions from fuel fired furnaces can be characterised using the emission estimation techniques provided in the *Emission Estimation Technique Manual for Combustion in Boilers.* Furnaces can also have significant fugitive emissions. Such emissions can be extremely difficult to characterise. Guidance on the characterisation of fugitive emissions is provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.* Table 4 of this Manual provides some default values from assays of fume emissions from tin smelting furnaces.
Tapping & Casting Operations • Furnace tapping operations • Ladles • Casting/Pouring	PM_{10} CO NO_x SO_x VOCs Boron & compounds Cobalt & compounds Manganese & compounds Zinc & compounds **Plus Category 2b substances**	There is limited data on the emissions from tapping and casting operations for non-ferrous metal operations. **Appendix A** of this Manual provides general guidance on emission estimation techniques that may be of use when characterising these emissions.

Table 3 - Potential Emissions to Air from Primary Smelting/Refining Operations for Tin & Silicon cont'

Process	Potential NPI Emission	Recommended Emission Estimation Techniques
Ancillary Operations • Maintenance Workshops • Saw Mills • Wastewater Treatment • Combustion Activities	PM_{10} VOCs **Category 2a & 2b substances**	Emissions from maintenance workshops will mostly consist of PM_{10} & VOCs from metalworking, vehicle operation and storage of solvents and acids. These activities are addressed in the following NPI Manuals: • *Emission Estimation Technique Manual for Structural & Fabricated Metal Product Manufacture;* (Section 3.1) • *Emission Estimation Technique Manual for Surface Coating;* (Section 3) • *Emission Estimation Technique Manual for Combustion Engines;* (Section 3.4) • *Emission Estimation Technique Manual for Alumina Refining;* (Section 6.5.1) Guidance on characterising emissions from combustion activities is provided in the *Emission Estimation Technique Manual for Combustion Engines* and the *Emission Estimation Technique Manual for Combustion in Boilers.* The *Emission Estimation Technique Manual for Timber & Wood Product Manufacturing* provides guidance on estimating emissions from saw milling activities. The *Emission Estimation Technique Manual for Sewage and Wastewater Treatment* provides guidance on estimating emissions from wastewater treatment operations.

There is limited published data on emissions from tin smelters. Table 4 provides data from one tin smelter. If facility-specific data is unavailable, the information provided in this table can be used to speciate particulate data, for NPI reporting.

Table 4 - Typical Fume Assays from Tin Smelter Processes with Impurities in Feed Ore

Compound	Roasting Fume		Primary Furnace Fume	
	Cassiterite Roasting	Stibio-tantalite Roasting	Reverberatory[b]	Submerged Arc
Tin	12.5%[a]	14.3%	55%	68%
Antimony	40%	55.6%	0.25%	4.8%
Arsenic	12%	0.64%	0.4%	0.16%
Lead	ND	ND	0.9%	ND
Copper	ND	ND	0.035%	ND
MgO	ND	ND	<0.6%	ND

Source: Gwalia, 1996.

[a] Where a range was given in the original source (Gwalia, 1996), the mid-range value is shown.

[b] Ullmann (1996). Where a range for the flue gas was given, the mid-range value is shown in this table.

ND = no data.

3.2 Secondary Metal Processing and Alloy Production

3.2.1 Description

Secondary Metal Processing and Alloy Production covers the recovery of copper, aluminium, lead, tin, zinc and magnesium from waste materials. While these processes vary, depending on the specific materials being processed, they all generally consist of the following operations:

- Raw material handling;
- Scrap pretreatment;
- Melting;
- Refining; and
- Forming/casting.

Raw Material Handling

Raw material handling operations include receiving, unloading, storing and conveying the metallic materials and processing materials such as fluxes, alloys and fuels. The specific raw material handling operations vary depending on the type of metal being recovered. For example, the raw material sources of secondary copper include machine shop punchings, turnings and borings, defective or surplus goods from manufacturers, automobile radiators, pipes, wires, bushings and bearings as well as metallurgical process skimming and drosses. Other metals will have different feedstock and different fuels and fluxes.

Scrap Pretreatment

Scrap metals consist of material such as old appliances, pipes and metal components, automobile parts, and also byproducts or waste from process operations such as slag. These materials all have varying physical and chemical properties. Pretreatment basically involves separating the metal of interest from other metals and removing unwanted materials like dirt, oil, plastics and paint. There are a number of different methods used.

- Solvent Cleaning;
- Centrifugation;
- Pyrometallurgical Cleaning;
- Hydrometallurgical Cleaning; and
- Heavy Media Separation.

Melting

Melting is used to refine and allow alloying of metals. Impurities can be removed from the molten material as slag. The melting process occurs in furnaces or heated crucibles. The pretreated scrap, fuels and fluxes are charged to the furnace where chemical reduction occurs as the fluxes break metallic-oxide bonds to produce pure metals. Oxidation of impurities also purifies the metal further.

Refining

This is the process where the metal is further purified. Refining is conducted in either melting furnaces or in holding furnaces or other heated vessels. Materials such as air or chlorine are added to remove impurities by oxidising or chemically reacting with impurities. Alloying can also occur during the refining process. This is simply melting of another material with the molten metal to produce the alloyed product. Distillation is also used as a refining method for secondary zinc processing, where the zinc is vaporised from the melt and condensed under various conditions to produce varying zinc products depending on temperature, recovery time, oxygen presence and equipment used.

Metal Forming/Casting

The final product of these recovered metals is usually sold as ingots, bars or sometimes is a final cast product. These are cast into permanent moulds.

3.2.2 Emissions to Air and Estimation Techniques

A range of NPI-listed substances is produced from secondary metal processing operations. Table 5 identifies the various emissions to air associated with secondary metal processing operations. Guidance on emission estimation techniques is also provided in the table.

Table 5 - Emissions to Air from Secondary Metal Processing Operations

Process	Potential NPI Emissions	Recommended Emission Estimation Techniques
Raw Materials Handling • Receiving; • Unloading; • Storing and conveying metallic materials; and • Processing materials such as fluxes, alloys, fuels.	PM_{10} VOCs	PM_{10} emissions are produced during the handling of scrap and flux materials. There is limited published information on emission from materials handling activities. For the stockpiling of material, Section 4.2 of the *Emission Estimation Technique Manual for Mining* may be used as a starting point for emissions estimation. VOCs may be released from fuels and solvent storage. The *Emission Estimation Technique Manual for Fuel & Organic Liquid Storage* provides guidance on estimation of emissions from fuel and solvent storage.
Scrap Pretreatment • Solvent cleaning; • Centrifugation; • Pyrometallurgical cleaning; • Hydrometallurgical cleaning; • Heavy media separation.	PM_{10} VOCs CO NO_x SO_x HCl Sulfuric Acid Chlorides Fluorides **Plus Category 2b substances**	VOC emissions from solvent cleaning operations can be estimated using the emission estimation techniques presented in Section 3.3 of the *Emission Estimation Technique Manual for Surface Coating.* Emissions from fuel combustion during preheating processes for pyrometallurgical cleaning can be estimated using to the *Emission Estimation Technique Manual for Combustion in Boilers.* **Section 3.4** of this Manual also provides general guidance on estimating PM_{10} and VOC emissions with pollution control equipment. Direct sampling or continuous emission monitoring data will provide the most accurate data for emissions estimation from point sources. It is likely that, for many facilities, such sampling will already be required as part of license conditions or other regulatory requirements. Information on the use of monitoring data for NPI reporting is provided in **Appendix A.1** of this Manual.
Pretreatment • Crushing; • Milling; • Screening; • Grinding; • Drying; • Classifying.	PM_{10}	Crushing, milling, screening, classifying and drying operations can lead to emissions of $PM_{10.}$ Emissions from these processes can be estimated using the metallic mineral processing emission factors that are provided in the material handling, crushing/grinding and drying sections of the *Emission Estimation Technique Manual for Non-Metallic Mineral Product Manufacture.*

Table 5 - Emissions to Air from Secondary Metal Processing Operations (cont)

Process	Potential NPI Emissions	Recommended Emission Estimation Techniques
Melting - Furnaces - Heated crucibles - Cupolas	PM_{10} VOCs CO NO_x SO_x HCl Sulfuric Acid Chlorides Fluorides Metals (eg. lead) **Plus Category 2b substances**	Direct sampling or continuous emission monitoring data will provide the most accurate data for emissions estimation from point sources. It is likely that, for many facilities, such sampling will already be required as part of license conditions or other regulatory requirements. Information on the use of monitoring data for NPI reporting is provided in **Appendix A.1** of this Manual. **Section 3.2.3** of this Manual provides emission factors for equipment used for metal melting operations (primary smelting) in the secondary metal processing industry. The available emissions factors are for: • Secondary Aluminium: PM_{10} emissions (Table 6) • Secondary Copper & Alloys: PM_{10} (point & fugitive sources) & lead emissions (Table 7). • Secondary Lead: PM_{10} emissions (point & fugitive sources), lead emissions (point & fugitive sources), and SO_2 emissions (Table 8, Table 9, Table 10, & Table 11). • Secondary Magnesium: PM_{10} emissions (Table 13). • Secondary Zinc: PM_{10} emissions – point & fugitive sources (Table 14 & Table 15). Section 5.0 of the *Emission Estimation Technique Manual for Non-Ferrous Foundries* also provides emission factors for: • Secondary Copper & Alloys: PM_{10} emissions - point & fugitive sources, lead, copper, NO_x, fluoride, hexane, toluene and benzene emissions. • Secondary Zinc: PM_{10} - point & fugitive emissions. • Secondary Lead: SO_2 & NO_x emissions. Emissions from combustion sources can be estimated using the *Emission Estimation Technique Manual for Combustion in Boilers.* **Section 3.4** of this Manual provides guidance on estimating PM_{10} and VOC emissions when pollution control equipment is in place and operating.

Table 5 - Emissions to Air from Secondary Metal Processing Operations (cont)

Process	Potential NPI Emissions	Recommended Emission Estimation Techniques
Refining - Sweating Furnaces - Kettles - Melting Pots	PM_{10} VOCs CO NO_x SO_x HCl Sulfuric Acid Chlorides Fluorides Metals (eg. lead) **Plus Category 2b substances**	Direct sampling or continuous emission monitoring data will provide the most accurate data for emissions estimation from point sources. It is likely that, for many facilities, such sampling will already be required as part of license conditions or other regulatory requirements. Information on the use of monitoring data for NPI reporting is provided in **Appendix A.1** of this Manual. **Section 3.2.3** of this Manual presents emission factors for equipment used for metal refining operations in the secondary metal processing industry. The available emission factors are shown for: - Secondary Aluminium: PM_{10} emissions (Table 6). - Secondary Lead: PM_{10} emissions (point & fugitive sources), lead emissions (point & fugitive sources), and SO_2 emissions (Table 8, Table 9, Table 10, & Table 11). - Secondary Zinc: PM_{10} emissions (point & fugitive sources) (Table 14 & Table 15) Section 5.0 of the Emission Estimation Technique Manual for Non-Ferrous Foundries also provides emission factors for: - Secondary Copper & Alloys: PM_{10} emissions (point & fugitive sources), lead, copper, NO_x, fluoride, hexane, toluene and benzene emissions. - Secondary Zinc: PM_{10} emissions (point & fugitive sources). - Secondary Lead: SO_2 & NO_x emissions. **Section 3.4** of this Manual provides guidance on estimating PM_{10} and VOC emissions when pollution control equipment is in place and operating.

Table 5 - Emissions to Air from Secondary Metal Processing Operations (cont)

Process	Potential NPI Emissions	Recommended Emission Estimation Techniques
Metal Forming/Casting	PM_{10} VOCs CO Metals (eg. lead)	**Section 3.2.3** of this Manual presents emission factors for equipment used for metal forming & casting operations in the secondary metal processing industry. The available emission factors are for: • Secondary Lead: PM_{10} emissions (point & fugitive sources), lead emissions (point & fugitive sources), and SO_2 emissions (Table 8 Table 9, Table 10, & Table 11). • Secondary Zinc: PM_{10} emissions (Point & Fugitive sources) (Table 14 & Table 15). Section 5.0 of the Emission Estimation Technique Manual for Non-Ferrous Foundries also has emission factors for: • Secondary Copper & Alloys: PM_{10} (point & fugitive sources), lead, copper, NO_x, fluoride, hexane, toluene and benzene emissions. • Secondary Zinc: PM_{10} emissions (point & fugitive sources). • Secondary Lead: SO_2 & NO_x emissions.

Source: Eastern Research Group, 1998.

3.2.3 Emission Factors for Secondary Metal Processing and Alloy Production

3.2.3.1 Secondary Aluminium Operations

Table 6 provides emission factors for the melting and refining operations in secondary aluminium operations. Other NPI-listed substances such as antimony, cobalt, cadmium, chlorine and compounds of manganese, lead, nickel and chromium are also released as air emissions from secondary aluminium plants but there are no emissions data available for these emissions.

Table 6 - PM_{10} Emission Factors for Secondary Aluminium Operations

Operation	**Emission Factors**			**Units**	**Emission Factor Rating**
	Uncontrolled	**Baghouse**	**ESP**		
Sweating Furnace	7.25[a]	1.65[a]	ND	kg/tonne of metal processed	E
Smelting Crucible Furnace	0.95[a]	ND	ND	kg/tonne of metal processed	E
Reverberatory Furnace	2.15[a]	0.65[a]	0.65[a]	kg/tonne of metal processed	E
Chlorine demagging	266	25[a]	ND	kg/tonne of chlorine used	E
Refining	1.3	ND	ND	kg/tonne of metal processed	E

Source: USEPA, 1986a.

[a] Emission factors are given as total PM. If size distribution data is not available, for the purposes of NPI reporting, total PM can be assumed to be the same as PM_{10}.

ND = No data.

3.2.3.2 Secondary Copper Smelting Operations

Table 7 provides emission factors for PM_{10} and lead for furnaces in secondary copper and alloying operations. The PM_{10} emissions will include NPI-listed substances such as lead, nickel and cadmium. In the absence of other information it can be assumed that these metals will be present in the emitted particulate matter in the same proportion as in the scrap.

Table 7 - PM$_{10}$ & Lead Emission Factors for Furnaces used in Secondary Copper Smelting and Alloying Processing

Furnace & Charge Type	Control Equipment	Emission Factor (kg/tonne of ore processed)		Emission Factor (kg/tonne of product)	
		PM$_{10}$	Rating	Lead	Rating
Cupola					
Scrap Iron	None	0.002	B	ND	NA
Insulated Copper Wire	None	105.6	E	ND	NA
	ESP	5[a]	B	ND	NA
Scrap Copper & Brass	None	32.1	E	ND	NA
	ESP	1.2[a]	B	ND	NA
Fugitive Emissions	None	1.1	E	ND	NA
Reverberatory Furnace					
High Lead Alloy (58%)	None	ND	NA	25	B
Red/Yellow Brass	None	ND	NA	6.6	B
Other Alloy (7%)	None	ND	NA	2.5	B
Copper	None	2.5	E	ND	NA
	Baghouse	0.2[a]	B	ND	NA
Brass & Bronze	None	10.8	E	ND	NA
	Baghouse	1.3[a]	B	ND	NA
Fugitive Emissions	None	1.5	E	ND	NA
Crucible & Pot Furnace					
Brass & Bronze	None	6.2	E	ND	NA
	ESP	0.5[a]	B	ND	NA
Fugitive Emissions	None	0.14	E	ND	NA
Electric arc Furnace					
Copper	None	2.5	E	ND	NA
	Baghouse	0.5[a]	B	ND	NA
Brass & Bronze	None	3.2	E	ND	NA
	Baghouse	3[a]	B	ND	NA
Electric Induction					
Copper	None	3.5	E	ND	NA
	Baghouse	0.25[a]	B	ND	NA
Brass & Bronze	None	10	E	ND	NA
	Baghouse	0.35[a]	B	ND	NA
Fugitive Emissions	None	0.04	E	ND	NA
Rotary Furnace					
Brass & Bronze	None	88.3	E	ND	NA
	ESP	7[a]	B	ND	NA
Fugitive Emissions	None	1.3	E	ND	NA

Source: USEPA, 1994

[a] Where no data is available for PM$_{10}$ emissions, the emission factor for total particulate has been given. In the absence of site-specific speciation data, this information can be used as an estimate of PM$_{10}$ emissions.

ESP = Electrostatic precipitator.

ND = No data.

NA = Not applicable.

3.2.3.3 Secondary Lead Processing Operations

It should be noted that the emission factors presented for secondary lead processing operations are for the processing of lead and may not be relevant to the processing of alloy materials. Table 8 provides emission factors for fugitive emissions of PM_{10} and lead from processes in secondary lead operations. These emission factors are based on the assumption that fugitive emissions equate to 5% of the stack emissions (USEPA, 1986b, Table 12.11-4).

Table 9, Table 10 and Table 11 provide emission factors for emissions of PM_{10}, lead and SO_2 from smelting, refining and casting processes in secondary lead operations. The emission factors for SO_2 in Table 11 are taken from USEPA data (USEPA, 1986b, Table 12.11-1). This data may be based on the re-melting of high sulfur scrap materials such as lead-acid batteries. If facility can justify their scrap materials as having a low sulfur content, then it is likely that the primary source of SO_2 emissions will be fuel combustion.

Table 12 provides emission factors for a number sources of lead from miscellaneous lead products. The main source of the lead release from these processes is the melting pot.

Table 8 - Fugitive Emissions Factors for Secondary Lead Processing

Operation	Emission Factors		Units	Emission Factor Rating
	PM_{10}[a]	Lead		
Sweating[a]	1.3[b]	0.55[b]	kg/tonne of material charged to furnace	E
Smelting[a]	8.2[b]	0.2[b]	kg/tonne of metal product	E
Kettle Refining[a]	0.001	0.0003	kg/tonne of metal product	E
Casting[a]	0.001	0.0004	kg/tonne of metal product	E

Source: USEPA, 1986b.

[a] Emission factors are given as total PM. If size distribution data is not available, for the purposes of NPI reporting, total PM can be assumed to be the same as PM_{10}.

[b] Where a range was shown in original table (AP-42 Table 12.11-3), the mean value of the range is provided.

[c] Fugitive emissions estimated to be 5% of uncontrolled stack emissions (USEPA, 1986a, Table 12.11-4).

Table 9 - PM_{10} Emission Factors for Secondary Lead Processing

Process	Units	Emission Factors			
		Uncontrolled $PM_{10}^{b,\,d}$	Emission Factor Rating	Controlled $PM_{10}^{c,\,d}$	Emission Factor Rating
Sweating	kg/tonne of material charged to furnace	25.5[e]	E	ND	NA
Reverberatory Smelting	kg/tonne of metal product	162	C	0.5	C
Blast smelting-cupola[a]	kg/tonne of metal product	153	C	1.12	C
Kettle refining	kg/tonne of metal product	0.02	C	ND	NA
Kettle oxidation	kg/tonne of metal product	20	E	ND	NA
Casting	kg/tonne of metal product	0.02	C	ND	NA

Source: USEPA, 1986b.

[a] Combined flue gases and associated ventilation hood streams (charging and tapping).

[b] Emission factors represent emissions without control technology.

[c] Emission factors represent emissions with control technology.

[d] Emission factors are given as total PM. If size distribution data is not available, for the purpose of NPI reporting, total PM can be assumed to be the same as PM_{10}.

[e] Where a range was shown in original table (AP-42 Table 12.11-1), the mean value of the range is provided.

ND = No data.

NA = Not applicable.

Table 10 - Lead Emission Factors for Secondary Lead Processing

Process	Units	Emission Factors			
		Uncontrolled Lead [b]	Emission Factor Rating	Controlled Lead [c]	Emission Factor Rating
Sweating	kg/tonne of material charged to furnace	6 [d]	E	ND	NA
Reverberatory Smelting	kg/tonne of metal product	32	C	ND	NA
Blast smelting-cupola[a]	kg/tonne of metal product	52	C	0.15	C
Kettle refining	kg/tonne of metal product	0.006	C	ND	NA
Kettle oxidation	kg/tonne of metal product	ND	NA	ND	NA
Casting	kg/tonne of metal product	0.007	C	ND	NA

Source: USEPA, 1986b.

[a] Combined flue gases and associated ventilation hood streams (charging and tapping).

[b] Emission factors represent emissions without control technology.

[c] Emission factors represent emissions with control technology.

[d] Where a range was shown in original table (AP-42 table 12.11-1), the mean value of the range is provided.

ND = No data.

NA = Not applicable.

Table 11 - SO_2 Emission Factors for Secondary Lead Processing

Process	Units	Emission Factor	
		Uncontrolled [b] SO_2	Emission Factor Rating
Sweating	kg/tonne of material charged to furnace	ND	NA
Reverberatory Smelting	kg/tonne of metal product	40	C
Blast smelting-cupola[a]	kg/tonne of metal product	27	C
Kettle refining	kg/tonne of metal product	ND	NA
Kettle oxidation	kg/tonne of metal product	ND	NA
Casting	kg/tonne of metal product	ND	NA

Source: USEPA, 1986b.

[a] Combined flue gases and associated ventilation hood streams (charging and tapping).

[b] Emission factors represent emissions without control technology.

ND = No data.

NA = Not applicable.

Table 12 - Emission Factors for Miscellaneous Sources

Lead Products	Emission Factors (kg/tonne lead processed)			
	PM_{10}[a]	Emission Factor Rating	Lead	Emission Factor Rating
Type Metal Production	0.4[b]	C	0.13	C
Cable Covering	0.3	C	0.25	C
Metallic Lead Products:				
Ammunition	ND	NA	0.5	C
Bearing Metals	ND	NA	negligible	NA
Other Sources of Lead	ND	NA	0.8	C

Source: USEPA, 1995b.

[a] Emission factors are given as total PM. If size distribution data is not available, then for the purpose of NPI reporting total PM can be assumed to be the same as PM_{10}.

[b] Calculated on the basis of 35% of the total.

ND = No data.

NA = Not applicable.

3.2.3.4 Secondary Magnesium Smelting Operations

Table 13 shows the emission factor for PM_{10} from secondary magnesium smelting. Other emissions from magnesium smelting include magnesium oxide, NO_x, CO and possibly others depending on the types of fluxes that are used. However, there is no published emissions estimation data for these.

Table 13 - PM_{10} Emission Factors for Secondary Magnesium Smelting

Type of Furnace	Emission Factor (kg/tonne of metal processed)	
	PM_{10}[a]	Emission Factor Rating
Pot Furnace		
Uncontrolled[b]	2	C
Controlled[c]	0.2	C

Source: USEPA, 1994.

[a] Emission factors are given as total PM. If size distribution data is not available, then for the purpose of NPI reporting total PM can be assumed to be the same as PM_{10}.

[b] Emission factors represent emissions without control technology.

[c] Emission factors represent emissions with control technology.

3.2.3.5 Secondary Zinc Processing Operations

Sweating and melting operations release emissions of particulate matter, zinc fumes, other volatile metals, flux fumes and smoke from incomplete combustion of grease, rubber, plastic and carbonaceous materials. Crushing and screening operations also release dust emissions consisting of zinc, aluminium, copper, lead, cadmium and chromium. Table 14 provides emission factors for PM_{10} from the processes involved in secondary zinc smelting operations.

Fugitive emissions from secondary zinc operations are provided in Table 15. Estimates are based on stack emission factors, assuming fugitive emissions to be equal to 5% of stack emissions (USEPA, 1981, Table 12.14-3).

Table 14 - PM_{10} Emission Factors for Secondary Zinc Melting

Operation	Units	Emission Factors	
		Uncontrolled PM_{10}[a, d]	Emission Factor Rating
Reverberatory sweating	mg/tonne of feed material		
Clean Metallic Scrap		Negligible	C
General Metallic Scrap		6.5	C
Residual Scrap		16	C
Rotary sweating	kg/tonne of zinc processed	9[b]	C
Muffle sweating	kg/tonne of zinc processed	10.7[b]	C
Kettle sweating	kg/tonne of zinc processed		
Clean Metallic Scrap		Negligible	C
General Metallic Scrap		5.5	C
Residual Scrap		12.5	C
Electric resistance sweating	kg/tonne of zinc processed	5	C
Sodium carbonate leaching calcining	kg/tonne of zinc processed	44.5	C
Kettle pot	mg/tonne of zinc product	0.05	C
Crucible melting	kg/tonne of zinc processed	ND	NA

Table 14 - PM_{10} Emission Factors for Secondary Zinc Melting cont'

Operation	Units	Emission Factors	
		Uncontrolled PM_{10}[a, d]	Emission Factor Rating
Reverberatory melting	kg/tonne of zinc processed	ND	NA
Electric induction melting	kg/tonne of zinc processed	ND	NA
Alloying	kg/tonne of zinc processed	ND	NA
Retort and muffle distillation	kg/tonne of zinc product		
Pouring		0.3 [b]	C
Casting		0.15 [b]	C
Muffle distillation		22.5	C
Graphite rod distillation	kg/tonne of zinc processed	Negligible	C
Retort distillation/oxidation[c]	kg/tonne of zinc oxide product	15 [b]	C
Muffle distillation/oxidation[c]	kg/tonne of zinc oxide product	15 [b]	C
Retort reduction	kg/tonne of zinc processed	23.5	C
Galvanising	kg/tonne of zinc processed	2.5	C

Source: USEPA, 1981.

[a] Emission factors are given as total PM. If size distribution data is not available, then for the purposes of NPI reporting total PM can be assumed to be the same as PM_{10}.

[b] Where a range was shown in original table (AP-42 table 12.14-1), the mean value of the range is provided.

[c] All product ZnO dust is carried over in the exhaust gas from the furnace and is recovered with 98-99% efficiency.

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

[e] ND = no data. NA = not applicable.

Table 15 - Fugitive PM_{10} Emission Factors for Secondary Zinc Melting

Operation	Units	Emission Factors	
		Fugitive PM_{10}[a]	Emission Factor Rating
Reverberatory sweating[b]	kg/tonne of zinc product	0.63	E
Rotary sweating[b]	kg/tonne of zinc product	0.45	E
Muffle sweating[b]	kg/tonne of zinc product	0.54	E
Kettle (pot) sweating[b]	kg/tonne of zinc product	0.28	E
Electric resistance sweating[b]	kg/tonne material processed	0.25	E
Crushing/Screening	kg/tonne of scrap processed	2.13	E
Sodium carbonate leaching	-	ND	NA
Kettle (pot) melting furnace[b]	kg/tonne of zinc product	0.0025	E
Crucible melting furnace[c]	kg/tonne of zinc product	0.0025	E

Table 15 - Fugitive PM_{10} Emission Factors for Secondary Zinc Melting cont'

Operation	Units	Emission Factors	
		Fugitive PM_{10}[a]	Emission Factor Rating
Reverberatory melting furnace[b]	kg/tonne of zinc product	0.0025	E
Electric induction melting[b]	kg/tonne of zinc product	0.0025	E
Alloying retort distillation	-	ND	NA
Retort and muffle distillation	kg/tonne of zinc product	1.18	E
Casting[b]	kg/tonne of zinc product	0.0075	E
Graphite rod distillation	-	ND	NA
Retort distillation/oxidation	-	ND	NA
Muffle distillation/oxidation	-	ND	NA
Retort reduction	-	ND	NA

Source: USEPA, 1981.

[a] Emission factors are given as total PM. If size distribution data is not available, for the purposes of NPI reporting total PM can be assumed to be the same as PM_{10}.

[b] Estimate based on stack emission factor, assuming fugitive emissions to be equal to 5% of stack emissions (USEPA, 1981 table 12.14-3).

[c] Assuming fugitive emissions from crucible melting furnace to be equal to fugitive emissions from kettle (pot) melting furnace.

ND = No data.

NA = Not applicable.

3.3 Other Non-Ferrous Metal Manufacturing

3.3.1 Solder Production

3.3.1.1 Description

Solder products are generally in the form of cast (and sometimes extruded) lead and tin alloy, or as metal oxide paste. These are similar to the melting phase and paste production in lead-acid battery manufacturing.

Melting: Lead and tin pegs are melted and blended in a kettle. The alloy is then cast into long sections. In some processes those cast billets of solder are extruded and drawn to produce wire.

Paste Solder: Paste solder can be produced by mixing various amounts of tin and lead or silver or lead oxide. The metal oxides are then blended in powder form by centrifuging or spraying. Solder powder is then mixed with water based or other solvents and other additional ingredients, which act as a flux for the solder.

3.3.1.2 Emissions to Air & Estimation Techniques

Emissions from solder manufacturing include small amounts of lead emissions during the melting and paste production stages. These emissions occur in a similar manner to those in lead battery production (except that there is a lower lead content in the alloy used in solder manufacturing). Lead from solder manufacturing is generally emitted as particulate matter. Therefore, certain control devices that are in use such as fabric filters and scrubbers, help to reduce the amount of lead emitted to atmosphere.

It is likely that most of the emissions associated with these activities will occur indoors. Techniques for estimating fugitive emissions from inside buildings are provided in Section 4 of the *Emission Estimation Technique Manual for Fugitive Emissions.*

Table 16 provides an emission factor for lead from the lead melting pots.

Table 16 - Lead Emission Factor for Solder Manufacturing Facilities.

Emission Source	Control Device	Emission Factor (kg lead/tonne of material processed)	Emission Factor Rating
Lead Melting Pot	Afterburner	0.023	D
	Scrubber	0.023	D

Source: USEPA, 1998.

3.3.2 Welding Rod Manufacture

There is at present, no publicly available emissions data for the manufacture of non-ferrous metal welding rods. Site-specific sampling data or emission factors would need to be used to estimate emissions from this process. **Appendix A.1** of this Manual provides guidance on how such data can be used in emissions estimation.

3.4 General Approach for Estimating PM_{10} & VOC Emissions

PM_{10} and VOC emissions can be estimated via a facility wide approach, if individual process emissions are unavailable. Particulate metal emissions may also be estimated by speciation of total particulate matter if weight fractions of individual metals are known. The general approach to estimating PM_{10} and VOC emissions can be performed, using the steps outlined below, if the following parameters are known:

- 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 17 of this Manual, for 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} and for 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*.

Table 17 - Default PM_{10} Collection Efficiency Values for Pollution Control Equipment

Control Equipment	**Collection Efficiency (%)**
Wet scrubber - high efficiency	99
Wet scrubber - medium efficiency	95
Wet scrubber - low efficiency	90
Gravity collector - high efficiency	6
Gravity collector - medium efficiency	4.8
Gravity collector - low efficiency	3.7
Centrifugal collector - high efficiency	95
Centrifugal collector - medium efficiency	85
Centrifugal collector - low efficiency	50
Electrostatic precipitator - high efficiency	99.5
Electrostatic precipitator - medium 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 - medium 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 without fly ash reinjection	95
Multiple cyclone with fly ash reinjection	85
Wet cyclonic separator	85
Water curtain	90

Source: USEPA, 1995c.

3.5 Emissions to Water

Most of the liquid releases from non-ferrous metal manufacturing facilities are likely to be routed to sewer or sent for off-site treatment, recycling or disposal. This effluent is classed as a transfer (see Section 3.6 below) under the National Pollutant Inventory and hence is not reportable.

In the unlikely event that wastewater is released to water (eg. after wastewater treatment), this release (and the NPI-listed substances contained in the wastewater) would be required to be reported. If wastewater treatment occurs on-site it needs to be examined for potential emissions. Please refer to the *Emission Estimation Technique Manual for Sewage and Wastewater Treatment* on how to estimate these emissions.

There may be NPI reporting issues associated with stormwater. 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.

3.6 Emissions to Land

Under the NPI, the following are classed as transfers and are not required to be reported (*NEPM*, Clause 3(3)):

- 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, spills and leaks, storage and distribution of liquids. Such emissions may contain listed substances. It is expected that all liquid and solid wastes will be sent to sewer, sent off-site for treatment or recycling or sent to landfill. As a consequence, there will be reporting requirements associated with these wastes. 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.

4.0 Glossary of Technical Terms and Abbreviations

ANZSIC	Australian and New Zealand Standard Industrial Classification
CEMS	Continuous Emission Monitoring System
Chlorine demagging	A process used to reduce the amount of magnesium in molten aluminium by injecting chlorine, which reacts with the magnesium.
Dross	The residual material that is skimmed off molten metals during smelting operations, which often contain an amount of the molten metal.
EEA	European Environment Agency
EET	Emission Estimation Technique
EFR	Emission Factor Rating
mg	Milligrams
NEPM	National Environment Protection Measure
NO_x	Oxides of Nitrogen
NPI	National Pollutant Inventory
PM_{10}	Particles which have an aerodynamic diameter less than or equal to 10 micrometers ($\leq 10\mu m$).
ppmv	Parts per million by volume
SO_2	Sulfur Dioxide
STP	Standard Temperature & Pressure ($T = 0^{o}C$, $P = 1$ atm)
Sweating	A process whereby the material that is charged to the furnace is heated to the point that one pure metal is reduced to a molten state and is separated from the rest of the charge.
TSP	Total Suspended Particulates
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound

5.0 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

Brosnan, J., 1999, Simcoa Oprations Pty Ltd, pers. comm., 02/09/99.

Eastern Research Group. June 1998a. EIIP Document Series Volume II: Point Sources. Chapter 9: *Preferred and Alternative Methods for Estimating Air Emissions from Secondary Metal Processing,* The Emission Inventory Improvement Program, EPA-454/R-97-004 a-g Washington, DC, USA. http://www.epa.gov/ttn/chief/eiip/ii09.pdf

Gwalia Consolidated Ltd, 1996, *Smelting at Greenbushes*, AUSIMM, Australia.

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

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

Ullmann, Fritz, 1996, *Ullmann's encyclopedia of industrial chemistry*, fifth, completely revised edition. Volume A27, Weinheim, Germany.

USEPA. April 1981. *Emission Factor Documentation for AP-42, Section 12.14 Secondary Zinc 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/c12s14.pdf

USEPA. January 1990. Section 313 Reporting Issue Paper: *Clarification and Guidance for the Metal Fabrication Industry*, Office of Toxic Substances, EPA 560/4-90-012. Washington, DC, USA.

USEPA. January 1995a. *Emission Factor Documentation for AP-42, Section 12.9 Secondary Copper Smelting and Alloying*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c12s09.pdf

USEPA. January 1995b. *Emission Factor Documentation for AP-42, Section 12.17 Miscellaneous Lead Products*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c12s17.pdf

USEPA. January 1995c. *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. May 1998. Locating & Estimating (L&E) Documents. *Lead,* EPA-454/R-98-006 Washington, DC, USA.
http://www.epa.gov/ttn/chief/efdocs/lead1.pdf

USEPA. November 1994. *Emission Factor Documentation for AP-42, Section 12.12 Secondary Magnesium Smelting*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c12s12.pdf

USEPA. October 1986a. *Emission Factor Documentation for AP-42, Section 12.8 Secondary Aluminum Operations*. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. Research Triangle Park, NC, USA.
http://www.epa.gov/ttn/chief/ap42pdf/c12s08.pdf

USEPA. October 1986b. *Emission Factor Documentation for AP-42, Section 12.11 Secondary Lead 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/c12s11.pdf

The following EET Manuals 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 Ferrous Foundries;*
- *Emission Estimation Technique Manual for Fuel and Organic Liquid Storage;*
- *Emission Estimation Technique Manual for Fugitive Emissions;*
- *Emission Estimation Technique Manual for Gold Ore Processing*;
- *Emission Estimation Technique Manual for Mining;*
- *Emission Estimation Technique Manual for Nickel Concentration, Smelting and Refining;*
- *Emission Estimation Technique Manual for Non-Ferrous Foundries;*
- *Emission Estimation Technique Manual for Non-Metallic Mineral Product Manufacture;*
- *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;*
- *Emission Estimation Technique Manual for Surface Coating;* and
- *Emission Estimation Technique Manual for Timber & Wood Product Manufacturing.*

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 list of the variables and symbols used in this Manual may be found in **Appendix C**.

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 18. 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 = 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 18 - 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 18, and an exhaust gas temperature of 150°C (423 K)). This is shown below:

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

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

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.

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

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 19 presents example 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 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 19 - 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/hr
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, 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
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

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

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 = 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 19, and an exhaust gas temperature of 150°C (423 K).

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

For Time Period 2, also at 150°C
$E_{SO2,2}$ = 8.11 kg/hr

For Time Period 3, also at 150°C
$E_{SO2,3}$ = 7.23 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 per year (generally expressed in kg/year for solids, L/year 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 sludges 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 sludges 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 (eg. kilograms of sulfur dioxide emitted per tonne fuel burned.

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 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 non-ferrous metal 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 non-ferrous metal 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 non-ferrous metal 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 non-ferrous metal manufacturing processes. Use of emission equations to estimate emissions from these 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^oC (273 K) and 1 atm (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	$Wt\%_i$	%