National Pollutant Inventory

Emission Estimation Technique Manual

for

Non-Ferrous Foundries

Environment Australia

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EMISSION ESTIMATION TECHNIQUES
FOR
NON-FERROUS FOUNDRIES

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NON-FERROUS FOUNDRIES

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1.0 Introduction

The purpose of all Emission Estimation Techniques (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 foundry activities.

The non-ferrous foundry activities covered in this Manual apply to facilities where the primary focus is the casting, die casting and machining of non-ferrous metals, (excluding primary and secondary non-ferrous metal production).

EET MANUAL: Non-Ferrous Foundries

HANDBOOK : Non-Ferrous Basic Metal Product Manufacturing

ANZSIC CODE: 273 (including 2733)

This Manual was drafted by the NPI Unit of the Queensland Department of Environment on behalf of the Commonwealth Government. It has been developed through a process of national consultation involving State and Territory environmental authorities and key industry stakeholders.

2.0 Processes and Emissions

2.1 Process Description

The general process for most foundries begins with the task of pattern-making, where patterns are made from a model of the component to be produced. The pattern is used to produce moulds for the metal casting. Molten metal is tapped from the melting furnace into a ladle for pouring into the mould cavity where it is allowed to solidify.

After it has solidified, the casting is shaken out of the mould and the risers and gates are removed. Risers are shapes that are attached to the casting to provide a liquid-metal reservoir, and control solidification. Gates are the channels through which liquid metal flows into the mould cavity proper. Heat treatment, cleaning, finishing, and inspection follow.

Figure 1 shows the basic process steps and possible emission points for a typical metal foundry.

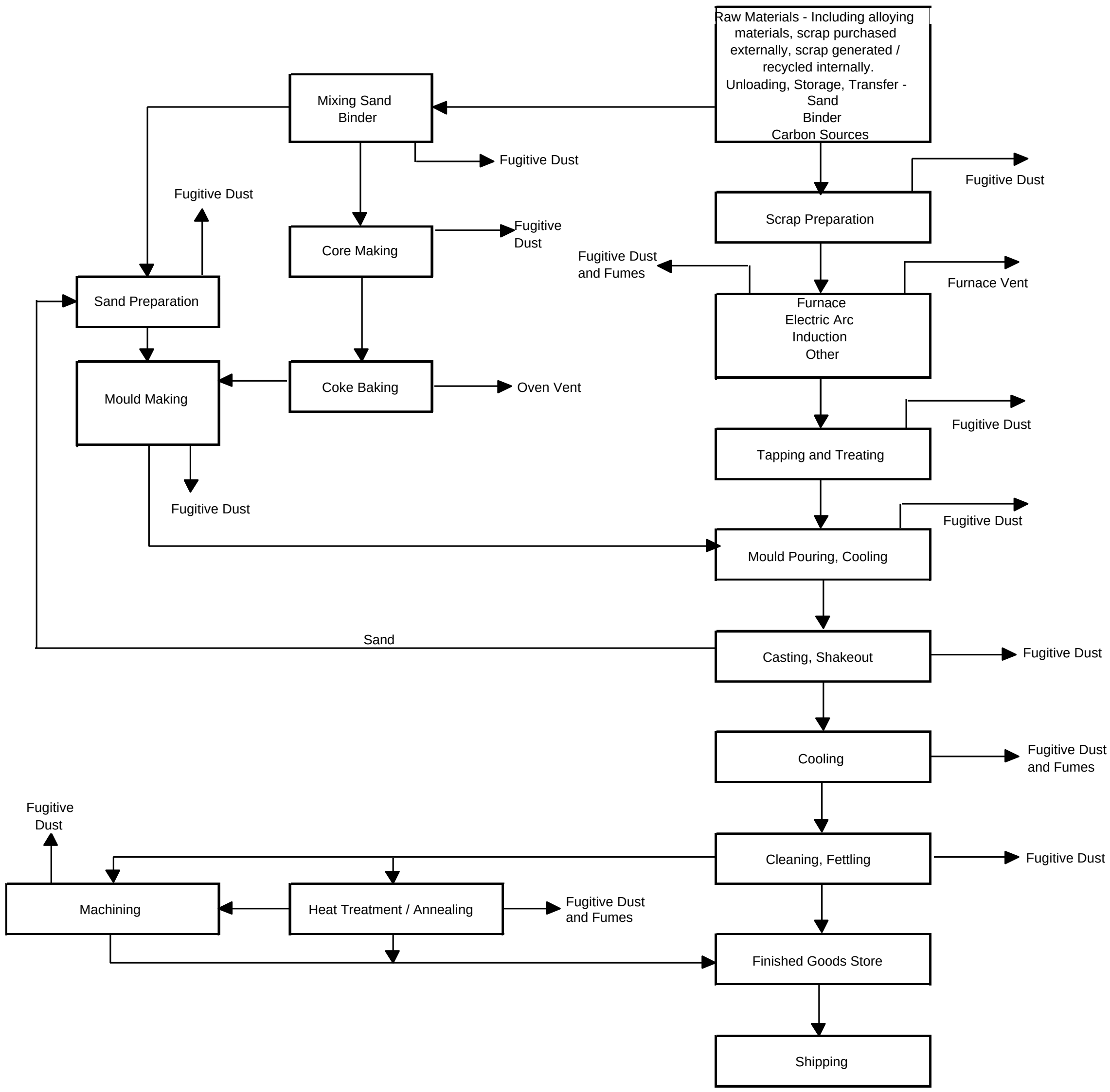

Figure 1 - Basic Process Steps for Metal Foundries
Source: National Cast Metals Association

2.2 Emission Sources and Control Technologies

Non-ferrous foundry activities can involve the handling and use of numerous substances on the NPI reporting list. Materials might include metal compounds such as zinc, lead, cadmium, and chromium, as well as gases such as sulfur dioxide, oxides of nitrogen, and carbon monoxide. Hydrocarbons, furans, and phenol may also be present. Foundry processes will vary according to the nature of the operations at your facility so that each reporting facility will likely handle a different range of substances on the reporting list.

As each facility in Australia is unique, you are encouraged to develop a process flow diagram for your own operations detailing the input of materials and listed substances, and the waste sources and emissions resulting from the operation of each process.

The NPI Guide at the front of this Handbook lists all of the reportable substances, and the associated thresholds. You should consult this information to determine whether your facility handles, manufactures, or otherwise uses any of these substances in excess of the threshold and therefore, requires that you report your emissions to the NPI.

2.2.1 Emissions to Air

Air emissions may be categorised as:

Fugitive Emissions

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

Point Source Emissions

These emissions are exhausted into a vent (excluding roof vents) or stack, and emitted through a single point source into the atmosphere.

Air emission control technologies, such as electrostatic precipitators, fabric filters or baghouses, and wet scrubbers, are commonly installed to reduce the concentration of substances in venting air streams prior to emission. Where such emission abatement equipment has been installed, and where emission factors from uncontrolled sources have been used in emission estimation, the collection efficiency of the abatement equipment needs to be considered. Guidance on applying collection efficiencies to emission factor equations is provided in later sections.

2.2.2 Emissions to Water

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

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

Inland and marine waters are discussed separately because the chemical pathways differ considerably.

Because of the significant environmental hazards posed by emitting toxic substances to water, most facilities emitting NPI-listed substances to waterways are required by their relevant State or Territory environment agency to closely monitor and measure these emissions. This existing sampling data can be used to calculate annual emissions.

If no wastewater monitoring data exists, emissions to water can be calculated based on a mass balance or using emission factors. However, the most appropriate method for determining emissions to the environment via wastewater is to use direct measurement.

The main source of wastewater from this industry is usually from air pollution control equipment such as wet scrubbers.

The discharge of listed substances to a sewer or tailings dam does not require you to report to the NPI. However, leakage and other emissions (including dust) from a tailings storage facility are reportable. (See also Section Three of *The NPI Guide*.)

2.2.3 Emissions to Land

Emissions of substances to land on-site include solid wastes, slurries, sediments, spills and leaks, storage and distribution of liquids, and such emissions may contain listed substances. These emission sources can be broadly categorised as:

- surface impoundments of liquids and slurries; and
- unintentional leaks and spills.

3.0 Emission Estimation

Estimates of emissions of listed substances to air, water, and land should be reported for each substance that triggers a threshold. The reporting list and detailed information on thresholds are contained in *The NPI Guide* at the front of this handbook.

In general, there are four types of emission estimation techniques (EETs) that may be used to estimate emissions from your facility. These are described in the NPI Guide. Select the EET, or mix of EETs, which is most appropriate for your purposes. If you estimate your emission by using any of these EET's, your data will be displayed on the NPI database as being of 'acceptable reliability'. Similarly, if your relevant environmental authority has approved the use of emission estimation techniques that are not outlined in this Handbook, your data will also be displayed as being of 'acceptable reliability'.

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.

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.

4.0 Emission Factor Rating

Every emission factor has an associated emission factor rating (EFR) code. This rating system is common to EETs for all industries and sectors and therefore, to all Industry 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 Section of this document. The emission factor ratings will not form part of the public NPI database.

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

The EFR system is as follows:

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

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

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

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

5.0 Emission Factors

The following tables contain emission factors to assist you in estimating emissions from various processes throughout your facility.

Table 1 - Emission Factors for Non-Ferrous Foundries Processing Zinc

Process Emission Categories	Emission[a]	Uncontrolled Emission Factor (kg/tonne)[b]	Emission Factor Rating	Reference
Point Source emissions:				
Kettle (pot) melting furnace, scrap melting	PM_{10} SO_2 NO_x Aniline Methylene(B)4-phenylisocyanate	0.05 0 0.95 0.8501 0.0004	C U U U U	2 1 1 3 3
Crucible melting furnace, scrap smelting	Aniline Methylene(B)4-phenylisocyanate	0.8855 0.0004	U U	3 3
Reverberatory melting furnace, scrap smelting	Aniline Methylene(B)4-phenylisocyanate	0.0708 0.0001	U U	3 3
Electric induction melting furnace, scrap melting	Aniline Methylene(B)4-phenylisocyanate	0.0638 0.000027	U U	3 3
Fugitive emissions:				
Kettle (pot) melting furnace (scrap)	PM_{10}	0.0025	E	2
Crucible melting furnace (scrap)	PM_{10}	0.0025	E	2
Reverberatory melting furnace (scrap)	PM_{10}	0.0025	E	2
Electric induction melting (scrap)	PM_{10}	0.0025	E	2
Casting	PM_{10}	0.0075	E	2

1. EMEP/ CORINAIR AIR CD Rom (1996)
2. USEPA Document AP-42 (1995)
3. USEPA "Speciate" computer programme

[a] Emissions are uncontrolled unless otherwise specified

[b] Units are kg of substance emitted / tonne of product produced

PM_{10} is particulate matter with a diameter of 10 µm or less

Table 2 - Emission Factors for Non-Ferrous Foundries Processing Aluminium

Process Emission Categories	Emission[a]	Uncontrolled Emission Factor (kg/tonne)[b]	Emission Factor Rating	Reference
Pouring, casting	SO_2 NO_x Aniline Methylene(B)4-phenylisocyanate	0.01 0.005 0.0496 0.000021	U U U U	1 1 3 3

1. EMEP / CORINAIR AIR CD Rom (1996).
3. USEPA "Speciate" computer program.

[a] Emissions are uncontrolled unless otherwise specified.
[b] Units are kg of substance emitted / tonne of aluminium product produced.

Table 3 - Emission Factors for Non-Ferrous Foundries Processing Copper, Brass, and Bronze

Furnace	Charge	Emission[a]	Emission Factor[b] (kg/tonne)	Emission Factor Rating	Reference
Point source emissions:					
Cupola	copper and brass scrap	Copper PM_{10} Trimethylfluoro-silane	0.0248 32.1 0.0758	U E U	3 2 3
		PM_{10} (electrostatic precipitator)	1.2	B	2
Crucible and pot furnace	brass and bronze	Copper PM_{10} SO_2 n-Hexane Trimethylfluoro-silane Benzene Toluene	0.0075 6.2 0.25 0.2345 1.34 0.4556 0.1206	U E U U U U U	3 2 1 1, 3 1, 3 1, 3 1, 3
		PM_{10} (electrostatic precipitator)	0.5	B	2
Reverberatory furnace	high lead alloy (58%)	Lead	25	B	2
	red / yellow brass	Lead	6.6	B	2
	Other alloy (7%)	Lead	2.5	B	2
	Copper	Copper PM_{10} n-Hexane Trimethylfluoro-silane Benzene Toluene	0.0018 2.5 0.007 0.04 0.0136 0.0036	U E U U U U	3 2 3 3 3 3
		PM_{10} (baghouse)	0.2	B	2

Table 3 - Emission Factors for Non-Ferrous Foundries Processing Copper, Brass, and Bronze (Cont')

Furnace	Charge	Emission[a]	Emission Factor[b]	Emission Factor Rating	Reference
	Brass and bronze	Copper	0.0128	U	3
		PM_{10}	10.8	E	2
		NO_x	0.04	U	1
		n-Hexane	0.007	U	3
		Trimethylfluoro-silane	0.04	U	3
		Benzene	0.0136	U	3
		Toluene	0.0036	U	3
		PM_{10} (baghouse)	1.3	B	2
Electric arc furnace	Copper	Copper	0.0018	U	3
		PM_{10}	2.5	E	2
		n-Hexane	0.1365	U	1, 3
		Trimethylfluoro-silane	0.78	U	1, 3
		Benzene	0.2652	U	1, 3
		Toluene	0.0702	U	1, 3
		PM_{10} (baghouse)	0.5	B	2
	Brass and bronze	Copper	0.0039	U	3
		PM_{10}	3.2	E	2
		SO_2	0.015	U	1
		PM_{10} (baghouse)	3	B	2
Electric induction furnace	Copper	Copper	0.0025	U	3
		PM_{10}	3.5	E	2
		PM_{10} (baghouse)	0.25	B	2
	Brass and bronze	Copper	0.0115	U	3
		PM_{10}	10	E	2
		SO_2	0.015	U	1
		PM_{10} (baghouse)	0.35	B	2
Fugitive emissions:					
Cupola		PM_{10}	1.1	E	2
Crucible and pot furnace		PM_{10}	0.14	E	2
Reverberatory furnace		PM_{10}	1.5	E	2
Electric induction furnace		PM_{10}	0.04	E	2

1. EMEP / CORINAIR AIR CD Rom (1997).
2. USEPA Document AP-42 (1995).
3. USEPA "Speciate" computer program (1993).

[a] Emissions are uncontrolled unless otherwise specified.
[b] Units are kg of substance emitted / tonne of product produced.

Table 4 - Emission Factors for Non-Ferrous Foundries Processing Lead

Furnace	Emission[a]	Emission Factor (kg/tonne)[b]	Emission Factor Rating	Reference
Point source emissions:				
Reverberatory furnace (scrap with high lead content)	SO_2 NO_x	40 0.15	U U	1 1
Blast furnace (cupola) (scrap smelting)	SO_2 NO_x	26.5 0.05	U U	1 1
Casting	PM_{10} Lead	0.02 0.007	C C	2 2
Fugitive emissions:				
Casting	PM_{10} Lead	0.001 0.0004	E E	2 2

1. EMEP/ CORINAIR AIR CD Rom (1996).
2. USEPA Document AP-42 (1995).

[a] Emissions are uncontrolled unless otherwise specified.
[b] Units are kg of substance emitted / tonne of product produced.

Table 5 - Emission Factors for Foundry Ancillary Operations

Process	Control Device	PM_{10} Emission Factor (kg/tonne)[b]	Emission Factor Rating	Reference
Scrap and charge handling, heating	Uncontrolled	0.3	E	2
Shakeout	Uncontrolled	1.6	E	2
Cleaning and finishing	Uncontrolled	8.5	E	2
Sand handling (in kg/tonne sand handled)	Uncontrolled Scrubber Baghouse	1.8 0.023 0.1	E D E	2 2 2
Core making, baking	Uncontrolled	0.6	E	2

2. USEPA Document AP-42 (1995)

[b] Units are kg of substance emitted / tonne of product produced

Table 6 - General Emission Factors for Non-Ferrous Foundries

Process	Process Origin	Emission Factor	Emission Factor Rating	Reference
From Point Sources:				
Discarded raw materials containers	Materials remaining in discarded containers, bags, and vessels	1% of vessel contents (10g/kg)	E	3
Equipment cleaning	VOCs, metals, and other listed substances	1% of vessel contents/ clean (10g/kg)	E	3
Spills	Accidental discharge	Total volume of spillage less recovered volume	C	3
Waste solvents	Equipment cleaning using solvent			
Wastewater sludge	Contaminated sludges removed from waste water			
From Fugitive Sources:				
Flanges	Solvent with vapour pressure >5mm Hg 37°C	0.82 g/hr	C	3
Valves	Solvent with vapour pressure >5mm Hg 37°C	7.3 g/hr	C	3
Pump seal	Solvent with vapour pressure >5mm Hg 37°C	50 g/hr	C	3
Sample connection	Solvent with vapour pressure >5mm Hg 37°C	15 g/hr	C	3

3. USEPA 560/4-88-004c (1988)

Table 7 - Acid Emission Factors

Acid Process	Process	Emission Factor[1] (kg/tonne of product)	Emission Factor Rating
Sulfuric acid Pickling	Alloys	9.8	U
Hydrochloric Acid Pickling	Alloys	44.5	U

[1] Economopoulos. (1993)
Units are kg of acid emitted/tonne of product produced

5.1 Binders

Table 8 - Table 10 contain emission factors for listed substances within binders. An example of how to use these emission factors is provided below:

<u>Example</u>

If you were to determine how much ammonia was emitting during the year from the use of 20 tonnes of Phenolic Nobake Binder, you would multiply the emission factor for ammonia in the Phenolic Nobake Binder table by the weight of binder used.

Emission Factor	*	Weight of Binder	=	Emission of Ammonia
0.039 g / kg		20 000 kg		780 g

Table 8 - Chemical Constituents of Common Foundry Binders

Chemical Constituent of Binder	Binder Emission Factor[1] (g / kg)[a]			
	Phenolic Nobake	Phenolic Urethane	Phenolic Hotbox	Green Sand
Ammonia	0.039	0.083	10.931	0.065
Hydrogen Sulfide	1.462	0.057	0.009	0.832
Nitrogen Oxides	0.029	0.044	0.638	0.562
Sulfur Dioxide	15.107	0.061	0.036	0.253
Benzene	11.209	5.351	1.002	0.611
Formaldehyde	0.01	0.022	0.006	0.004
Hydrogen Cyanide	0.029	1.053	1.184	0.118
M-Xylene	0.097	0.439	0.121	0.021
Naphthalene[b]	0.049	0.022	0.03	0.021
O-Xylene	0.049	0.132	0.03	0.021
Phenol	0.975	3.904	0.203	0.131
Toluene	0.694	0.833	0.182	0.063
Total Aromatic Amines[b]	0.049	0.351	1.275	0.021

[1] Mosher (1994)
[a] Units expressed as grams of chemical released to air per kilogram of seacoal or index resin.
[b] Add these together and list as a Polycyclic Aromatic Hydrocarbon

Table 9 - Chemical Constituents of Common Foundry Binders

Chemical Constituent of Binder	Binder Emission Factor[1] (g / kg)[a]			
	Core Oil	Shell	Alkyd Isocyanate	Sodium Silicate-Ester
Ammonia	0.038	3.86	0.037	0.038
Hydrogen Sulfide	0.057	0.094	0.007	0.197
Nitrogen Oxides	0.081	0.994	0.355	0.028
Sulfur Dioxide	0.115	3.509	0.04	0.244
Benzene	2.344	6.667	5.336	1.41
Formaldehyde	0.098	0.035	0.106	0.169
Hydrogen Cyanide	0.086	10.526	0.175	0.179
M-Xylene	0.239	0.585	2.522	0.094
Naphthalene[b]	0.048	0.058	0.037	0.005
O-Xylene	0.287	0.117	3.838	0.094
Phenol	0.057	2.456	0.11	0.273
Toluene	0.478	2.907	1.535	0.282
Total Aromatic Amines[b]	0.096	2.939	0.037	0.094

[1] Mosher (1994)
[a] Units expressed as grams of chemical released to air per kilogram of index resin.
[b] Add these together and list as a Polycyclic Aromatic Hydrocarbon

Table 10 - Chemical Constituents of Common Foundry Binders

Chemical Constituent of Binder	Binder Emission Factor[1] (g / kg)[a]		
	Low Nitrogen Furan	Medium Nitrogen Furan TSA Catalyst	Furan Hotbox
Ammonia	0.04	0.202	19.579
Hydrogen Sulfide	0.405	0.485	0.06
Nitrogen Oxides	0.012	0.372	0.411
Sulfur Dioxide	0.607	4.858	0.088
Benzene	0.648	4.534	0.537
Formaldehyde	0.257	0.065	0.009
Hydrogen Cyanide	0.368	0.607	3.474
M-Xylene	2.227	0.243	0.032
Naphthalene[b]	0.04	0.04	0.032
O-Xylene	0.729	0.04	0.032
Phenol	0.024	0.101	0.016
Toluene	0.121	8.825	0.032
Total Aromatic Amines[b]	0.081	0.364	3.032

[1] Mosher (1994)
[a] Units expressed as grams of chemical released to air per kilogram of index resin.
[b] Add these together and list as a Polycyclic Aromatic Hydrocarbon

6.0 Control Technologies

Abatement equipment and control technologies such as fabric filters are often used to reduce emissions in the metallurgical industry. If you have installed these or other abatement equipment at your facility, or you have implemented work practices that reduce emissions, you should multiply the control efficiency of the technology or the practice adopted by the appropriate emission factors.

Table 11 provides expected control efficiencies for emissions to air on commonly used abatement equipment. In the absence of precise data on the efficiencies of control equipment at your facility, you should assume that any abatement equipment used reduces emissions by 90 percent. Therefore, to obtain an emission total from a controlled source, multiply the uncontrolled emission total (obtained by using either the emission factors above or another EET such as mass balance) by 0.1.

For more information on using emission factors, please refer to *the Combustion in Boilers EET Manual*.

Table 11 - Control Technologies for Air Emissions

Method	Emission Type			Efficiency (%)
	Organic Vapours	Inorganic Vapours	Particulates	
Cyclones			X	98[a]
Fabric Filter			X	80-99
Wet Scrubbers	X[b]	X	X	95
Electrostatic precipitators			X	99.5-99.9
Carbon adsorption	X[c]	X		50-99
Fluidised-bed systems	X[d]			ND
Absorption	X[e]			90-99
Condensation	X	X[f]		50-95[g]
Thermal incineration	X			>99
Catalytic incineration	X			95-99

[1] Eastern Research Group, 1997.
[a] The greatest amount of control would be achieved for particles larger than 5µm.
[b] Depends on material, should be miscible in water.
[c] Carbon adsorption or fired-bed systems.
[d] Not widely used.
[e] Material must be readily soluble in water or other solvents.
[f] Depends on vapourisation point of material.
[g] Highly dependent on the emission stream characteristics.
ND = no data.

6.1 Estimating for Annual Reporting

Large foundries in Australia may work 24 hour shifts and therefore be continually emitting listed substances. Smaller plants may only work single shifts of around 8 hours each day. In the absence of other data, it may be assumed for the purposes of reporting, that emissions are relatively consistent during the year. You will need to convert your emission estimations from amounts per hour or per batch into annual averages.

7.0 References

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The following EET Manual referred to in this Manual is available from the NPI Website (http://www.npi.gov.au) and from your local Environment Protection Authority:

- Emission Estimation Technique Manual for Combustion in Boilers.