



National Pollutant Inventory

Emission Estimation Technique Manual

for

Ferrous Foundries

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**EMISSION ESTIMATION TECHNIQUES
FOR
FERROUS FOUNDRIES**

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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 ferrous foundry activities.

The steel and iron industries covered by this Handbook include facilities primarily engaged in iron and steel casting, forging, and machining including the manufacture of cast iron or steel pipes or tubes, cast iron or steel pipe or tube fittings, or steam, gas, or water fittings of cast iron or steel. The Handbook also covers facilities mainly engaged in manufacturing seamless or welded steel pipes or tubes or ferrous metal pipe or tube fittings.

EET MANUAL: Ferrous Foundries

HANDBOOK: Iron and Steel Manufacturing
 - Casting and Forging
 - Steel Pipe and Tube Manufacturing

ANZSIC CODE : 271, 2712 and 2713

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

Ferrous foundries (iron and steel) involve the casting and forging of iron. Products include castings for machinery parts, transportation manufacturing, and non-industrial components such as hand-tools and motor vehicle equipment. Typical iron compositions used are grey iron, ductile iron, malleable iron, steel, and scrap iron.

1. Raw material handling and preparation;
2. Metal melting;
3. Mould and core production; and
4. Casting and finishing.

The final product is determined by the composition of the iron, design of casting, rate of cooling, and heat treatment. As each foundry 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.

Production of castings involves the following process steps, as outlined in Figure 1.

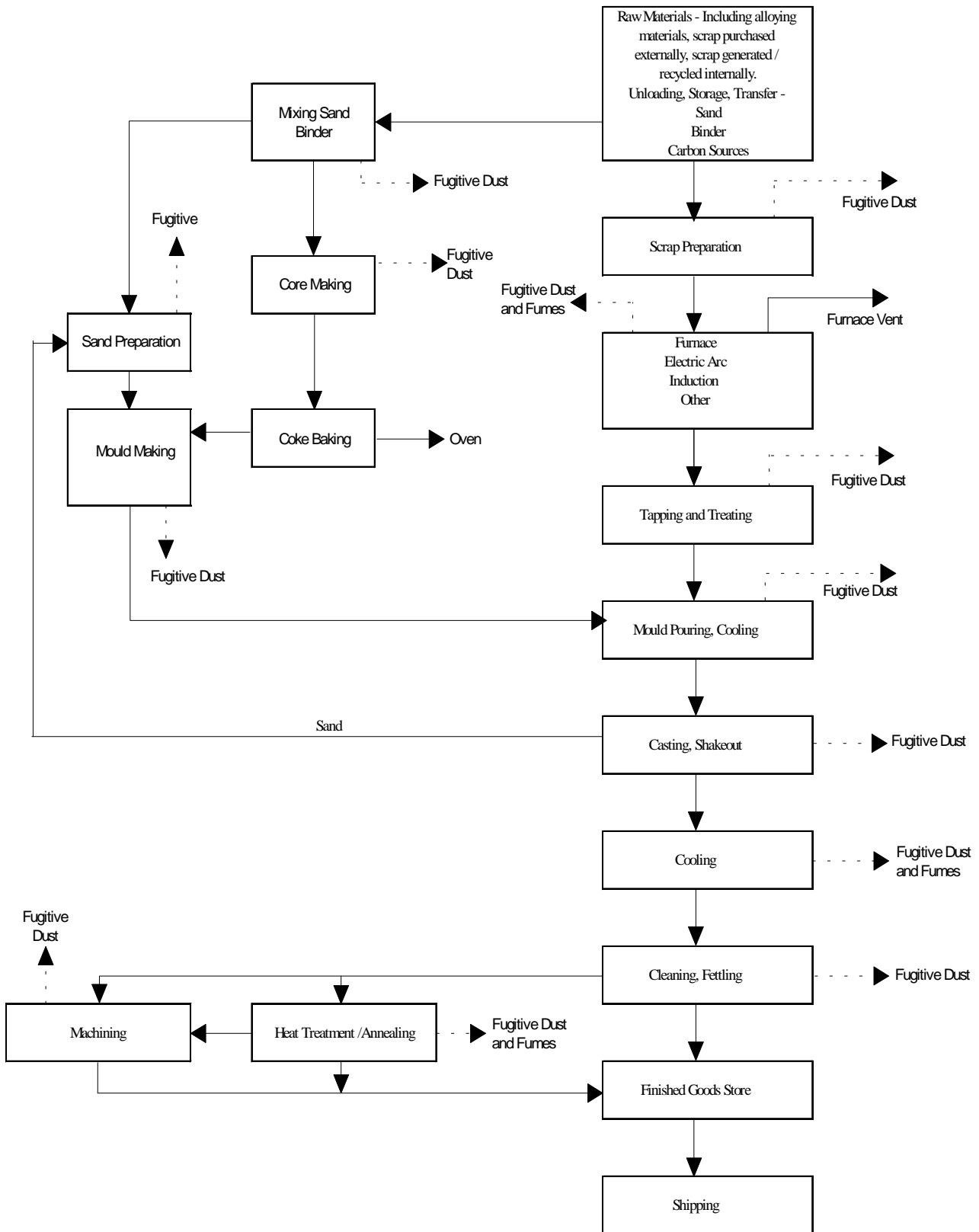


Figure 1 - Basic Process Flow Diagram for a Ferrous Foundry
 Cast Metals Association, 1998

2.2 Emission Sources and Control Technologies

Iron and steel foundries and allied manufacturing may involve the handling and use of numerous listed substances. These include volatile organic compounds (VOCs) present in solvents and cleaning aids, metal compounds (eg. those containing manganese, copper or other NPI listed metals) and other substances (eg. ammonia, and hydrochloric and sulfuric acids). Each process may be slightly different, and emit a different range of substances on the reporting list.

Table 1 - NPI-Listed Substances Commonly Used in Iron and Steel Foundries

Organics Commonly Used in Iron and Steel Foundries	Inorganic Acids Commonly Used in Iron and Steel Foundries	Metals Commonly Used in Iron and Steel Foundries
ammonia xylenes (individual or mixed isomers) methanol acetone methyl ethyl ketone methyl isobutyl ketone dichloromethane trichloroethylene tetrachloroethylene	HF HCl H ₂ SO ₄	copper and compounds chromium and compounds manganese and compounds nickel and compounds

QLD Department of Environment, 1998

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 if your facility handles, manufactures, or otherwise uses any of the listed substances in excess of the threshold, and therefore, whether you are required to report emissions of these substances.

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.

With regards to emission controls for PM₁₀ emissions (particulate matter with an equivalent aerodynamic diameter of 10 micrometres or less ie. $\leq 10\mu\text{m}$), in the absence of measured data, or knowledge of the collection efficiency for a particular piece of equipment, an efficiency of 90% should be used in the emission factor equation to calculate actual mass emissions. This default should only be used if there is no other available control efficiency.

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.

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.

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 7.0 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 that may assist you in estimating emissions from various processes throughout your facility.

Table 2 - General Emission Factors for Iron Foundries and Steel Manufacturing

Process Description	Process Origin	Emission Factor	Emission Factor Rating
From Point Sources			
Discarded raw materials containers	Materials remaining in discarded containers, bags, and vessels	1% of vessel contents (10kg/tonne) ¹	E
Equipment cleaning	VOCs, metals, and other listed substances	1 percent of vessel contents/clean (10kg/tonne) ¹	E
Spills	Accidental discharge	Total volume of spillage less recovered volume	C
Waste solvents	Equipment cleaning using solvent	1% of vessel contents per clean (10kg/tonne) ¹	
Wastewater sludge	Contaminated sludges removed from waste water		
From Fugitive Sources			
Flanges	Solvent with vapour pressure >5mm Hg 37°C	0.00082 kg/hr ¹	C
Valves	Solvent with vapour pressure >5mm Hg 37°C	0.0073 kg/hr ¹	C
Pump seal	Solvent with vapour pressure >5mm Hg 37°C	0.050 kg/hr ¹	C
Sample connection	Solvent with vapour pressure >5mm Hg 37°C	0.015 kg/hr ¹	C

¹USEPA 560/4-88-004c (1988)

Table 3 - Particulate Matter (PM₁₀) Emission Factors for Iron and Steel Foundry Furnaces

Furnace Type	Control Device	PM₁₀ Emission Factor¹ (kg/tonne)^a	Emission Factor Rating
Cupola	Uncontrolled	6.9	E
	Scrubber ^b	1.6	C
	Venturi Scrubber	1.5	C
	Electrostatic Precipitator	0.7	E
	Baghouse	0.3	E
	Single Wet Cap	4.0	E
	Impingement Scrubber	2.5	E
	High Energy Scrubber	0.4	E
Electric Arc Furnace	Uncontrolled	6.3	C
	Baghouse	0.2	C
Electric Induction Furnace	Uncontrolled	0.5	E
	Baghouse	0.1	E
Reverberatory	Uncontrolled	1.1	E
	Baghouse	0.1	E

¹ USEPA AP-42 Section 12.10 (1996).

^a Units expressed as kg of substance emitted per tonne of iron produced.

^b Includes averages for other scrubbers and wet caps not already mentioned.

Table 4 - Emission Factors for Iron and Steel Foundry Furnaces

Furnace Type	Substances Emitted	Emission Factor ¹ (kg/tonne) ^a	Emission Factor Rating
Cupola Uncontrolled High Energy Scrubber	CO	73	E
	SO ₂	0.6S ^b	E
	NO _x	-	N/A
	VOCs	-	N/A
	Lead	0.05-0.06	B
	CO	73	E
	SO ₂	0.3S ^b	E
	NO _x	-	N/A
	VOCs	-	N/A
	Lead	-	N/A
Electric Arc Furnace	CO	0.5-19	E
	SO ₂	Neg	E
	NO _x	0.02-0.3	E
	VOCs	0.03-0.15	E
	Lead	-	N/A
Electric Induction Furnace	CO	Neg	E
	SO ₂	Neg	E
	NO _x	-	N/A
	VOCs	-	N/A
	Lead	0.005-0.05	E
Reverberatory	CO	-	N/A
	SO ₂	-	N/A
	NO _x	-	N/A
	VOCs	-	N/A
	Lead	0.006-0.07	E

¹USEPA AP-42 Section 12.10 (1996)

^a Units expressed as kg of substance emitted/tonne of iron produced.

N/A = Not applicable

S^b = % sulfur in the coke (average sulfur content of Australian coal is 0.5%) and assumes 100% of the sulfur is converted to SO₂

Table 5 - Solvent Emission Factors

Solvent Used	Use in industry	Emission Factor ¹ (kg/kg solvent used)	Emission Factor Rating
Dichloromethane	Vapour degreasing Cold Cleaners		
		<i>Uncontrolled</i>	0.930
<i>Controlled</i>		0.890	E
Tetrachloroethylene	Vapour degreasing Cold Cleaners		
		<i>Uncontrolled</i>	0.890
<i>Controlled</i>		0.850	E
Trichloroethylene	Vapour degreasing Cold Cleaners		
		<i>Uncontrolled</i>	0.910
<i>Controlled</i>		0.870	E

¹USEPA EPA- EPA 560/4-90-012. (1990)

Factor units are kg of solvent emitted / kg of solvent used.

Table 6 - Emission Factors for Foundry Ancillary Operations

Process	Control Device	PM ₁₀ Emission Factor ¹ (kg/tonne) ^a	Emission Factor Rating
Scrap and charge handling,heating	Uncontrolled	0.3	E
Magnesium treatment	Uncontrolled	0.9	E
Refining	Uncontrolled	2.0	E
Pouring and cooling	Uncontrolled	2.1	E
Shakeout	Uncontrolled	1.6	E
Cleaning and finishing	Uncontrolled	8.5	E
Sand handling (in kg/tonne sand handled)	Uncontrolled	1.8	E
	Scrubber	0.023	D
	Baghouse	0.1	E
Core making, baking	Uncontrolled	0.6	E

¹USEPA AP-42 Section 12.10 (1996).

^a Units expressed as kg of PM₁₀ emitted /tonne of iron produced.

5.1 Binders

Tables 7 - 9 contain emission factors for listed substances within binders. An example of how to use these emission factors is provided below:

Example

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.

$$\begin{array}{rclcl}
 \text{Emission Factor} & * & \text{Weight of Binder} & = & \text{Emission of Ammonia} \\
 0.039 \text{ g/kg} & & 20\,000 \text{ kg} & & 780 \text{ g}
 \end{array}$$

Table 7 - 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 8 - 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 9 - 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 baghouses, cyclones and afterburners, are often used to reduce emissions in foundries. If you have installed these, or other abatement equipment at your facility, or if you have implemented work practices that reduce emissions, you should multiply the uncontrolled emission total by the control efficiency of the technology or practice adopted.

Table 10 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 from either using 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 10 - Control Technologies for Air Emissions¹

Method	Emission Type			Efficiency (%)
	Organic Vapours	Inorganic Vapours	Particulates	
Cyclones			X	80-90 ^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

¹Eastern Research Group, 1997.

^aThe greatest amount of control would be achieved for particles larger than 5µm.

^bDepends on material, should be miscible in water.

^cCarbon adsorption or fired-bed systems.

^dNot widely used.

^eMaterial must be readily soluble in water or other solvents.

^fDepends on vapourisation point of material.

^gHighly 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 VOCs, metal compounds, particulates, and other listed substances. In contrast, smaller plants may only work single shifts of around 8 hours per 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. When providing data on your average yearly emissions, it is important to apply EETs to an average production run to give a reliable estimate of your emissions.

7.0 References

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<http://www.epa.gov/ttn/chief/ap42.html>

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.

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.