SNAP CODE: **030303**

SOURCE ACTIVITY TITLE: **PROCESSES WITH CONTACT**
Grey Iron Foundries

NOSE CODE: **104.12.04**

NFR CODE: **1 A 2 a**

ISIC: **2410**

1 ACTIVITIES INCLUDED

This chapter covers emissions released from combustion processes within grey iron foundries. The grey iron foundries are in general part of production processes for a wide range of metal products. A detailed description of non-combustion processes in iron and steel industries and collieries can be found in chapters B146 and B422 up to B428.

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution of emissions released from grey iron foundries to total emissions in countries of the CORINAIR90 inventory is given as follows:

Table 2.1: Contribution to total emissions of the CORINAIR90 inventory (*28 countries*)

Source-activity	**SNAP-code**	**Contribution to total emissions [%]**										
Grey Iron Foundries	030303	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3	TSP*	PM_{10}*	$PM_{2.5}$*
Typical contribution		0	0	0	0	1.4	0.1	-	-	0.141	0.086	0.021
Highest value										0.255	0.152	0.032
Lowest value										0.076	0.051	0.012

* contribution of pig iron foundries to total national emissions ,exluding agricultural soils, EU $PM_{2.5}$ Inventory project for EU25 for the year 2000 (TNO, 2006)
0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
\- = no emissions are reported

For heavy metal emissions, no specific figures for this source activity are available. The average relative contribution from the total iron and steel production industry and the production of pig iron to the total emission of heavy metals has been presented for European countries in Table 2.2. Grey iron foundries can be considered a part of the production of pig iron. The data in Table 2 is according to Baart *et al.* (1995). /1/

Table 2.2: Average relative contribution of the production of iron and steel and the production of pig iron to the total emission of heavy metals in European countries.

Compound	Total iron & steel production (%)	Pig iron production (%)
Cadmium	22	-
Chromium	36	3.7
Copper	16	-
Nickel	14	3.0
Lead	12	-
Zinc	33	-

- = not available

3 GENERAL

3.1 Description of activities

Foundry activities are generally part of the following type of industrial activities:

- Malleable foundries
- Nodular foundries, for instance:
  - machine construction
  - automobile and bicycle industry
- Lamellar foundries, for instance:
  - sewer pipe foundries, accessories for tubes
  - tubes for heating purposes
  - machine construction parts
  - automobile industry
- Steel foundries

The activities of the foundries can be seperated in five parts:

- pretreatment of shot metals
- production of casting models
- smelting of metals with flux compounds and treatment of smelt
- casting of metal smelt in casting models
- treatment of castings

The activities, the composition, the scaling and the use of raw materials of the foundries depend strongly on the products made by the foundries and on economic aspects. The casting process is described in Section 3.3.

3.2 Definitions

Pretreatment of the raw materials	Some raw materials need to be pretreated since they are not always suitable for the casting process.
Smelting process	The shot metals and flux compounds are mixed with cokes and heated by combustion of the cokes to a temperature above the melting point of iron (»1500 °C). These processes can be either batchwise, or continuous.
Production of casting models	A casting model is made of sand with a chemical binding agent, or of clay bounded sand. The shape of the casting model is the inverse of the casting to be produced. The casting model can only be used once, because after solidification of the metal smelt the casting will be destroyed.
Metal smelt	The shot metals used in the smelting process contain mainly iron. Since shot materials are used the iron may be contaminated with other metals.
Treatment of the metal smelt	The treatment of the metal smelt is a process intended to increase the quality of the smelt. Increase of quality is necessary for the casting process or the properties of the product.
Casting process	The casting process is the pouring of the drained off metal smelt in a casting process and the solidification of the metal smelt.

3.3 Techniques

The casting starts with the pretreatment of the metals. This pretreatment consists of breaking big parts of shot metals, and mixing the metals with the flux compounds. Three types of smelt ovens are commonly used: dome ovens, electro ovens and tumbler ovens. These ovens are described in Section 3.3.1.

After the metal smelt is drained from the ovens, the quality of the smelt can be improved by deslagging with slag binding compounds, desulphurating with fine cokes and calcium carbide, inoculation with ferro alloys (based on ferro silica) and nodulisation with magnesium.

The drained metal smelt is casted in a casting model. The casting method is specific for the products. The production of the casting models is described in paragraph 3.3.2. After solidification of the metal smelt the casting model is removed. Cleaning of the casting is generally done by shot peening. Besides shot peening the casting can be been grinded, rolled, chopped and milled. Sometimes the castings will also be treated by glowing, or hardened, tared, red-leaded, painted or lacquered.

3.3.1 Smelt ovens

Dome oven	The dome oven is a continuous operating installation. In the shaft the smelt aggregate is accumulated via an opening in the side wall. Alternately the cokes and the metals are added. During the filling of the shaft the cokes are lighted and the metal smelts and flows into the oven.
Electro oven	The metals and flux compounds are smelted by electric lighting of the petrol cokes. The process is discontinu.
Tumbler oven	The tumbler oven is heated by an oil lighted flame. The metals direct heated by the flame will melt. The turning of the tumbler assures that the metals will be heated on both sides.

3.3.2 Production of casting models

The casting models can be classified in two categories, namely the clay bounded sand models for the light casting production and the models of sand with a chemical hardener. The clay bounded sand model is strengthened by compression. The sand contains concrete, water and coal powder for the production of a smooth structure on the the casting. The casting model made of sand with the chemical agent is also strengthened by compressing during which process the chemicals are polymerized in the sand.

3.4 Emissions

The main emissions of the casting process are emissions of dust and gaseous compounds. The emissions occur during the smelting process, the production of the casting model and the treatment of the castings. The main emission is dust which contains metal oxides like iron and silica oxide. Also some solvents may be part of the emissions into air.

The emissions of dust depend strongly on the type of oven used for the smelting process and quality of the process management.

Gaseous compounds released are sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and methane (CH_4)), carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (N_2O) and ammonia (NH_3). The emissions are released through the stack. According to CORINAIR90 the main relevant pollutants are CO and CO_2 (see also table 1).

Coke burned in cupola furnaces produces several pollutants. Incomplete combustion of coke causes carbon monoxide emissions and the coke sulphur content gives rise to sulphur dioxide emissions. /3/

Electric arc furnaces produce CO emissions which result from combustion of graphite from electrodes and carbon added to the charge. Hydrocarbons (NMVOC) result from vaporisation and incomplete combustion of oil residues remaining on the scrap iron charge. /3/

Electric induction furnaces release negligible amounts of hydrocarbon and carbon monoxide emissions. /3/

3.5 Controls

Possible areas for improvement in emission control are:

- Dome oven — Treatment of off-gas with bagfilters and electrofilters
- Electro oven — Treatment of off-gas with bagfilters or electrofilters
- Tumbler oven — Treatment of off-gas with bagfilters, use of low sulphur containing oil, lime injection combined with bagfilters
- Smelt treatment — Treatment of off-gas with bagfilters
- Sand preparation — Use of bagfilters and wet scrubbers
- Model production — Good humidity control. For the sand model production with the chemical hardened binding resin the choice of the resin can influence the emission.

A cupola furnace typically has an afterburner as well, which achieves up to 95 % efficiency. The afterburner is located in the furnace stack to oxidise CO and burn organic fumes, tars and oils. /3/

Electric induction furnaces are typically uncontrolled since they emit negligible amounts of hydrocarbons and carbon monoxide. /cf. 2/

4 SIMPLER METHODOLOGY

Emissions can be estimated at different levels of complexity; it is useful to think in terms of three tiers[1]:

Tier 1: a method using readily available statistical data on the intensity of processes (“activity rates”) and default emission factors. These emission factors assume a linear relation between the intensity of the process and the resulting emissions. The Tier 1 default emission factors also assume an average or typical process description.

Tier 2: is similar to Tier 1 but uses more specific emission factors developed on the basis of knowledge of the types of processes and specific process conditions that apply in the country for which the inventory is being developed.

Tier 3: is any method that goes beyond the above methods. These might include the use of more detailed activity information, specific abatement strategies or other relevant technical information.

By moving from a lower to a higher Tier it is expected that the resulting emission estimate will be more precise and will have a lower uncertainty. Higher Tier methods will need more input data and therefore will require more effort to implement.

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[1] The term “Tier” is used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and adopted here for easy reference and to promote methodological harmonization.

For the simpler methodology (equivalent to Tiers 1 and 2), where limited information is available, a default emission factor can be used together with production capacity information for the country or region of interest without further specification on the type of industrial technology or the type and efficiency of control equipment.

Consequently the simplified methodology is to combine an activity rate (AR) with a comparable, representative, value of the emissions per unit activity, the emission factors (EF). The basic equation is:

$$\text{Emission} = AR \times EF$$

In the energy sector, for example, fuel consumption would be activity data and mass of material emitted per unit of fuel consumed would be a compatible emission factor.

NOTE: The basic equation may be modified, in some circumstances, to include emission reduction efficiency (abatement factors).

Default emission factors for this purpose are provided in Section 8.1.

5 DETAILED METHODOLOGY

The detailed methodology (equivalent to Tiers 3), to estimate emissions of gaseous pollutants from the iron and steel production is based on measurements or estimations using plant specific emission factors. Guidance on determining plant specific emission factors is given in Measurement Protocol Annex.

Reference emission factors for comparison with users own data are provided in Section 8.2.

6 RELEVANT ACTIVITY STATISTICS

Information on the production of iron, steel and malleable iron castings, suitable for estimating emissions using of the simpler estimation methodology (Tier 1 and 2), is widely available from UN statistical yearbooks or national statistics. For energy consumption statistics, data from the IEA can be used.

The detailed methodology (Tier 3) requires more detailed information. For example, the quantities of iron, steel and malleable iron castings produced by various types of industrial technologies employed in the iron and steel industry at plant level. This data is however not always easily available.

Further guidance is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 3 on Industrial Processes and Product Use (IPPU), chapter 2.2.1.3 " Choice of activity statistics".

7 POINT SOURCE CRITERIA

Foundries can vary strongly in size. Small foundries can be treated as area source. At the national level big foundries or a concentration of foundries in a small area would be treated as point sources.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

8.1 Default Emission Factors for use with simpler methodology.

Table 8.1: Emission factors for grey iron foundries

Pollutant	Emission Factor	Units
Arsenic	0.3	g/tonne liquid steel
Cadmium	0.1	g/tonne liquid steel
Chromium	1	g/tonne liquid steel
Copper	1	g/tonne liquid steel
Mercury	0.04	g/tonne liquid steel
Nickel	0.3	g/tonne liquid steel
Lead	3	g/tonne liquid steel
Selenium	0.01	g/tonne liquid steel
Vanadium	1	g/tonne liquid steel
Zinc	5	g/tonne liquid steel
Particulate matter*		
TSP	2 (2)**	kg / tonne cast iron
PM_{10}	0.6 (2)**	kg / tonne cast iron
$PM_{2.5}$	0.09 (2)**	kg / tonne cast iron

Source: Pacyna et al, 2002, (*) except for particulate matter , CEPMEIP [6]
** note: NOTE: The factor between brackets () represents the uncertainty (95% confidence) in the emission factor. The lower limit of the uncertainty range can be found by dividing the emission factor by the uncertainty factor, whereas the upper limit of the uncertainty range can be found by multiplying the range with the uncertainty factor. Example (emission factor for TSP): The uncertainty in the emission factor for TSP is 2 . The emission factor with uncertainty range will therefore be 2 kg per tonne cast iron with an uncertainty range of 1 (2 /2) to 4 (2 x 2).

8.2 Reference Emission Factors

Table 8.2 contains reference emissions factors for comparison with users own data. Technique related emission factors, mostly given in other units (e.g. g/Mg charged), are listed in footnotes. In case of using production statistics the specific energy consumption (e.g. GJ/Mg product) has to be taken into account, which is process and country specific. At this stage no data for the definition of appropriate conversion factors are available.

For the Netherlands, emission factors are calculated from measurements in mixtures consisting of 60% of hot blast air cupolas (1500 m^3 Mg^{-1} off-gases) and 40% of cold blast air off-gases (300 m^3 Mg^{-1} off-gases), using an average dust concentration of 300 mg m^{-3}. The emission factors are calculated from formula 1:

$$\text{Emission} = [\text{Dust}]_{average} \times \text{Flow}_{off\text{-}gases} \times [\text{Metal composition}]_{dust} \quad \text{[Formula 1], where}$$

$[\text{Dust}]_{average}$: Average dust concentration in off-gases
$\text{Flow}_{off\text{-}gases}$: Average flow of off-gases

$[\text{Metal composition}]_{dust}$: Average weight percentage of metal composition in dust

The emission factors are given in table 8.2.

Table 8.2: Emission factors for grey iron foundries[7)]

Type of fuel			NAPFUE code	Emission factors SO_2 [g/GJ]	NO_x [g/GJ]	NMVOC [g/GJ]	CH_4 [g/GJ]	CO [g/GJ]	CO_2 [kg/GJ]	N_2O [g/GJ]	NH_3 [g/GJ]
s	coal	hc steam	102	130-160[1)]	12-80[1)]	15-57[1)]	5-15[1)]	20[1)]	93-94[1)]	4-5[1)]	
s	coal	bc briquettes	106	44[1)]	12[1)]	15-57[1)]	6.3-15[1)]		97[1)]	3.5[1)]	
s	coke	hc coke oven	107	100-584[1)], 92-593[2)]	12-220[1)], 12-45[2)]	0.5-80[1)]	0.5-6.3[1)]	97[1)]	105-110[1)], 105[2)]	3-4[1)]	
s	coke	bc coke oven	108	650[1)]	150[1)]	5[1)]	15[1)]	18[1)]	86[1)]	3[1)]	
l	oil	residual	203	143-930[1)]	100-175[1)]	3-57[1)]	3-6.3[1)]	10-15[1)]	73-78[1)]	2-10[1)]	
l	oil	gas	204	55-94[1)]	50-100[1)]	1.5-57[1)]	1.5-8[1)]	10-20[1)]	74[1)]	2[1)]	
g	gas	natural	301	0.3-8[1)], 1[2)]	50-100[1)],145[2)]	2.5-57	2-6.3[1)]	10-20[1)], 8[2)]	53-60[1)], 55[2)]	1-3[1)]	
g	gas	liquified petroleum gas	303	0.04[1)]	100[1)]	2.1[1)]	0.9[1)]	131)	65[1)]	1[1)]	
g	gas	coke oven	304	12-54[1)], 54[2)]	5.5-50[1)],5[2)]	2.5-80[1)]	2.5-6.3[1)]	10[1)]	44-45[1)], 45[2)]	1-1.5[1)]	

1) CORINAIR90 data, area sources; 2) CORINAIR90 data, point sources

3) SO_x: /1/	450	g/Mg charged	cupola furnace
	90,000	g/Mg charged	reverberatory furnace
	0	g/Mg charged	electric induction furnace
	125	g/Mg charged	electric arc furnace
4) NO_x: /1/	50	g/Mg charged	cupola furnace
	2,900	g/Mg charged	reverberatory furnace
	0	g/Mg charged	electric induction furnace
	160	g/Mg charged	electric arc furnace
5) VOC: /1/	90	g/Mg charged	cupola furnace
	75	g/Mg charged	reverberatory furnace
	0	g/Mg charged	electric induction furnace
	90	g/Mg charged	electric arc furnace
6) CO: /1/	72,500	g/Mg charged	cupola furnace
	0	g/Mg charged	reverberatory furnace
	0	g/Mg charged	electric induction furnace
	9,500	g/Mg charged	electric arc furnace

7) It is assumed, that emission factors cited within the table are related to combustion sources in grey iron foundries; other process emissions are not covered.

9 SPECIES PROFILES

The heavy metal emissions are related to the metal profile of the dust.

10 UNCERTAINTY ESTIMATES

The emission factors given are based on the data from a small number of measurements, with a rather large variation caused by individual conditions. The quality class of the emission factors other than of CORINAIR90 is estimated to be [D].

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

The weakest aspect for heavy metals is the lack of data and adequate measurements.
For emissions other than heavy metals, the weakest aspects discussed here are related to emission factors.

The fuel specific emission factors provided in table 4 are related to point sources and area sources without specification. CORINAIR90 data can only be used in order to give a range of emission factors with respect to point and area sources. Further work should be invested to develop emission factors, which include technical or fuel dependent explanations concerning emission factor ranges.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Not applicable.

13 TEMPORAL DISAGGREGATION CRITERIA

The temporal disaggregation depends on the management of the plant. Some foundries do emit only during Mondays to Fridays from ± 7.00 hour to ± 18.00 hour and others emit continuously.

As result of market conditions a seasonal variation might be present.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

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[16] Environmental Protection Agency; Compilation of air pollutant Emission Factors AP-42
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16 VERIFICATION PROCEDURES

A verification method could be the comparison of the heavy metals emissions calculated with a profile of the composition of the products.

17 REFERENCES

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[6] Visschedijk, A.J.H., J. Pacyna, T. Pulles, P. Zandveld and H. Denier van der Gon, 2004, Cooordinated European Particulate Matter Emission Inventory Program (CEPMEIP), In: P. Dilara et. Al (eds), Proceedings of the PM emission inventories scientific workshop, Lago Maggiore, Italy, 18 October 2004, EUR 21302 EN, JRC, pp 163 - 174

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE, AND SOURCE

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20 POINT OF ENQUIRY

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