

SNAP CODE: 030303

SOURCE ACTIVITY TITLE: PROCESSES WITH CONTACT
Grey Iron Foundries

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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 1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)

Source-activity	SNAP-code	Contribution to total emissions [%]							
		SO ₂	NO _x	NMVOG	CH ₄	CO	CO ₂	N ₂ O	NH ₃
Grey Iron Foundries	030303	0	0	0	0	1.4	0.1	-	-

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. 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: 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 separated 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 ($\gg 1500$ °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 mainly	The shot metals used in the smelting process contain 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-lead, 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

Multiplying the emission factor with the appropriate energy consumption or production figure yields the emission.

5 DETAILED METHODOLOGY

The quality of an estimation of emission is strongly dependent on the management of the process. The estimation of the main emission sources should be based on measurements at the different process stages.

6 RELEVANT ACTIVITY STATISTICS

European statistics for the production of iron, steel and malleable iron castings in the European Community are available. For energy consumption statistics, data from the IEA can be used.

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

The following Table 3 contains fuel related emission factors for grey iron foundries based on CORINAIR90 data in [g/GJ]. 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.

Table 3: Emission factors for grey iron foundries⁷⁾

		Emission factors								
Type of fuel	NAPFUE code	SO ₂ [g/GJ]	NO _x [g/GJ]	NMVOC [g/GJ]	CH ₄ [g/GJ]	CO [g/GJ]	CO ₂ [kg/GJ]	N ₂ O [g/GJ]	NH ₃ [g/GJ]	
s coal	h steam c	102	130-160 ¹⁾	12-80 ¹⁾	15-57 ¹⁾	5-15 ¹⁾	20 ¹⁾	93-94 ¹⁾	4-5 ¹⁾	
s coal	b briquettes c	106	44 ¹⁾	12 ¹⁾	15-57 ¹⁾	6.3-15 ¹⁾	97 ¹⁾	3-5 ¹⁾		
s coke	h coke oven c	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	b coke oven c	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.

For the situation in the Netherlands, the following can be proposed for heavy metal emissions:

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

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

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

The emission factors are given in table 4.

Table 4: Emission factors for foundries (g.Mg^{-1} product)

Substance	Emission factor [15]	Range [15]
Arsenic	0.3	0.02 - 3.6
Cadmium	0.14	0.006- 0.45
Chromium	1.1	0.09 - 3.0
Lead	7.2	0.24 -15
Nickel	0.5	0.01 - 1.3
Zinc	5.0	2.4 - 7.2

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

15 SUPPLEMENTARY DOCUMENTS

- [1] Annual report of the Common Association of Dutch Foundries 1989; AVNEG; 1990
- [2] AVNEG; 1990 personal communication
- [3] Basic document Cadmium; Slooff, W., Ros, J.P.M.; RIVM report number 758476002; July 1987 (in Dutch)
- [4] Basic report Zinc; Haskoning; 1990 (in dutch)
- [5] Energy use for basic metal industry; Braun; 1990
- [6] Foundries 1987-1988 (SBI 34.0); Industrial production statistics; Central Office of Statistics; 1990
- [7] Air Note L214 concerning foundries (I); DHV-MT; 1990
- [8] Air Note L215 concerning foundries (II); DHV-MT; 1990
- [9] Emission Registration 13, Report Emission Registration Netherlands; Ministry VROM; May 1990
- [10] Atmospheric data from the Emission Registration concerning ferro and non-ferro companies; RIVM; 1991
- [11] Handbook of emission factors, Part 2: Industrial sources; Government Publishing Office, The Hague; 1983
- [12] Handbook of Model Descriptions of atmospheric emissions from the Iron Casting Foundries; TA-Luft; 1983
- [13] Die Europäische Giesserei-Industrie; Annual Statistic Report from the Association Committee of European Foundries; 1992

- [14] Industrial emission in the Netherlands, 5th inventory round - 1990; Publicatiereeks Emissieregistratie; Ministry VROM; 1993
- [15] Datenerhebung über die Emissionen Umweltgefährdenden Schwermetalle; Jöckel, W., Hartje, J.; Forschungsbericht 91-104 02 588 TÜV Rheinland e.V. Köln; 1991
- [16] Environmental Protection Agency; Compilation of air pollutant Emission Factors AP-42
- [17] PARCOM-ATMOS Emission Factors Manual.

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

- /1/ A.C. Baart, J.J.M. Berdowski, J.A. van Jaarsveld; Calculation of atmospheric deposition of contaminants on the North Sea; IWAD; ref. TNO-MW-R 95/138; TNO MEP; Delft; The Netherlands; 1995
- /2/ EPA (ed.): AIR Facility Subsystem, EPA-Doc. 450/4-90-003, Research Triangle Park, 1990
- /3/ EPA (ed.): AIR Chief; Version 4.0; 1995
- /4/ Air Pollution Aspects of the Iron Foundry Industry; APTD-0806, U.S.-EPA, Research Triangle Park (NC); 1974

18 BIBLIOGRAPHY

19 RELEASE VERSION, DATE, AND SOURCE

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20 POINT OF ENQUIRY

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