SNAP CODE: **030203**

SOURCE ACTIVITY TITLE: **PROCESS FURNACES WITHOUT CONTACT**
Blast Furnaces Cowpers

NOSE CODE: **104.12.01**

NFR CODE: **1 A 2 a**

ISIC: **2410**

1 ACTIVITIES INCLUDED

This chapter covers emissions released from the industrial combustion of blast furnace gas in cowpers (cupolas or hot stoves).

Other emissions of blast furnaces are covered by the following SNAP-codes of the category “Processes in Iron and Steel Industries and Collieries”.

- Blast furnace charging SNAP code 040202, see chapter B422
- Pig iron tapping SNAP code 040203, see chapter B423

Figure 1 gives a key plan of a blast furnace process including a blast furnace cowper.

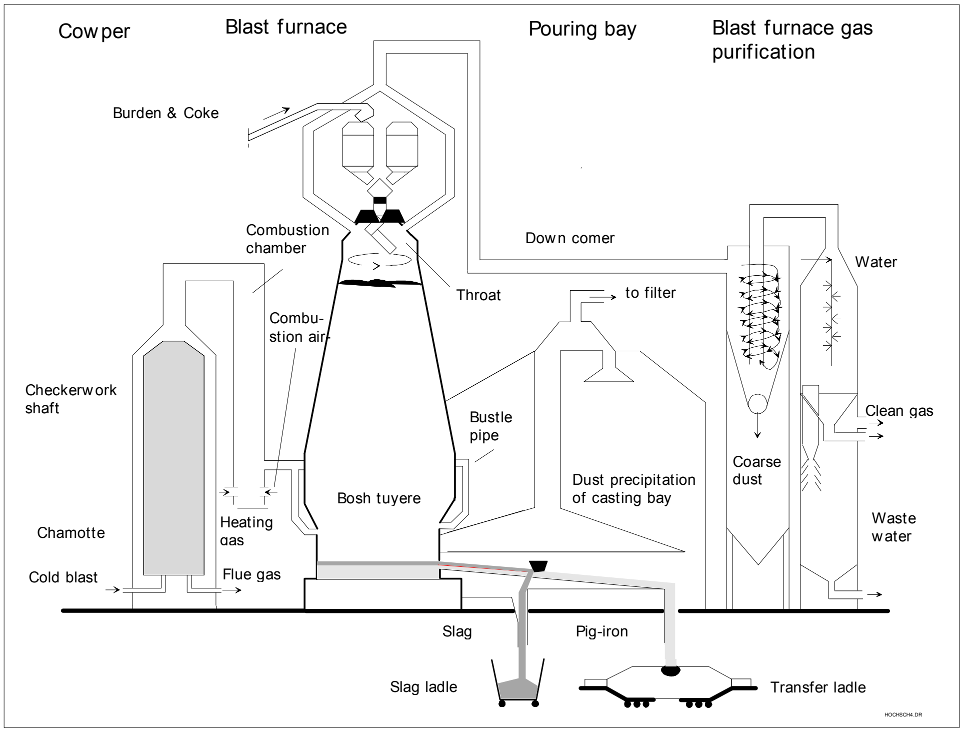

Figure 1: Flow diagram of the blast furnace process /cf. 9/

2 CONTRIBUTION TO TOTAL EMISSIONS

The contribution of emissions released from blast furnace cowpers to total emissions in countries of the CORINAIR'90 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 [%]**										
Blast Furnaces Cowpers	030203	SO_2	NO_x	NMVOC	CH_4	CO	CO_2	N_2O	NH_3	TSP*	PM_{10}*	$PM_{2.5}$*
Typical contribution		0.1	0.2	0	0	1.6	1.3	0.1	-	0.092	0.171	0.201
Highest value										0.235	0.413	0.444
Lowest value										0.005	0.012	0.020

* for total blast furnace process (cowpers, charging and tapping), EU $PM_{2.5}$ Inventory project for EU25 for the year 2000 (TNO, 2006), contribution to total national emissions, excluding agricultural soils
0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)
- = no emissions are reported

3 GENERAL

3.1 Description

Here, the blast furnace is described as a whole in order to understand the role of the blast furnace cowpers or hot stove within the overall process[1]. Detailed information concerning emissions other than from blast furnace cowpers is given in chapters B422 and B423.

The blast furnace operates as a countercurrent process. Iron ore sinter and size-graded iron ore, coke and limestone are charged as necessary into the top of the furnace. Preheated air is introduced through a large number of water-cooled nozzles at the bottom of the furnace (tuyeres) and passes through the descending charge. Carbon monoxide is produced, which reacts with the heated charge to form molten high-carbon iron, slag and blast furnace gas. /2, 7/ The molten iron and slag are periodically discharged from tap holes.

3.2 Definitions

Blast furnace refractory-lined shaft furnace. The ore and the preheated air (coming from the cowper) are charged countercurrently (see also section 3.3). In a blast furnace the iron ore is reduced to pig iron by using the reaction of coke (coming from the coke oven plant) and oxygen as energy source, producing CO as reduction agent (for further details see chapters B422 and B423).

Cowpers process unit, which is fired by blast furnace gas for indirect preheating of air.

3.3 Techniques

Blast furnace gas (off-gas) released at the top of the furnace is collected and is used as fuel for the cowpers. Typical fuels used for the cowpers are natural gas, coke oven gas and blast furnace gas. But also liquid fuels can be used which require different types of burner. In some countries (e.g. Sweden) a blend of coke oven and blast furnace gas is used as fuel /5/.

In order to facilitate the combustion of blast furnace gas, dust removal is necessary. In most cases a cyclone and a one or two-stage cleaning device are installed. The primary cleaner is normally a wet scrubber which removes 90 % of the particulates. The secondary cleaner is normally a high-energy wet scrubber (usually a venturi) or an electrostatic precipitator. Cleaned blast furnace gas contains less than 0.05 g/m^3 of particulates. /2, 3/

3.4 Emissions

Blast furnace gas contains about 21 - 28 % CO, inert components (50 % N_2, 23 % CO_2), some sulphur compounds and high amounts of dust (from iron ore, sinter and coke) /cf. 7, 8/. CO_2 originates from the complete oxidation of carbon in the blast furnace. Some blast furnace cowpers use a blend of blast furnace gas and alternative fuels. The most common alternative is coke oven gas, but also natural gas can be used.

[1] For a more detailed explanation of the functioning of cowpers see the chapter 7.1.2 on hot stoves in the BREF on Production of Iron and Steel production.

Relevant pollutants are carbon monoxide (CO) and carbon dioxide (CO_2). Sulphur oxides (SO_x), nitrogen oxides (NO_x), volatile organic compounds (non-methane VOC and CH_4) and nitrous oxide (N_2O) are of less relevance. Emissions of dust which may contain heavy metals, are also of relevance /cf. 3/. Emissions of ammonia (NH_3) are not relevant. Emissions of carbon monoxide (CO) occur due to incomplete combustion of blast furnace gas components.

3.5 Controls

Due to the low relevance of SO_2 and NO_x emissions, reduction measures for these pollutants are normally not installed.

4 SIMPLER METHODOLOGY

Emissions can be estimated at different levels of complexity; it is useful to think in terms of three tiers[2]:

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.

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 (A) with a comparable, representative, value of the emissions per unit activity, the emission factors (EF). The annual emission is determined according to Equation (1) by an activity and an emission factor:

$$E_i = EF_i \cdot A \quad (1)$$

E_i annual emission of pollutant i
EF_i emission factor of pollutant i

2 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.

A activity

The activity A and the emission factor EF_i have to be determined on the same level of aggregation by using available data. The CORINAIR90 methodology requires for blast furnace cowpers activity data, which is related to fuel consumption in [GJ/a].

Here, it is assumed, that the required activity data (according to CORINAIR90) are not available (see Equation (1)). In practice, statistics (see also Section 6), which often provides only the production of pig iron in [Mg/a], have to be used.

In order to approximate activity data referring to the energy input into blast furnace cowpers in [GJ/a] the specific blast furnace gas consumption and the lower heating value have to be taken into account as given e.g. in Equation (2):

$$A_{COR} = F \cdot H_u \cdot A_{Stat} \qquad (2)$$

A_{COR} activity in CORINAIR-compatible unit (energy input [GJ])
F specific blast furnace gas consumption (blast furnace gas/pig iron produced [m^3/Mg pig iron])
H_u lower heating value of coke oven gas [GJ/m^3]
A_{stat} activity directly obtained from statistics (pig iron production [Mg])

For the determination of the energy input only the gas consumption by the blast furnace cowpers has to be taken into account. The production of blast furnace gas can be given as about 1,300 to 2,000 m^3/Mg crude steel. About 25 % of the blast furnace gas obtained is used for the cowpers /4/. Country specific conditions have to be taken into account, e.g. one of the two Swedish iron and steel plants uses 46 % of the blast furnace gas produced and 18 % of the coke oven gas produced for combustion in cowpers /5/. Blast furnace gas has a lower heating value of about 2,790 to 3,350 kJ/m^3 /2/.

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 Tier 3), to estimate emissions of gaseous pollutants from the cowpers is based on measurements or estimations using plant specific emission factors .

Here, CORINAIR90 compatible activity data for blast furnace cowpers (related to the type of fuel consumed in [GJ/a]) are directly available (Equation (1)).

Guidance on determining plant specific emission factors is given in the Measurement Protocol Annex.

5.1 Emission factors

Emission factors for SO_2, NO_x, NMVOC and CH_4, CO, CO_2, and N_2O in mass pollutant/mass product [g/Mg] and in mass pollutant/energy input [g/GJ] are given in Table 8.1 (see Section 8) based on literature data.

6 RELEVANT ACTIVITY STATISTICS

Information on the production of pig iron, suitable for estimating emissions using of the simpler estimation methodology (Tier 1 and 2), is widely available from UN statistical yearbooks or national statistics.

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

Statistics concerning the fuel consumption of blast furnace cowpers are not 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

Integrated iron and steel plants with a production capacity of more than 3 million Mg/a have to be treated as point sources according to the CORINAIR90 methodology. Blast furnace cowpers included in these integrated iron and steel plants have to be considered as parts of the point source.

8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

The following Table 8.1 contains emission factors for blast furnace cowpers. Blast furnace cowpers are mostly fired by blast furnace gas; other types of fuel, which have been reported in CORINAIR90, are given in footnotes. A blend of blast furnace gas and coke oven gas is not taken into account.

Table 8.1: Emission factors for blast furnace cowpers

Type of fuel[1)]			NAPFUE code	Emission factors						
				SO_2 [g/GJ]	NO_x [g/GJ]	NMVOC[4)] [g/GJ]	CH_4[4)] [g/GJ]	CO[5)] [g/GJ]	CO_2[3)] [kg/GJ]	N_2O [g/GJ]
g	gas	natural	301	0.5 - 8[2)]	15 - 50[2)]	2.5 - 5[2)]	2.5 - 5[2)]	10 - 200[2)]	55 - 56[2)]	1.5 - 3[2)]
g	gas	coke oven	304	12 - 25[2)]	15 - 146[2)]	2.5 - 6.2[2)]	2.5 - 112[2)]	10 - 70[2))]	42 - 46[2)]	1 - 3[2)]
g	gas	blast furnace	305	0.93 - 56[2)]	13 - 145[2)]	5 - 6.2[2)]	112[2)]	10 - 69[2)]	100 - 290[2)]	1 - 3[2))]

1) The following fuels have been reported within CORINAIR90, but it can be assumed, that their relevance is very low:

sub-bituminous coal: NAPFUE 103; NMVOC 10; CH_4 10; CO 15; N_2O 12 [g/GJ][2)]

coke oven coal: NAPFUE 107; NO_x 141; NMVOC 2; CH_4 0.03; CO 120; CO_2 15 10^3-108 10^3; N_2O 3 [g/GJ][2)]

residual oil: NAPFUE 203; SO_2 223-305; NO_x 112-521; NMVOC 3; CH_4 3-112; CO 13-15; CO_2 76 10^3 -78 10^3; N_2O 2.8-14 [g/GJ][2)]

gas oil: : NAPFUE 204; NMVOC 2.5-6.2; CH_4 2.5; CO 12; CO_2 74 10^3; N_2O 14 [g/GJ][2)]

2) CORINAIR90 data

3) CO_2: 367 - 385 kg/Mg pig iron: conventional blast furnace (1989) /6/

4) VOC: 198 g/Mg iron: conventional blast furnace, average /6/

5) CO: 640 - 5,023 g/Mg product: conventional blast furnace process (1989) /6/

Particulate matter emissions from the hot stoves total less than 10 mg/Nm3. This is equivalent to approximately 3-6 g/t pig iron produced (10). No information is available on particle size distribution; ‘expert judgement’ would be to assume all PM is $PM_{2.5}$ (that is use PM factor for TSP, PM10 and $PM_{2.5}$ and is consistent with chapter B111 on gas-fired combustion sources,

For emission factors on particulate matter (TSP, PM_{10} and $PM_{2.5}$) from CEPMEIP (11) from the whole blast furnace operation see chapters 422 on blast furnace charging and 423 on pig iron tapping.

9 SPECIES PROFILES

Species profiles for oxides of sulphur and nitrogen are comparable to those released from combustion installations. Details can be found in chapter B111 “Combustion Plants as Point Sources” (Section 9).

10 UNCERTAINTY ESTIMATES

11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY

Weakest aspects discussed here are related to emission factors and activities.

At this stage emission factors are only applicable when using 100 % blast furnace gas. Further work should be invested toward providing activity data for a representative split of the fuel gases used and in providing corresponding emission factors e.g. for a blend of blast furnace and coke oven gas. CORINAIR90 data can only be used in order to give a range of emission factors.

12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES

Not applicable.

13 TEMPORAL DISAGGREGATION CRITERIA

Temporal disaggregation of annual emission data (top-down approach) would provide a split into monthly, weekly, daily and/or hourly emission data. Temporal disaggregation of annual emissions released from blast furnace cowpers can be obtained by taking into account the

- time of operation, and
- variation of load depending on the demand for iron and steel.

Data for the annual time of operation in iron and steel plants should take into account that

- iron and steel plants produce during the whole year and blast furnace gas is continuously released.

Data for the variation in the demand for iron and steel can only be obtained directly from plant operators.

14 ADDITIONAL COMMENTS

No additional comments.

15 SUPPLEMENTARY DOCUMENTS

No supplementary documents.

16 VERIFICATION PROCEDURES

As outlined in the chapter on "Concepts for Emission Inventory Verification" different verification procedures can be recommended. Verification procedures considered here are principally based on the verification of emission data on a national level and on a plant level.

Emission data for blast furnace cowpers can be verified on territorial unit level (e.g. national level) by comparing the annual emissions related to a territorial unit to independently derived emission estimates (e.g. obtained by using population equivalents). Another possibility is the use of emission density comparisons of e.g. emissions per capita or emissions per GDP between countries with comparable economic structures.

Verification on a plant level takes into account e.g. the number of blast furnace cowpers within the iron and steel plants considered. The verification on a plant level relies on comparisons between calculated emissions/emission factors and those derived from emission measurements.

17 REFERENCES

/1/ CITEPA (ed.): CORINAIR - Emission Factor Handbook; Paris; 1992

/2/ US-EPA (ed.): Compilation of the Pollutant Emission Fraction; Version 1; Stationary Point and Area Sources; 1986; AIR CHIEF Version 2.0 Beta; 1992

/3/ Economic Commission of Europe (ed.): Task Force on Heavy Metals Emissions; State-of-the-Art Report; Prague; 1994

/4/ Krumm, Wolfgang: Mathematische Modellierung und Optimierung der Energieverteilung im integrierten Hüttenwerk; in: Energieerzeugung VDI; Düsseldorf (Germany); 1989

/5/ Ms. Froste, Mr. Kvist, Mr. Lannerblom: Personal communication; 1995

/6/ Annema, J. A.; Albers, R. A. W.; Boulan, R. P.: Productie van Primair Ijzer en Staal; RIVM-report 736301131; RIZA-report 92.003/31; 1992

/7/ Parker, Albert (ed.): Industrial Air Pollution Handbook; Maidenhead (England); 1978

/8/ Havenaar, P.; Santen, D. J.; Verrier, K.: Blast furnace gas fired co-generation plant; in: Combustion Technology 1994, VGB Technische Vereinigung der Großkraftwerkbetreiber e.V. (ed.), Essen (Germany); 1994

/9/ Rentz, O.; Püchert, H.; Penkuhn, T.; Spengler, T.: Produktionsintegriertes Stoffstrommanagement in der Eisen- und Stahlindustrie; Konkretisierung des § 5 Abs. 1 Nr.3 BImSchG; Umweltbundesamt Berlin (ed.); Deutsch-Französisches Insitut für Umweltforschung; Karlsruhe; 1995 (to be published)

/10/ IPPC Best Available Techniques Reference Document on the Production of Iron and Steel, December 2001, http://eippcb.jrc.es

/11/ 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

No additional documents.

19 RELEASE VERSION; DATE AND SOURCE

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20 POINT OF ENQUIRY

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