

**SNAP CODE:** 040205

**SOURCE ACTIVITY TITLE:** PROCESSES IN IRON & STEEL INDUSTRIES & COLLIERIES  
*Open Hearth Furnace Steel Plant*

**NOSE CODE:** 105.12.05

**NFR CODE:** 2 C 1

## 1 ACTIVITIES INCLUDED

Steel production process in an open-hearth furnace is divided into five basic stages: furnace adaptation, furnace charging, melting, refining and cast finishing.

Individual stages differ from each other with respect to heat load, metallurgical reactions processing and duration. These differences directly influence the quality and quantity of emitted pollutants.

## 2 CONTRIBUTION TO TOTAL EMISSIONS

This process is being gradually phased out in particular in Western Europe and its percentage contribution to total pollutant emission should decrease. According to the OSPARCOM-HELCOM-UNECE inventory for 1990 almost all heavy metal emissions from this source category occur in Central and Eastern Europe (see Table 2-3). The share of steel smelting by the open hearth method in the CIS countries exceeds 60-65%, though there is a tendency for its decrease and transition to a converter method and electric arc smelting. (Kakareka et al; 1998).

**Table 2-1: Contribution to total emissions of the CORINAIR90 inventory (28 countries)**

Source-activity	SNAP-code	Contribution to total emissions [%]								
		SO <sub>2</sub>	NO <sub>x</sub>	NMVOC	CH <sub>4</sub>	CO	CO <sub>2</sub>	N <sub>2</sub> O	NH <sub>3</sub>	PM*
Open Hearth Furnace Steel Plant	040205	0	0.1	0	0	0	-	-	-	-

0 = emissions are reported, but the exact value is below the rounding limit (0.1 per cent)

- = no emissions are reported

\* = PM (inclusive of TSP, PM<sub>10</sub> and PM<sub>2.5</sub>) is <0.1% of total PM emissions

**Table 2-2: Contribution to total heavy metal emissions of the OSPARCOM-HELCOM-UN/ECE inventory for 1990 (up to 38 countries)**

Source-activity	SNAP-code	Contribution to total emissions [%]							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Open Hearth Furnace Steel Plant	040205	0.4	4.1	2.8	2.5	-	-	1.7	2.7

**Table 2-3: Contribution of Central and Eastern European countries (19 countries) to total sector emissions of the OSPARCOM-HELCOM-UN/ECE inventory for 1990**

Source-activity	SNAP-code	Contribution to total <u>sector</u> emissions [%]							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Open Hearth Furnace Steel Plant	040205	100	92	100	100	-	-	95	100

### 3 GENERAL

#### 3.1 Description

This process covers the production of steel in an air furnace fired with gas or fuel oil. The basic metallic charge consists of pig iron and scrap. Ferroalloys, deoxidizers and ore are also used as charge.

Slag generation depends on limestone, lime, fluorite and bauxite used in the process. The composition of charge and the properties of added compounds influence the steel quality as well as the quality and quantity of air pollutants generated in the process. Fuel gas and air necessary in the process are heated up in the regenerator to a temperature of 1100°C and then led to the working space of furnace, where after combustion the furnace gases reach a temperature of 1700 - 1800° C and heat the charge in the oxidising atmosphere.

#### 3.2 Definitions

- pig iron - crude iron obtained directly from the blast furnace and cast in moulds
- scrap method - re-use of metals as raw material for the process
- deoxidizers - substances used for removing oxygen from molten metals
- direct emissions - stack emissions (i.e. ducted gas flow), excludes fugitive emissions

### 3.3 Techniques

Metal smelting by the open-hearth method is performed on the bottom of the combustion reverberatory kiln supplied with regenerators (Kakareka et al.; 1998).

The construction of individual parts of the furnace depends on many factors, including the type of fuel and process as well as oxygen addition. Types of furnaces can vary with respect to the construction of heads, type of automatisisation and lining with refractory materials of the furnace bottom, walls and roof.

As the basis for the classification of open hearth furnaces the following elements were assumed: furnace capacity, fuel type, bottom surface, calorific value of the fuel used, number of charging doors. Taking into consideration the calorific value of the fuel used and the roof lining, open-hearth furnaces can be divided into four groups:

- furnaces fired with low calorific value fuel with acidic roof;
- furnaces fired with low calorific value fuel with basic roof;
- furnaces modernised for high calorific value fuels;
- furnaces adapted for oxygen aiding.

Open-hearth furnace capacities range 100 to 900 tonnes. The most widespread are open-hearth one-bath furnaces with regenerators, which make up 65% of all furnaces used in CIS countries. In one-bath furnaces fuel together with air is previously heated up in regenerators then goes to the above-bath space, where it melts the metal by charge combustion. The products of combustion at a temperature of 1600-1700°C go to a reserve regenerator heating it up. Periodically the direction of a fuel-air mixture feed changes, thus, the temperature of blast is maintained in the range of 1000-1200°C. During the smelting process the following periods are distinguished: fettling, batch charging, warm-up, smelting, bath-boiling, finishing, deoxidisation and steel alloying. Dust emissions increase significantly in the period of smelting and bath boiling due to the process of intensive oxygen use.

As a whole, at operation of one-bath open-hearth furnaces the oxygen blow is used in 30 % of installations in CIS countries.

Double-bath furnaces represent the unit of two aligned and alternately blown down baths. The furnaces do not have regenerators and operate mainly without fuel burners, and CO formed in one bath is combusted above the second one. Double-bath furnaces are characterised by high productivity and high dust emissions. Thus, if in a usual furnace the duration of smelting depends on its capacity and varies from 8 to 15 hours, and at the increase of oxygen charge it takes 5-11 hours, then in double-bath – it is only 4-5 hours. (Kakareka et al.; 1998)

### 3.4 Emissions

Dust generation in open-hearth furnaces depends on three basic processes that take place in the working surface of the furnace:

- combustion
- mechanical impact of furnace atmosphere and charge,
- chemical processes

The furnace gases flow through the working chamber of the furnace with velocity of 1.5 - 2.5 m/s. This flow results in entrainment of fine particles of charge in the initial process of heating and in the refining process.

The chemical processes taking place in fluid metal actively increase dust-generation in the furnace gases. Especially in the process of intensive refining, rising CO bubbles throw particles to the surface of the melt which are then entrained by furnace gases increasing in this way the dust load.

Introduction of ore materials into the furnace as well as of dolomite and limestone affects slag generation and results also in an increase in furnace gas dust generation. Moreover, a considerable increase of furnace gas dust generation is observed during oxygen application for intensification of combustion and refining processes.

The concentration of dust in furnace gas heating changes during the process. Moreover, the concentration in individual periods depends on a whole range of factors, from which the following are the most important ones:

- type of charge material,
- type of process used,
- technical condition of the furnace,
- type of fuel,
- application of oxygen during the melting and refining processes.

The amount and temperature of furnace gases depends also on many factors including: furnace capacity, type of fuel, type of roof lining, furnace construction (stationary, tilting), type of heads and technical condition of a furnace. The SO<sub>2</sub> content in furnace gas is relatively low even in the case of using residual oil as a fuel.

### 3.5 Controls

In the case of purifying furnace gases from open-hearth furnaces the effectiveness of dust removal units should not be lower than 99%. That is why wet scrubbers, electrostatic precipitators or fabric filters are used for furnace gas dust removal.

The wet scrubbers were the earliest to be applied for furnace gas dust removal from open-hearth furnaces. They usually consist of two elements: dust coagulator and basic dedusting unit. The dedusting systems most often used in the case of open-hearth furnaces are electrostatic precipitators. Their efficiency is very high and usually exceeds 99%. Only in a few cases lower efficiencies (i.e. in the range 94-98%) are observed. However, obsolete equipment reduces cleaning efficiency to about 85%.

For flue gas cleaning at double-bath furnaces both wet and dry cleaning systems are applied. Dry systems are more widely used where gases are cooled and cleaned first in the waste heat boiler and in the scrubber and then in an electrostatic precipitator. (Kakareka et al.; 1998)

Recently, fabric filters have been applied to the purification of furnace gas from open-hearth furnaces. They allow to reach an efficiency of 99% or even higher, independently from the

dust contents in furnace gas. Nonetheless, they require an especially precise design and proper selection of technical parameters.

#### 4 SIMPLER METHODOLOGY

The simplest method of emissions estimation is their assessment on the basis of the amount of steel production from individual open-hearth furnace steel plants, or country production of steel in open-hearth furnace steel plants and average emission factors for a particular pollutant (one factor for systems without abatement and an alternative factor for systems with abatement).

The USEPA has published particulate size distribution data for open hearth steel making and these are summarised in Table 8.1.

#### 5 DETAILED METHODOLOGY

The detailed methodology is based on emission factors as well and requires in addition the consideration of:

- type and capacity of furnace;
- type of charge (ore, scrap, ore + scrap);
- type of fuel used (residual oil, natural gas + residual oil, coke-oven gas + residual oil, generator gas + residual oil);
- type of emission control devices.

This method can be applied for the whole period of steel production process or to its separate stages, i.e.:

- charging
- melting
- refining
- finishing

In the detailed methodology, emissions are assessed on the basis of the data on the amount of steel production in open-hearth furnace processes for individual steel plant and adequate emission factors considering: furnace capacity, type of charge, type of used fuel and abatement devices used for the whole process or its separate stages.

Emissions can be also determined on the basis of emission measurements, covering the individual stages of the process.

Should a key source analysis indicate this to be a major source of particulate matter (TSP, PM<sub>10</sub> or PM<sub>2.5</sub>) then installation level data should be collected using a measurement protocol such as that illustrated in Measurement Protocol Annex.

## 6 RELEVANT ACTIVITY STATISTICS

For the simpler methodology, steel production in individual open-hearth furnace steel plants or on the country level is required.

For the detailed methodology of emissions assessment statistical data on steel production for individual steel plants with further split into furnace capacity, type of process and fuel used are required.

## 7 POINT SOURCE CRITERIA

Open-hearth furnace steel plants should be considered as point sources where relevant point source data are available.

## 8 EMISSION FACTORS, QUALITY CODES AND REFERENCES

**Table 8-1: Open hearth steel-making PM emission factors**

Process	Control	Emission factor, kg/Tonne		
		TSP	PM <sub>10</sub>	PM <sub>2.5</sub>
Open hearth steel-making	Unabated	10.55	8.76	6.33
	Electrostatic precipitator	0.14	0.07	0.05

Note that these emission factors are dated 1986 and may not be appropriate to facilities with modern abatement. The factors have the lowest USEPA quality rating (E).

Emission factors relevant for the whole process consisting of 5 stages are presented in table 8-2.

## 9 SPECIES PROFILES

A detailed chemical composition of furnace gas generated in the open-hearth furnace process is presented in table 9-1 for volatile organic compounds (VOC).

**Table 9-1: Composition of open-hearth furnace gas**

		according to Veldt (CORINAIR 1995)	Poland (Olczak (1993))
methane	C <sub>1</sub>		89.13 %
ethane	C <sub>2</sub>		2.9 %
propane	C <sub>3</sub>		
butane	C <sub>4</sub>		
ethylene	C <sub>2=</sub>		
acetylene	C <sub>2</sub>		
propylene	C <sub>3=</sub>		
butylene	C <sub>4</sub>		
hexane	C <sub>6</sub>	7 %	

heptane	C7	36 %	
benzene	B	13.5 %	7.97 %
toluene	T	3.5 %	
xylene	K		
trimethyl-fluorosilane	tmFs	40 %	
Total		100 %	100 %

Concentrations of heavy metals in dust from various sampling points at an open-hearth furnace are presented in table 9-2.

**Table 9-2: Content of heavy metals in open-hearth dust [mg/kg] (Kakareka et al.; 1998)**

Sampling point	Hg	Cd	Pb	Zn	Ni	Cu
Collector of gas removal from the open-hearth furnace	-	269.2	7584	7553	85	390
Collector of gas removal from the drop separator	-	329.2	7856	10680	148	682
Spray catcher of Venturi scrubber	0.098	60.8	1083	2914	70	235

Table 8-2: Emission Factor Table

Compound	Plant type	Emission factor	Data Quality	Abatement type	Abatement efficiency	Fuel type	Country or region	Ref.
SO <sub>2</sub>	Capacity up to 100 Mg	0.09 kg/Mg steel	E	n. a.	n. a.	n. a.	Poland	Jarzebski(1970)
SO <sub>2</sub>	Capacity > 100 Mg	0.16 kg/Mg steel	E	n. a.	n. a.	n. a.	Poland	Jarzebski(1970)
SO <sub>2</sub>	unknown	0.09 kg/Mg steel	E	n. a.	n. a.	gaseous	Poland	Jarzebski(1970)
SO <sub>2</sub>	unknown	0.18 kg/Mg steel	E	n. a.	n. a.	residual oil	Poland	Jarzebski(1970)
NO <sub>x</sub>	unknown	55 – 96 g/GJ	E	n. a.	n. a.	n. a.	Europe	CORINAIR(1995)
NO <sub>x</sub>	unknown	5.1 g/Mg steel	C	n. a.	n. a.	n. a.	Poland	Jarzebski(1970)
NM VOC	unknown	0.45 kg/Mg steel	D	n. a.	n. a.	n. a.	Europe	CORINAIR(1995)
NM VOC	unknown	0.02 kg/Mg steel	C	n. a.	n. a.	n. a.	Poland	Fudala (1993)
CH <sub>4</sub>	unknown	0.005 kg/Mg steel	E	n. a.	n. a.	n. a.	Europe	CORINAIR(1995)
CH <sub>4</sub>	unknown	0.12 kg/Mg steel	C	n. a.	n. a.	n. a.	Poland.	Olczak (1993)
Particulates	unknown	10.55 kg/Mg steel	A	uncontrolled	0 %	n. a.	USA	US EPA (AP-42)
Particulates	unknown	0.142 kg/Mg steel	A	controlled	n. a.	n. a.	USA	US EPA (AP-42)
Particulates	Capacity up to 100 Mg	1.9 kg/Mg steel	E	n. a.	n. a.	n. a.	Poland	CORINAIR(1995)
Particulates	Capacity > 100 Mg	2.5 kg/Mg steel	E	n. a.	n. a.	n. a.	Poland	CORINAIR(1995)
Particulates	unknown	2.03 kg/Mg steel	E	n. a.	n. a.	gaseous	Poland	CORINAIR(1995)
Particulates	unknown	2.4 kg/Mg steel	E	n. a.	n. a.	residual oil	Poland	CORINAIR(1995)
As	Capacity 50-370 Mg	0.6 – 0.9 g/Mg steel	E	n. a.	n. a.	liquid &/or gaseous	Poland.	Wessely (1993)
Cd	unknown	0.5 – 0.9 g/Mg steel	E	n. a.	n. a.	n. a.	Germany	Jockel (1991)
Cd	Capacity 50-370 Mg	0.2 g/Mg steel	E	n. a.	n. a.	liquid &/or gaseous	Poland	Wessely (1993)
Cd	one-bath furnace, air	0.12 g/Mg steel	C	direct em.	85 %	n. a.	CIS	Kakareka (1998)
Cd	one-bath furnace, air	0.008 g/Mg steel	C	direct em.	99 %	n. a.	CIS	Kakareka (1998)
Cd	one-bath furnace, O <sub>2</sub>	0.40 g/Mg steel	C	direct em.	85 %	n. a.	CIS	Kakareka (1998)
Cd	one-bath furnace, O <sub>2</sub>	0.03 g/Mg steel	C	direct em.	99 %	n. a.	CIS	Kakareka (1998)
Cd	double-bath furnace	0.59 g/Mg steel	C	direct em.	85 %	n. a.	CIS	Kakareka (1998)
Cd	double-bath furnace	0.04 g/Mg steel	C	direct em.	99 %	n. a.	CIS	Kakareka (1998)
Cr	Capacity 50-370 Mg	6.6 – 13.8 g/Mg steel	C	n. a.	n. a.	liquid &/or gaseous	Poland	Wessely (1993)



**Table 8-2: continued**

Cu	<i>Capacity 50-370 Mg</i>	3.6 – 7.8 g/Mg steel	<i>C</i>	<i>n. a.</i>	<i>n. a.</i>	<i>liquid &amp;/or gaseous</i>	<i>Poland</i>	<i>Wessely (1993)</i>
<i>Cu</i>	<i>one-bath furnace, air</i>	0.23 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Cu</i>	<i>one-bath furnace, air</i>	0.015 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Cu</i>	<i>one-bath furnace, O<sub>2</sub></i>	0.78 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Cu</i>	<i>one-bath furnace, O<sub>2</sub></i>	0.05 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Cu</i>	<i>double-bath furnace</i>	1.18 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Cu</i>	<i>double-bath furnace</i>	0.08 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>one-bath furnace, air</i>	0.05 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>one-bath furnace, air</i>	0.003 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>one-bath furnace, O<sub>2</sub></i>	0.18 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>one-bath furnace, O<sub>2</sub></i>	0.01 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>double-bath furnace</i>	0.27 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Ni</i>	<i>double-bath furnace</i>	0.02 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>unknown</i>	7.0 – 18.0 g/Mg steel	<i>E</i>	<i>n. a.</i>	<i>n. a.</i>	<i>n. a.</i>	<i>Germany</i>	<i>Jockel (1991)</i>
<i>Pb</i>	<i>Capacity 50-370 Mg</i>	9.1 – 19.8 g/Mg steel	<i>C</i>	<i>n. a.</i>	<i>n. a.</i>	<i>liquid &amp;/or gaseous</i>	<i>Poland</i>	<i>Wessely (1993)</i>
<i>Pb</i>	<i>one-bath furnace, air</i>	5.30 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>one-bath furnace, air</i>	0.35 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>one-bath furnace, O<sub>2</sub></i>	18.18 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>one-bath furnace, O<sub>2</sub></i>	1.21 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>double-bath furnace</i>	27.27 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Pb</i>	<i>double-bath furnace</i>	1.82 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>Capacity 50-370 Mg</i>	73.3 – 150.2 g/Mg steel	<i>C</i>	<i>n. a.</i>	<i>n. a.</i>	<i>liquid &amp;/or gaseous</i>	<i>Poland</i>	<i>Wessely (1993)</i>
<i>Zn</i>	<i>one-bath furnace, air</i>	7.81 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>one-bath furnace, air</i>	0.52 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>one-bath furnace, O<sub>2</sub></i>	26.77 g/Mg steel	<i>C</i>	<i>direct em.</i>	85 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>one-bath furnace, O<sub>2</sub></i>	1.78 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>double-bath furnace</i>	40.15 g/Mg steel	<i>C</i>	<i>direct em.</i>	85%	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>
<i>Zn</i>	<i>double-bath furnace</i>	2.68 g/Mg steel	<i>C</i>	<i>direct em.</i>	99 %	<i>n. a.</i>	<i>CIS</i>	<i>Kakareka (1998)</i>

n. a.= not available

direct em = direct stack emissions (i.e. ducted gas flow), excludes fugitive emissions

**10 UNCERTAINTY ESTIMATES**

The uncertainty in the emission factors given in Section 8 varies, but in many cases a data quality rating of C has been assigned because process technologies and abatement efficiencies are documented. Uncertainty of estimates based on default emission factors without such a specification is high and only the order of magnitude may be assessed.

**11 WEAKEST ASPECTS/PRIORITY AREAS FOR IMPROVEMENT IN CURRENT METHODOLOGY**

Priority for further work is low because the process is almost phased out in Western Europe and is being phased out in Eastern Europe.

**12 SPATIAL DISAGGREGATION CRITERIA FOR AREA SOURCES**

Not applicable because open-hearth furnace steel plant should be considered as point sources (see Section 7).

**13 TEMPORAL DISAGGREGATION CRITERIA**

The open-hearth furnace process is a continuous process.

**14 ADDITIONAL COMMENTS**

No additional comments.

**15 SUPPLEMENTARY DOCUMENTS**

No supplementary documents are required.

**16 VERIFICATION PROCEDURE**

Verification would involve internal checking of completeness and consistency of the estimate (to see if all process steps are covered by emission factors in section 8) as well as a comparison to alternative estimates for this source category e. g. from other countries.

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## 19 RELEASE VERSION, DATE AND SOURCE

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