



# BAT Guide for electric arc furnace iron & steel installations

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# **GLOSSARY AND ABBREVIATIONS**

UNITS

Term	Meaning
kWh	kilowatt-hours
billion	thousand million (10 <sup>9</sup> )
°C	degree Celsius
cm	centimetre
d	day
g	gram
GWg	gigawatt hours
h	hour
hPa	hectopascals
J	joule
К	kelvin (0 °C = 273.15 K)
kcal	kilocalorie (1 kcal = 4.19 kJ)
kW	kilowatt
kWh	kilowatt-hour (1 kWh = 3.6 MJ)
m	metre
Mt	megatonne
MW <sub>c</sub>	megawatts electric (energy)
MW	megawatt
Nm <sup>3</sup>	normal cubic metre (at 101.325 kPa, 273 K)
ppb	parts per billion (1 ppb = 10 <sup>-9</sup> )
ppm	parts per million (1 ppm = $10^{-6}$ )
ppmv	parts per million (by volume)
S	second
t	metric tonne (1000 kg or 10 <sup>6</sup> g)
t/d	tonnes per day
trillion	million million (10 <sup>12</sup> )
t/yr	tonnes per year
vol-%	percentage by volume
wt-%	percentage by weight
W	watt (1 W = 1 J/s)
yr	year
μg	microgram
μm	micrometre (1 $\mu$ m = 10 <sup>-6</sup> m)
μs	microsiemens
Ω	ohm, unit of electrical resistance

#### LIST OF CHEMICAL ELEMENTS

SYMBOL	NAME
Al	aluminium
As	arsenic





С	carbon
Са	calcium
Cd	cadmium
CI	chlorine
Cm	curium
Со	cobalt
Cr	chromium
Cu	copper
F	fluorine
Fe	iron
Н	hydrogen
Hg	mercury
К	Potassium
Mg	Magnesium
Mn	Manganese
Мо	Molybdenum
Ν	Nitrogen
Na	Sodium
Ni	Nickel
0	Oxygen
Р	Phosphorous
Pb	lead
Pt	platinum
S	sulphur
Sb	antimony
Se	selenium
Si	silicon
Sn	tin
Те	tellurium
Ti	titanium
V	vanadium
W	tungsten
Zn	zinc

#### ACRONYMS AND DEFINITIONS

Acronym	Definition
AC	Alternating current
AISI	American Iron and Steel Institute
AOD	Argon oxygen decarburisation
AOX	Absorbable organically bound halogens in water
AS	Activated sludge
ASK	Ammoniumsulphide Kreislaufwäscher
BaP	Benzo(a)pyrene
BF	Blast furnace
BOD	Biochemical oxygen demand





BOF	Basic oxygen furnace
Borneff 6	Sum of six PAH (Fluoranthene, Benzo[b]fluoranthene,
	Benzo[k]fluoranthene,Benzo[a]pyrene, Indeno[1,2,3-cd]pyrene
	and Benzo[g,h,i]perylene)
Bq	Bequerel
BTX	Benzene, Toluene, Xylene
с.	circa
CAS	Chemical abstracts service
CAS-OB	Composition adjustment by sealed argon bubbling
CCF	Cyclone converter furnace
CCGT	Combined cycle gas turbine
ССМ	Continuous casting machine
ССРР	Combined cycle power plant
CCS	Carbon capture and storage
CDQ	Coke dry quenching
CEN	European committee for standardisation
CFD	Computational fluid dynamics
СНР	Combined heat and power
COD	Chemical oxygen demand
COG	Coke oven gas
COS	Carbon oxysulphide
CRI	Coke reactivity index
CSQ	Coke stabilisation quenching
CSR	Coke strength after reaction
CV	Calorific value
DAV	Daily average
dBA	A-weighted decibels
DC	Direct current
DCI	Direct carbon injection
DH	Dortmund-Hörder
Diffuse emission	Diffuse emissions occur during regular operation such as coal and
	coke handling, transport of coal and coke, coal blending beds,
	ascension pipes, coke pushing, coke quenching; if not captured
	they can be released by the roof, roofhatch, window or from
	stored material. Minimisation is possible only by prevention
	and/or further treatment after transferring them into ducted
DIOS	Direct iron are smalting reduction
	Direct non ore smelling reduction
	Direct reduced iren
	Direct reduced non
	Direct sample induction
	Economicor
	Economiser
ECSU	
ECU	European Currency Unit
LEINECS	I European inventory of existing commercial chemical substances





ELPI	Electrical low pressure impactor
ELV	Emission limit value
EMS	Environmental management system
EMAS	Eco-Management and Audit Scheme
EN ISO 14001	European norm (EN) published by the International Organisation for Standardisation (ISO) concerning environmental management standards.
EOF	Energy optimised furnace
EOS	Emission optimised sintering
EPA	Environmental Protection Agency (US)
ESP	Electrostatic precipitator
ESCS	Electrostatic space cleaner super
ETP	Electrostatic tar precipitator
FF	Fabric filter
Fine dust	Fine dust in the sense of this BREF shall mean fine particulate matter smaller than 10 micrometer
Fugitive emissions	Fugitive emissions happen during irregular operation from leakages at the battery, e.g. because of leakage of vessels, oven doors, flanges etc. or at the byproduct plant. For minimisation the first option is prevention by good maintenance. PAH compounds, like benzo(a)pyrene (BaP), and benzene play an important role with regard to fugitive emissions
FTIR	Fourier transform infrared spectroscopy
GSA	Gas suspension absorber
НВІ	Hot briquetted Iron
НСВ	Hexachlorobenzene
HHAV	Half-hourly average
HM	Hot metal
hPa	Hectopascals
IISI	International Iron and Steel Institute
I-TEQ	International Toxicity Equivalents
IUPAC	International Union of Pure and Applied Chemistry
КОВМ	Klöckner Oxygen Blowing Maximillanshuette
kW	Kilowatt
LD	Linz-Donawitz
LD-AC	Linz-Donawitz-Arbed-CRM process
LEEP	Low emission and energy optimised sintering process
Leq	Equivalent Continuous Sound Level
LIBS	Laser-induced breakdown spectroscopy
LIDAR	Light detection and ranging
LPG	Liquefied petroleum gas
LS	Liquid steel
LTE	lance tuyère equilibrium
L <sub>WA</sub>	weighted sound power level
LWS	Loire-Wendel-Sprunck process
MEA	Monoethanolamine
MEEP	Moving electrodes Electrostatic Precipitator
MEROS	Maximised emission reduction of sintering





MHF	Multiple hearth furnace
MLSS	Mixed liquor suspended solids
NG	Natural gas
NMVOC	Non-methane volatile organic compounds
OBM	Oxygen-bottom Maxhuette process
OCP	Open circuit process
РАН	Polycyclic aromatic hydrocarbons
РСВ	Polychlorinated biphenyls
PCDD/F	Polychlorinated dibenzo-p-dioxins/dibenyofurans
PCI	Pulverised coal injection
PLC	Programmable Logic Controllers
PM <sub>10</sub> , PM <sub>25</sub>	Particulate matter smaller than 10 or 2.5 micrometer according to
	the definition of the Directive 2008/50/EC on air quality
POM	Polycyclic organic matter
POP5	Persistent organic pollutants
PTFE	Polytetrafluoroethylene
Q-BOP	Oxygen-bottom Maxhuette process
RAC	Regenerative activated carbon
RAFT	Raceway adiabatic flame temperature
RDM	Reverse dispersion modelling
RH	Ruhrstahl-Heraeus
RHF	Rotary hearth furnace
SCN	Thiocyanate
SCOPE 21	Super coke oven for productivity and environment enhancement
	in the 21 <sup>st</sup> century
SCR	Selective catalytic reduction
SI	Shatter index
Split view	Where a 'split view' is explicitly mentioned it means that there
	was not a consensus in the Technical Working Group elaborating
	the corresponding BREF document on the best available
	techniques and associated emission/consumption levels
SR	Smelting reduction
SRE	Smelting reduction furnace
SS	Suspended solids
STD	Standard temperature and pressure
ТЕЛ	Triethanolamine
TEO	
TEE	Toxic equivalent factor
TBM	Thyssen blowing metallurgy process
TOC	Total organic carbon
TWG	Technical working group
	Illtra high power operation
	Illtra Low <b>CO</b> <sub>2</sub> Steelmaking EC funding research programme to
01003	reduce CO <sub>2</sub> emissions from steelmaking
VDI	Verein Deutscher Ingenieure
VOC	Volatile organic compounds
VOD	Vacuum oxygen decarburisation
·	





w.c.	Water column
Wobbe index	The Wobbe Index (WI) is an indicator of the interchangeability of fuel gases such as natural gas, liquefied petroleum gas (LPG), and Town Gas and is frequently defined in the specifications of gas supply and transport utilities. If $V_c$ is the higher heating value, or calorific value, and $G_s$ is the specific gravity, the Wobbe Index, $I_w$ , is defined as: $I_w = Vc/(G_s)_{1/2}$
WWT	Waste water Treatment Plant
WHO TEFs	World Health Organisation toxic equivalent factors. This toxic equivalency factor (TEF) value is the only one for currently taking into account not only PCDD and PCDF values but 'dioxin-like' PCB [219, Van den Berg et al. 1998]





# 0 FOREWORD

This guide forms part of the work done by the Ministry of Environment and Urbanism of Turkey (MoEU) to align the environmental policies to the standards of the European Union. Within this context, one of the key targets is the alignment with the specifications stated in the Industrial Emissions Directive 2010/75/EU on the establishment of an integrated environmental permits system. According to this Directive, the environmental conditions established in the new integrated environmental permits must be based on the so-called Best Available Techniques (BATs) and the Associated Emission Levels (AELs), which are described in a series of BATs Reference Documents (BREFs).

The current target is to start the implementation of the new integrated environmental permits system in 2015, and as the associated environmental standards requested to the industries falling within the scope of this system will be substantially changed, there is a need of awareness and tools that may help them and the environmental authorities to start taking some measures in order to soften this transition.

The excessive length and wide scope of the BREF for the iron and steel industry, plus the importance of the electric arc furnace installations in Turkey were the reasons to prepare a BAT National Guide for the Iron and Steel Electric Arc Furnace Industry, focused just on this kind of installations, more understandable and adapted to the characteristics of the sector in Turkey, addressing in addition (but in less depth) related processes usually associated to this industry, and providing practical for both this industry and the staff of the MoEU. Therefore the scope of this Guide is the production of steel in electric arc furnace and the processes normally associated to it: hot and cold rolling, temperature treatments, wire plants and galvanization. When describing the processes and the BATs associated, whereas in the case of the production of steel, it has been done with a high level of detail, in the cases of the associated processes a summary has been reported with the reference to the associated BAT and only, for the most relevant environmental points, more detailed information has been included.

Moreover, it may serve as well to communicate to a broader audience the main characteristics of the sector and its main pollution abatement techniques, given its simple and concise style.

The objectives of this guide are the following:

- Present an overview of the sector in Turkey, and its current position in terms of environmental performance, with reference to the currently applicable environmental legislation (Chapters 1 & 3).
- Describe the processes, technologies and techniques particular of this kind of industry (Chapter 2).
- Discuss the BATs and some emerging techniques to increase the environmental performance, and present the ranges of ELVs associated to them whenever this is possible (Chapters 4 and 6).





- Discuss the available tools and methods to monitor and control the environmental impacts of the installations (Chapter 5).

In this manner, this guide should constitute a reference for both the staff of the MoEU responsible for the issuance of environmental permits for this sector, and for the iron and steel electric arc furnace industry representatives. This guide is not a law stating some emission limit values (ELVs) for certain parameters which have to be respected, but rather a reference on which the environmental authority should base its decisions on the contents of environmental permits issued to installations of this sector, taking of course as well into consideration the relevant applicable environmental legislation in the process of issuance of the new permits.





# **1** INTRODUCTION.

# 1.1 IMPLEMENTATION OF THE DIRECTIVE ON INDUSTRIAL EMISSIONS IN THE SECTOR OF STEEL PRODUCTION IN ELECTRIC ARC FURNACE

1.1.1.National Legislation transposing the permitting requirements of the Directive on Industrial Emissions. Other sectoral legislation applicable to the sector.

The Ministry of Environment and Urbanism is drafting the By-Law on Integrated Environmental Permits, that will transpose the permitting requirements stated in chapters 1 and 2 of the Directive on Industrial Emissions 2010/75/EU. Explanations about how to implement in practice this new By-Law are provided in the guidance document "Integrated Environmental Permits: Supporting guideline for the Applicants".

The list of current national environmental legislation of relevance for the environmental permitting of iron and steel electric arc furnace installations is provided in Annex III.

#### 1.1.2.Installations regulated under this legislation and covered by this guidance

The installations covered by this guidance which are subject to the legislation mentioned in section 1.1.1 are the ones fulfilling both of the following conditions:

- Production of steel (secondary fusion in electric arc furnaces) including casting,
- with a nominal production capacity exceeding 2,5 tonnes per hour

1.1.3. Administrative procedure to apply for the Integrated Environmental Permit.

The administrative procedure is explained in detail in chapter 5 of the guidance document "Integrated Environmental Permits: Supporting guideline for the Applicants" .

# **1.2 OVERVIEW OF THE SITUATION OF THE SECTOR IN TURKEY**

### **1.2.1** Current Situation

After entirely compensating the losses of the crisis period by growing 15 %, production growth in the world steel industry slowed down to 6.8 % in 2011. Compared to the previous years, it is observed that Chinese effect in the world steel industry growth continued to ease. Chinese steel production growth leveled off to 9-10 % levels during the last 2 years after growing consistently by 20 % in 2000's. In comparison to 2010, production of Japan and Spain dropped and growth rate of the USA, India, Russia, Germany, Ukraine, Brazil and France, stayed below the world average. While world crude steel production growth dropped from 15 % to 6.8 % in





2011, Turkey achieved 2 percentage points higher growth rate of 17 % compared to 2010. With this growth rate of around 2 times higher than the Turkish economy growth, Turkey became the top growing country among the 30 largest steel producers.

#### **Production**

Turkey's crude steel production reached a record high of 34.1 million tons in 2011 with a 17 % increase. Owing to the high production growth performance, which is also the highest among the top steel producers of the world, Turkey's crude steel production surpassed the pre-crisis production of 2007 by 32.2 %. In this respect, Turkey has been the 4<sup>th</sup> producer in terms of carrying its production beyond the pre-crisis level after China, India and South Korea. However, it is observed that the production of Spain, France, Ukraine, USA, Japan, Germany, Italy and Russia has not achieved the pre-crisis levels yet.

Turkey's billet production grew by 11.8 % to 24.4 million tons in 2011. With the support of new capacities that came on stream, slab production continued its sharp rise by 33 % to 9.7 million tons after growing by 53 % in 2010.

As new steel production facility investments are all focused on EAF route, EAF mills accounted for 88 % of the total crude steel production upsurge of 4.96 million tons. While total crude steel production of EAF mills rose by 20.9 % to 25.28 million tons, expansion in the crude steel production of BOF route stayed at 7.2 % to 8.83 million tons.

#### <u>Capacity</u>

Increasing by 10 % in 2011, Turkey's crude steel production capacity reached around 47 million tons level, up from 42.7 million tons in 2010. However, capacity utilization rate, which dropped below 70 % level in 2009 and slightly improved to 71 % in 2010, recovered to 76 % level in 2011.

#### Finished Steel Production & Consumption

Turkey's total finished steel production increased by 21.5 % yoy from 26.30 million tons to 31.94 million tons in 2011. Turkey's total finished steel production growth was higher than 17% in crude steel production. With the help of new capacities, highest production growth rate was seen in flat products, reaching 9.08 million tons up by 36.9 %. Long steel production rose by 16.3 % to 22.87 million tons up from 19.67 million tons. Long steel products accounted for 71.6 % of the total finished steel production in 2011, while the share of flat steel products was 28.4 %. In 2011, Turkey's total finished steel production grew by 5.64 million tons and flat steel production growth accounted for 57 % of that expansion.

Turkey's total apparent finished steel consumption was 26.93 million tons in 2011 up by 14.1 % from 23.60 million tons. While total consumption in long steel products which are generally used by construction industry grew by 17.7 % to 13.72 million tons, total consumption in flat steel products which are generally used by automotive, machinery and white goods industries reached 13.2 million tons up by 10.6 %. In 2011, long steel accounted for 51 % of the total 26.93 million tons of steel consumption and flat steel accounted for 49 % of the total.

Furthermore, due to the strong production upsurge, Turkey's flat steel production/consumption ratio went up to 69 % in 2011 compared to 40 % in 2005. The production/consumption ratio in long products, which was around 174 % in 2005, dropped down to 167 % in 2011 after touching the highest point of 215 % in 2008.

#### <u>Turkish Economy</u>





Despite uncertainties in the world economy, social problems in some Middle East countries and deepening debt crisis in the EU, 2011 was a year that Turkish economy has caught high growth rate. Although concerns on the global economic development bothers markets from time to time, Turkish economy kept its position at the forefront among the developing countries and EU economies, due to the high economic growth rate and continued fiscal discipline.

As a result of Turkey's exports reaching 135 billion USD up by 18.5 % and imports expanding to 241 billion USD up by 29.8 %, Turkey's foreign trade deficit soared by 47.7 % to 105.9 billion USD. Sharp growth in foreign trade deficit caused the expansion of the current account deficit by 61 % to 77.9 billion USD.

#### <u>Export</u>

Turkey's total iron and steel exports, including the articles of steel and steel pipes, reached 18.54 million tons by 5.1 % in terms of tonnage, and by 25.2 % to 16.63 billion USD in terms of value. Turkey's semi finished steel export dropped sharply by 34.3 % to 2.45 million tons in 2011.

Most remarkable export growth was seen in flat products due to the increasing capacity and production, which grew by 51 % to 2.3 million tons in terms of tonnage and by 65 % to 1.94 billion USD in terms of value. Long products export, which is the largest product group that Turkish steel industry traditionally exports, rose by 14 % to 10.5 million tons and 38 % to 7.36 billion USD. In this respect, while share of semi finished products in Turkey's total steel export declined from 21 % to 13 %, share of flat steel products stepped up from 9 % to 12 % and share of long products from 52 % to 57 %.

In terms of regions, because of the social and political instabilities, largest export drops in Turkey's total steel products export excluding articles of steel and steel pipes, is seen in Middle East and North Africa Regions. Turkey's steel products exports to Middle East and Gulf Region, which is the biggest export market of Turkish steel fell by 13.6 % to 6.36 million tons. Exports to North Africa Region, which had been the second biggest export market for Turkish steel products declined by 27.5 % to 1.56 million tons, moving the region to the third place among the biggest export markets. In 2011 EU became the 2<sup>nd</sup> largest export market for Turkish steel products, with the help of the first half strong performance. Export to the EU rose by 59 % to 2.28 million tons.

#### <u>Import</u>

Although Turkey's total steel export dropped by 3.3 % to 10.68 million tons in terms of tonnage, value of the imported steel increased by 18.5 % to 11.82 billion USD because of the continued recovery in the unit price levels.

Due to the production increase of 37 %, flat steel was the main product group which showed the sharpest import drop. Turkey's total flat steel import declined by 5.9 % to 6.43 million tons in terms of tonnage, but flat steel import value increased by 11.8 % to 6.36 billion USD. Despite being Turkey's largest export product and in this respect Turkey is one of the biggest exporters of long products in the world, long product import also rose surprisingly by 13.2 % to 1.36 million tons. In addition to the long products, tube and pipe import growth of 21 % to 366.000 tons was another remarkable development in Turkey's total steel import.

In terms of steel product imports by regions excluding articles of steel and pipe, EU Region stayed at the top of the list exporting Turkey 4.22 million tons of steel, followed by CIS countries with 4.13 million tons of export. EU accounted for 42.5 % of Turkey's total steel





import and CIS accounted for 41.5 % of the total. In this respect, Turkey realized 84 % of its total steel import from those two regions.

Turkey's export/import ratio improved from 133 % in 2010 to 141 % in 2011. Turkey's net steel export rose from 6.55 million tons to 7.86 million tons in terms of tonnage and from 3.31 billion USD to 4.81 billion USD. Steel trade deficit with the EU dropped by 11.4 % yoy to 2.62 billion USD, while steel trade deficit with the CIS expanded to 2.87 billion USD, up by 10.2 %.

#### Steel Trade Balance

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#### <u>Scrap</u>

Due to the crude steel production growth of 5 million tons in 2011, Turkey's total ferrous scrap consumption also rose by around 5 million tons from 25.26 million tons to 30.79 million tons, up by 22 %. Although Turkey's total crude steel production growth was 17 % and mainly scrap consuming EAFs' crude steel production growth was 20.9 %, total scrap import rose by just 11.8 %, because of the increase in local scrap production. Despite sharp rise in consumption, share of imported scrap in Turkey's total scrap consumption dropped from 76 % in 2010 to 70 % in 2011 and this allowed local scrap share to increase around 30 % of the total consumption. Turkish steel industry consumed 21.46 billion tons of imported scrap and 9.3 million tons of local scrap.

Despite scrap import from the EU region dropped by 6.4 % to 9.9 million tons, EU kept its position as the largest scrap supplier to Turkey accounting for 46 % of all scrap that Turkey imported in 2011. Scrap import from the USA rose by 36 % to 5.82 million tons. After the USA, third largest country in Turkey's scrap import was Russia whose scrap export to Turkey grew by 51 % to 2.33 million tons.

#### <u>Forecasts</u>

In 2012, Turkey's crude steel production is expected to grow by 11 % to around 38 million tons. Steel consumption is forecasted to rise by 8 %. New started urban transformation and infrastructure projects are expected to continue to support Turkey's economic growth and thus steel consumption, despite some slowdown arising from the concerns on the global economy which might have a cooling effect on Turkish economy. New production capacities will not only support establishment of new industry branches consuming steel products but also provide import substitution.

Depending on new capacities coming on stream and activity levels in the domestic market, steel production has the potential to surpass the expected levels. Shrinking demand in the export markets and continued import substitution in flat products are forecasted to continue supporting local sales of the Turkish steel industry. As Turkish steel industry has the opportunity to utilize its domestic market more efficiently, production growth will not make pressure on the industry and probable expansions in the export markets will support the production further.

### **1.2.2** Iron and Steel Production Processes





Crude steel in iron and steel industry is produced by 2 different processes using different technologies: integrated facilities (BOF) and electric arc furnaces (EAF). Iron and steel industry consumes energy and raw materials intensively. Currently, 3 integrated facilities and 27 electric arc furnace mills are operating in Turkey.

Because of high energy consumption and slow operation, open hearth furnace (OHF) technology was replaced by basic oxygen furnace (BOF) and electric arc furnace (EAF) processes in 1999. Since then, steel production has been realized using latest technologies and under similar conditions to the ones of European steelmaking facilities.

Integrated iron and steel production process begins with the preparation of iron ores by crushing, screening and sintering process or direct charging of lump ore into the blast furnace. Iron ore reduced by the carbon monoxide formed as the coke burns with blast air and melted with the heat energy, turns into hot metal. During primary steelmaking process, a certain amount of scrap and alloying elements are added to hot metal in converter. In BOF technology, pure oxygen is blown on to the alloy and then the liquid steel is obtained. After refining process in ladle, liquid steel is transformed into the desired size of semi-finished products (billet, bloom, slab) at the continuous casting machine.

In electric arc furnaces, liquid steel is produced by melting the steel scrap with the help of graphite electrodes. After refining process, liquid steel transferred from the ladle to the continuous casting machine is solidified and finally shaped as the desired size of semi-finished products.

Semi-finished product (billet, bloom, slab) is charged into the reheating furnace to obtain the required rolling temperature. After the reheating process, the semi-finished product is passed from the rolling stand to be able to produce finished product with desired size.

### **1.2.3** The Role Of Steel Sector in Turkish Economy

Steel sector supplies inputs for many sectors, especially, for construction, automotive, white goods and machinery sector.

With the export value of 16.600 million dollars in 2011, the sector contributed enourmously to the diminishing of foreign trade deficit. In the same year, by 17 % increase in production, making the greatest contribution to the economic growth of 8.5 %, among other sectors, became the locomotive sector of the economy.

# **1.3 RELEVANT ENVIRONMENTAL IMPACTS OF THE SECTOR.**

In the following a very brief summary of the main environmental impacts of this sector is presented. For more detailed information and explanations about the production processes and related impacts please read chapters 2 and 3.

One of the main environmental aspects of the iron and steel industry is the consumption of materials and energy. In order to get an idea of the magnitude of the consumptions, the 22 EAF installations operating in Turkey in 2010 consumed 23.4 million tons of scrap, and had an average eletric energy consumption per ton of crude steel produced of 475 kWh.





The <u>most relevant environmental aspects</u> for electric arc furnace steelmaking can be summarised in as follows. The direct smelting of materials which contain iron (mainly scrap) is usually performed in electric arc furnaces which need considerable amounts of electrical energy and causes substantial emissions to air and solid process residues such as wastes and by-products (mainly filter dust and slag). The emissions to air from the furnace consist of a wide range of inorganic compounds (iron oxide dust and heavy metals) and organic compounds such as persistent organic pollutants (e.g. PCB and PCDD/F).

<u>Other relevant aspects.</u> On top of the previous, there are other environmental issues to be considered in the steelmaking processes. Some of them are the following ones:

- Greenhouse gas emissions. Steelmaking is very demanding on energy and CO2 is generated when energy is consumed. The specific energy consumption for steel production in electric arc furnaces in Europe is on average about 1.8 GJ/t liquid steel. Considering the efficiency of energy supply, primary energy consumption will be considerably higher. Additionally there is a fossil fuel input of about 0.5 GJ/t liquid steel on average. Different strategies have been used to reduce the contribution of this sector to GHG emissions: energy savings, waste energy recovery equipments, CO2 capture and storages,...
- Odour and noise emissions can be important under certain circumstances. Noise from scrap and products handling and during the furnace charging and the start of melting can be relevant.
- The risk of soil and groundwater pollution is not of big concern but they have to be taken into account when assessing the environmental impact.

Table 1.1 provides a detailed overview of the releases in the different parts of the electric steelmaking processes. In this table, the different processes that can be found in a electric arc steelwork are placed in columns and the pollutants in rows. In the table, the releases of a main pollutant to the environment are indicated with a letter in upper cases in the corresponding cell (A = release to air, W = release to water, L = release to land (soil)); and if the release is of other substances not considered as main pollutants the letters are in lower cases (a = release to air, w = release to water, I = release to land (soil)).





Table 1.1: Table showing potential release routes for prescribed substances and other substances that may cause environmental harm

→ sources releases ↓	Raw material handling	EAF: charging	EAF: melting and refining	EAF: steel and slag tapping	EAF: furnace and ladle lining repairs	Alloying	Ladle treatment	Reladling and recarburisation	Degassing	Decarburisation	Electroslag remelting	Vacuum induction melting	Induction melting	Ferrous alloy powders	Continuous casting	Ingot casting	Scarfing	Slag processing	Skull burning *
SO <sub>2</sub>		Α	Α			Α	Α						Α					Α	
NOx		Α	Α				Α						Α						
CO2		Α	Α				Α	Α		Α			Α				Α		
СО		Α	Α				Α	Α		Α			А						
HCI		Α																	
HF			Α				Α				Α								
HS2																		Α	
Oxides of iron	Aw	Α	Α	Α	Al	А	Α	Α		Α	Ι		Α		Awl	Al	Awl	wl	Al
Alkali metals																		wL	AL
Alkaline earth metals																		wL	AL
Metal oxide particulates	Aw														Awl	Al	Awl	wl	Al
Non-metallic particulates	Aw																	wl	
Metallic iron					Al									Α				wl	
Inorganic					A1	۸													
fluorides						^													
Hydrogen cyanide					AL	А													
Cadmium and cadmium oxide	w	A	A						WI	A	I								
Zinc, lead and their oxides	w	А	А						wl	А	I				Awl	Al	Awl		Al
Other metals and their oxides	Aw	A	А	А			А	А	wLl	А	L			A	Awl		Awl		AL
Phosphorus compounds							A												
Sulphur																		wl	
Other inorganic chemicals	A W	A	A		AI	AL	A												
Oils and greases	w														w				
Slag			L	L	Al		L	AL		L		L	L		L	L		L	L
Sludges																	wl		
Refractory	Aw				AL				I	L	L	L	L		L	L		L	
waste																			
PCDD/F		A	Α																
PAH and PCB			Α																
VOCs			Α																
NB:*Skull burning except where a se technique employ	g: proce eparate /ed, e.g	ss to c refere . via co	lean the ince to ollected	e inner the con dusts,	surface npound sludges	of the is mad or liqu	furnaco e. Rele ors.	e from a ases to	idherec air may	l solidif also b	ied res e relea	ts by m sed to la	elting t and or	hem.So water,	ubstanc depend	es inclu ling upo	ide thei on the a	r comp bateme	ounds ent





# 2 PRODUCTION PROCESSES AND TECHNIQUES



# 2.1 STORAGE AND HANDLING OF RAW MATERIALS







Scrap metal is stored normally outside on large, uncovered and often unpaved ground. The ferrous scrap metal is loaded into baskets by magnets or grabs. Scrap is purchased based on specific international specifications which minimise non-metallic inclusions. The handling minimises any rogue non-magnetic material like stones, wood or non-ferrous metals from entering the process. Some types and quality of scrap during metal storage and handling operations may lead to the deposit of residual materials on the ground, as well as to the deposition of heavy metals and hydrocarbons.

Depending upon the types and qualities of scrap being processed, handling operations may also lead to inorganic (dust) and organic emissions under certain weather conditions. Some types of scrap may also give rise to noise emissions during handling. Some scrap sorting is carried out to reduce the risk of including hazardous contaminants. Inhouse generated scrap can be cut into manageable sizes using oxygen lancing. The scrap may be loaded into charging baskets in the scrapyard or may be transferred to temporary scrap bays inside the melting shop. In some cases, the scrap is preheated in a shaft or on a conveyor.

With the single shaft furnace, at least 50 % of the scrap can be preheated. A further modification is the double shaft furnace which consists of two identical shaft furnaces (a twin shell arrangement) which are positioned next to each other and are serviced by a single set of electrode arms. The scrap is partly preheated by off-gas and partly by side wall burners. A very efficient shaft furnace design is the finger shaft furnace. The finger shaft design uses a unique scrap retaining system with fingers which allow the preheating of 100 % of the scrap amount. The first basket is preheated during the refining of the previous heat and the second during meltdown of the first one. Through the utilisation of the furnace off-gas during the heat cycle, scrap can be preheated to a temperature of approximately 800 °C prior to the final melting in the furnace vessel. This means considerable energy and cost savings with a substantial reduction in tap-to-tap times.

A recent development of the scrap preheating process is the COSS technology which combines the benefits of the shaft systems – high scrap preheating – with those of the CONSTEEL process – the continuous scrap feeding.(for a detailed explanation of those technologies and environmental performance achieved please check section 4.4.1)

Radioactivity present in the incoming scrap may be an issue in some cases.

Other raw materials including fluxes in lump and powder, powdered lime and carbon, alloying additions, deoxidants and refractories are normally stored under cover. Following delivery, handling is kept to a minimum and, where appropriate, dust extraction equipment may be used.

Powdered materials can be stored in sealed silos (lime should be kept dry) and conveyed pneumatically or kept and handled in sealed bags.





# 2.2 SCRAP CHARGING

The scrap is usually loaded into baskets together with lime or dolomitic lime which is used as a flux for the slag formation. Carbon-bearing materials are also charged for the needs of the metallurgical work to be performed in the furnace. At some plants, lump coal is also charged in order to adjust the carbon content. Even though this has not been confirmed up to now by emissions measurements, this may result in relevant emissions of benzene (as well as toluene and xylenes). The furnace electrodes are raised into top position, the roof is then swung away from the furnace for charging. It is normal to charge about 50 - 60 % of the scrap initially with the first scrap basket; the roof is then closed and the electrodes lowered to the scrap. Within 200 - 300 mm above the scrap, they strike an electric arc. After the first charge has been melted, the remainder of the scrap is added from a second or third basket.

The amount of scrap charging into the EAF is directly proportional to the size of the furnace. For example, one EAF of 6.7 metres diameter charges around 60 tonnes of scrap.

A commercially available system is known as the shaft furnace which allows part of the scrap to be charged into a vertical shaft integrated into the furnace roof and thus prevents the opening of the furnace roof halfway through the melting process. The scrap present in the shaft is preheated by the hot gases coming from the furnace.

Another new charging system that has been adopted by some operators is the CONSTEEL process where the scrap is continuously fed via a horizontal conveyor system into the arc furnace. This also allows the scrap to be preheated by the furnace off-gas flowing in countercurrent.

# 2.3 ARC FURNACE MELTING AND REFINING.







During the initial period of melting, the applied power is kept low to prevent damage from radiation to the furnace walls and the roof whilst allowing the electrodes to bore into the scrap. Once the arcs have become shielded by the surrounding scrap, the power can be increased to complete the melting. Oxygen lances and/or oxy-fuel burners are used more and more to assist in the early stages of melting. Fuels include natural gas and oil. Furthermore, oxygen may be brought to the liquid steel by specific nozzles in the bottom or side wall of the EAF.

Oxygen in electric furnace steelmaking has become increasingly considered over the last 30 years not only for metallurgical reasons but also for increasing productivity requirements. The purpose of using oxygen is manifold:

□ the combined injection of oxygen and granular carbon allows for the generation of a foamy slag thanks to the generation of CO bubbles. The 'foamy slag' technique, which is now in wide use in carbon steelmaking, improves the shielding of the furnace walls from the radiation of the arc and allows for an improved energy transfer from the arc into the steel bath.

□ for metallurgical reasons, oxygen is used for decarburisation of the melt and removal of other undesired elements such as phosphorus and silicon.

 $\Box$  oxygen is also injected into the top of the furnace for 'post-combustion' in order to react with CO and hydrocarbons before the fumes leave the furnace with the aim of keeping as much of the heat as possible of the heat generated by the exothermic reactions within the furnace.

Oxygen injection results in an increase in gas and fume generation from the furnace. CO and  $CO_2$  gases, extremely fine iron oxide particles and other product fume are formed. In the case of post-combustion, the CO content is below 0.5 vol-%.

Argon or other inert gases may be injected into the melt to provide bath agitation and temperature balancing. The slag-metal equilibrium is also improved by this technique. Fumes and gases generated from the melting operation are processed in a flue-gas treatment plant which includes the collection and treatment devices aimed at reducing pollutant emissions.

Slag may need to be removed during heating and oxidising at the end of the heat prior to tapping. The furnace is tilted backwards towards the slagging door and the slag runs off or is raked into a pot or on the ground below the furnace resulting in dust and fume generation. For special steels, mainly alloyed steel, for metallurgic reason, the slag is tapped with the liquid steel into the ladle. Most of the slag is separated from the steel at a deslagging station into a slag pot. The fumes generated there should be captured by an exhaust system.

# 2.4 SECONDARY STEEL MAKING







### Carbon steel

Secondary metallurgy is carried out on the molten steel after the tapping of the primary steelmaking furnace up to the point of casting. It is typically carried out at ladle treatment stations while the molten steel stays in the ladle. These treatment stations are generally comprised of an arc-heating unit (a ladle furnace) which allows an adjustment of the final temperature of the liquid steel for the casting operation. The treatment includes the addition of deoxidising agents and alloying elements in order to adjust the chemical composition of the finished steel. In some cases, vacuum treatment units are used for achieving special requirements regarding the concentration of elements such as hydrogen, nitrogen and oxygen of finished steel. In order to achieve a good homogenisation, inert gases (Ar or N<sub>2</sub>) are injected into the ladle for stirring purpose. Some minor ladle treatment stations are based on inert gas or powder injection equipment.

### **Stainless steel**

The secondary metallurgy of stainless steel may be performed either under vacuum in the ladle (VOD process – vacuum oxygen decarburisation) or in a separate metallurgical vessel called an AOD (argon oxygen decarburisation) converter and a subsequent ladle treatment. Depending on the steel grades to be produced, some operators apply a combination of both AOD and VOD. A flow diagram of a stainless steel melt shop with an AOD converter is shown in Figure 2.1







Figure 2.1: Material flow of a stainless steel melt shop with an Argon oxygen decarburisation converter

### Alloys steel

The secondary metallurgy of alloy steels which contain (besides carbon) substantial quantities of alloying elements but do not rank in the stainless steel category consist generally of a ladle furnace and, if required, a vacuum treatment, depending on the steel grades produced. During most of the processes of secondary metallurgy, slags are used to capture the non-metallic compounds generated during the treatment.

# 2.5 CASTING







Once the final steel quality has been achieved, the steel is conveyed in a casting ladle to the casting machines. Some years ago, the standard method was to pour the molten steel into permanent moulds (permanent mould or ingot casting) by a discontinuous process. Today, the method of choice is continuous casting, whereby the steel is cast in a continuous strand (i.e. slabs of different sizes, thin strip).

### **Continuous casting**

Figure 2.2 shows the schematic diagram of a continuous casting plant.



Figure 2.2: Scheme of a continuous casting plant with a soaking furnace and a rolling mill with hot charging





Continuous casting offers several important benefits in comparison with ingot casting:

- improved working conditions
- energy savings, reduces emissions and reduced water utilisation due to the elimination of slabbing mills and billet mills
- high yield rates, in excess of 95%
- high productivity

Since continuous casting was first introduced on an industrial scale in the late 1960s, its share in overall EU steel output has risen to approximately 97 %. Worldwide, about 90 % of all steel is now cast by the continuous method. Apart from the traditional ingot casting process, continuous casters have also replaced the blooming-slabbing and semifinishing operations of conventional hot rolling mills. Today, almost all steel grades for rolled products can be handled by the continuous casting route, since the necessary preconditions such as deoxidation and degassing are provided by modern secondary metallurgy.

Various types of continuous casters exist and are referred to as vertical type, bending-andstraightening type, bow type and oval bow type machines, depending on their configuration.



The liquid steel is poured from the converter into a ladle which transports the steel after secondary metallurgy to the 'tundish' of the continuous casting machine (CCM). This is an intermediate ladle with a controllable outlet. The ladles are preheated prior to accepting a liquid steel charge in order to avoid temperature stratification in the tundish.





When the liquid steel has reached the desired temperature, it is poured into the tundish. From here, it passes to a short water-cooled copper mould where no air is present and which performs oscillating up and down movements to prevent the steel from sticking. The mould gives the metal the desired shape. Continuous casting is a process which enables the casting of one or a sequence of ladles of liquid steel into a continuous strand of billet, bloom, slab, beam blank or strip. Mould lubricant is added in powder form or vegetable oil. When the metal leaves the casting mould, a 'skin' of solidified steel has formed and a large number of trundles (the 'pinchroll') guide the cast steel with a gentle curve toward a horizontal position. Here, the endless casting is cut in pieces with a torch cutter. Slabs, blooms and billets are cast in this way. In the case of non-self-supporting sections, the red-hot strand, with its solidified surface zone, moves through a number of driven and undriven roll pairs which support its shell against ferrostatic pressure. As the core is still liquid, it is sprayed carefully with water and cooled until fully solidified (secondary cooling). This process prevents cracks in the strand surface zone, which is still fairly thin, and also protects the rolls from overheating. The supporting, conveying and driving elements are commonly equipped with idler-roller with interior and exterior cooling. In the secondary cooling zone, interior roll cooling becomes dispensable as soon as the temperature is reduced sufficiently by the water spray. A number of bearings are connected to an automatic grease-lubricating system. Once the strand has fully solidified, it can be cut to size by cutting torches moving with the strand or by shears. The rapid cooling process gives the steel a uniform solidification microstructure with favourable technological properties. The solidification microstructure of the strand can be influenced by downstream air or water cooling.

The shape of the strand is determined by the mould geometry. Current mould types include rectangular, square, round or polygonal sections. For the production of steel shapes, it is possible to use moulds resembling the approximate cross-section of the intended product. Typical strand dimensions in continuous casting vary between  $80 \times 80$  mm and about  $310 \times 310$  mm, 600 mm (round) in billet and  $450 \times 650$  mm in bloom systems, while slab casters produce izes of up to 350 mm in thickness and up to 2720 mm in width. Billet casters can handle everal (currently up to eight) strands at the same time, while the number of strands in slab asting is limited to two.

### Near net shape casting

Since the end of the 1980s, continuous casting has been developed for the manufacturing of flat products. These route can be summarised under the heading 'near net shape casting' which includes thin slab casting, near net shape strip casting also known as direct strip casting (DSC) and thin strip casting. There is actually an installed capacity of about 7 million tonnes of these processes in the EU. The thin strip casting shortens the process from liquid steel to hot rolled sheet, therefore reducing the overall energy demand and increasing material efficiency but requires other secondary metallurgical steps. Typical dimensions for thin slab casting vary between sizes of 15 and 50 mm in thickness. Near net shape strip casting leads to a strand thickness of below 15 mm and thin strip casting to less than 5 mm.





The decision to build a thin strip casting highly depends on local conditions and the required product quality. In case near net shape strip casting is used, it should be taken into account that special secondary metallurgical steps are needed and therefore the emissions and energy consumption for these treatments in relation to LS production could be higher compared with other processes. Scale formation during this type of casting is typically higher than in conventional casting.

### Ingot casting

In ingot casting, the liquid steel is cast into casting moulds. Depending on the desired surface quality, degassing agents (such as NaF) can be added during casting in the ingot mould. After cooling, the ingots are taken out of the casting mould and transported to the rolling mills. Subsequently, after preheating, the ingots are rolled into slabs, blooms or billets. In many places, ingot casting has been replaced by continuous casting. It is expected that ingot casting will eventually be almost completely replaced by continuous casting except in the case of those products which require ingot casting to achieve the necessary quality, such as producing heavy weights for forging .

# 2.6 SLAG TREATMENT, LANDFILLS

### Slag processing

If slag is collected in a slag pot at the EAF (or at secondary metallurgic plants like AOD or VOD) it needs to be poured into outside slag basins for solidification. The cooling of the slag may be enhanced by water sprays. Some sites operate a slag treatment during the liquid phase to improve the slag final quality and its dimensional stability, by adding silica, alumina, boron (colemanite or sodium borate) and checking the cooling duration. In some plants the slags from the different processes are mixed in the liquid phase to make them more suitable for further processing.

If the slag is poured on the floor, it is precrushed after solidification using excavators or shovel loaders and brought to an outside storage area. After a certain period of time, the slag is processed in crushing and screening devices in order to give it the desired consistency for its further use in construction. During this operation, any metallic particles contained in the slag are separated magnetically, manually or using digging, crushing and sieving in order to be recycled into the steelmaking process. Recovering metals from slags is particularly sensitive for metals with a high commercial value. Slag breaking and metal recovery can create dust emissions.

Sometimes water is used to cool down the slag during slag tapping which improves the microstructure, achieving better mechanical properties. This 'black electric kiln' slag is





processed to street and road building material, while the 'white slag' from open basins can be used, e.g. as a lime fertiliser .

# 2.7 HOT ROLLING MILLS



### 2.7.1 Process Overview

In hot rolling the size, shape and metallurgical properties of the steel slabs, blooms, billets or ingots are changed by repeatedly compressing the hot metal (temperature ranging from 1050 to 1300 Co) between electrically powered rollers. The steel input for hot rolling differs in form and shape, depending on the process route and on the product to be manufactured:

**Cast ingots**, predominantly with square cross section, are used for the manufacture of slabs and blooms on slabbing-/ blooming mills. Slabs and blooms are further processed to plates or strips on other rolling mills. Nowadays, the use of cast ingots and slabbing/blooming is decreasing as continuous casting has made this step obsolete. Approximately 93.7 percent (1995) of the crude steel produced in Europe is cast continuously into semi-finished products such as slabs, blooms or billets. Only a minor part is cast into discrete moulds to produce ingots for some special products (e.g. heavy plates).

**Slabs** (400 up to 2500 mm wide and 40 to 500 mm thick) are semi-finished, continuous cast products for the rolling of flat products.

**Billets** (of square or rectangular shape with cross sections of 2500 mm2 to 14400 mm<sup>2</sup> (50 x 50 mm to  $120 \times 120$  mm)) and blooms (of square or rectangular shape with cross sections of





14000 mm<sup>2</sup> up to approx. 100000 mm<sup>2</sup> (120 x 120 mm up to 250 x 400 mm)) are semi-finished continuous cast products used for the rolling of long products.

**Beam blanks** (with dimensions of 170 x 240 mm up to 500 x 1120 mm) are continuously cast to near net shape. Beam blanks are used for rolling of long products.

Hot rolling mills usually comprise the following process steps:

- Conditioning of the input (scarfing, grinding).
- Heating to rolling temperature.
- Descaling.
- Rolling (roughing including width reduction, rolling to final dimension and properties).
- Finishing (trimming, slitting, cutting).

Products obtained from hot rolling are usually classified in two basic types according to their shape: flat and long products. Tubes, are also covered by the term 'long product' in this document.

Hot rolling mills are classified by the type of product that they produce and by their design features. The following chapters give an inside on the different mill layouts and manufacturing sequences. More detailed information on the individual processing steps, which are often similar in different mills, is given thereafter.



### 2.7.1.1 Blooming/Slabbing Mills

Blooming and slabbing mills are used to roll cast ingots into semi-finished products, like

blooms and slabs, for further processing on other mills. The raw material is heated in soaking pits to ca.  $1300 \circ C$  and subsequent formed on heavy two-high reversing stands in 15 - 30 rolling passes.





The material to be rolled is moved along roller tables, positioned with the aid of manipulators, and fed into the roll gap. The material is rotated repeatedly by 90  $_{\circ}$  about its long axis during the series of passes.

The main difference between blooming and slabbing stands is the greater height of the stands used for rolling slabs. This is associated with the product characteristics, as slabbing mills are mainly used to roll flat semi-finished products they require a bigger lift height of the upper rolls.

Another rolling system is the universal slabbing stand. Working pairs of rolls are arranged horizontally and vertically in succession. The vertical rolls form the narrow sides.

The rolled semi-finished products are cropped with shears at both ends, and divided into ordered lengths. Surface defects of the product maybe removed by flame deseaming (scarfing).

With the growth of continuously cast products, the number and importance of slabbing and blooming mills has decreased.

### 2.7.1.2 Hot Strip Mills

For the production of hot strip, the heated slab - after descaling - passes the roughing mill, where it is reduced from a thickness of approx. 120 - 300 (500) mm to approx. 20 - 50 mm (transfer bar). Roughing can also include a reduction in width.

This roughing is done either in several passages through an individual rolling stand by repeated reversing, or in a continuous passage through several roughing stands. The designations of strip mills (semi-continuous hot strip mill, 3/4 continuous hot strip mill and continuous hot strip mill, see Figure 2.3) originate from this plant configuration







Figure .2.3: Typical designs for Hot Strip Mills

The material reduced to a transfer bar is directed to the finishing train via an intermediate Soller table, which in some cases is combined with a so-called coil box. Before entering a train of rolling stands for thickness reduction to the final size (between 1.2 and approx. 20 mm) the transfer bar is cropped. Temperature controlled rolling in the finishing train, involving controlled strip cooling installed at the delivery roller table, provides the requested technological parameters (strength, toughness, etc.) of the hot strip. At the end of the rolling mill the finished product is wound up in a coil.

Hot strip, which is not foreseen for further processing in the cold mills is partly sold with rolled strip edges, but depending on the planned external use the strip has to be conditioned. This





coil finishing includes side trimming, cutting to small bands on slitting lines and cutting into sheets.

### Steckel Mill

A special method of hot strip production is rolling in so-called STECKEL mills. Here the prematerial is usually processed into strip by reversing through a roughing stand and a finishing stand, in some cases even by reversing through one stand only.

To keep the heat losses during the rather long forming process within reasonable limits and to handle the relatively long strip more easily, heated coiling devices referred to as STECKEL coilers are attached on both sides of the rolling stand (finishing stand), where the rolled stock is temporarily stored.

### Sendzimir Planetary mill

Mills of this type are characterised by the use of rotating backup rolls which drive the work rolls so that the surface of the latter move in a direction opposite to that of the workpiece. The work rolls are held in cages, which rotate around the backup rolls in a synchronised manner. To facilitate the use of thicker ingoing material (slabs) planetary mills may be assisted by attached eccentric presses.

Special kinds of planetary mills are the single planetary mill - only the bottom roll set is designed as planetary type and either a rotating top roll or fixed die is arranged above passline - and the 'Krupp-Platzer' planetary mill where intermediate rolls are arranged between the work rolls and backup roll.



Figure .2.4 : Planetary Mill (SENDZIMIR)





### 2.7.1.3 Plate Mills

Production of heavy plates (thickness between 5.0 and 380 mm, width up to 5.2 m) is done by reversing operation at one mill stand or in tandem operation.

After rolling, the plates are placed on a cooling bed (cross transfer) and cooled to room temperature and/or temperatures down to max. 500°C for further processing.

In special cases the rolled product is heat treated by water cooling systems (e.g. water curtains) immediately after hot rolling. Hot and/or cold levellers are arranged in front or behind the cooling bed to straighten the plates.

After the cooling process on the cooling bed, secondary treatment of the sheets is performed in the finishing shops (shearing, side trimming cutting to length). A part of the production is subjected to a subsequent heat treatment prior to shipment. Such treatments include annealing, spherodise annealing, stress relieving, normalising, quenching and tempering.

### Clads

Special products such as multi-layer plates (clads) require a separate preparation and rolling technique (mainly a two-heat rolling operation). In such products, a corrosion-resistant surface material is permanently bonded to lower-cost, possibly stronger, carbon steel.

The first step involves the fabrication of 'sandwiches' which consist of plates of the cladding and the backing materials with thickness in the exact proportion to produce the required plate size with the percentage of metals ordered. The assembly is then rolled to the desired gauge, width and length, with the two materials becoming permanently bonded because of the high rolling pressure.

In the rolling operation, drafts are usually limited and the finishing temperatures are carefully controlled. In some cases the sandwiches are rolled in a first stage into slabs, cut to required sizes and in a second heat, final rolled either on hot strip mills or on the plate mill. Sometimos heat treatments are required to produce the desired corrosion resistance and physical properties, the resultant scale being removed by sand- or shot blasting.

### 2.7.1.4 Bar and Rod Mills

Bars and rods (wire rods) constitute hot rolled products of relatively small cross sections produced in coiled or straight form. For the rolling operation profiled rolls are in use to give the steel its desired final shape.

### Wire rods

Wire rods generally have circular cross sections with a diameter of 5 to 14 mm. Larger cross sections and different section shapes such as oval, square, hexagonal, octagonal etc. Can also




be rolled on wire rod mills with adequately shaped rollers. Hot rolled wire rod is mainly used for further processing by cold drawing or cold rolling.

The billets fed into rod mills are heated to hot rolling temperature in pusher or walking beam furnaces. A descaling system is installed between the furnace exit and the first rolling stand.

Rod mills are continuous mills with roughing, intermediate and finishing sections. The rolling stands are 2-high and their number is generally in excess of 25, depending on the cross section of the billets feeding the mill (80 to 155 mm). Roughing and intermediate sections may be multi-strand (up to 4 strands), while finishing sections are always single stranded.

Crop shears are installed between the different sections of the mill and are used to provide a clean cut for improved introduction into the following roll stand. Crop shears are also used to cut the bar engaged into the rolling process in case of an incident downstream in the mill.

In-line heat treatment of the wire rod is performed with water cooling ramps located between the final rolling stands and the coilers, followed by air cooling of the coils laid on conveyor belts. Controlled air-flow gives the wire rod the desired micro-structure for further processing (STELMOR\* cooling).

#### Bars

Hot rolled bars include basically two types of steel products, **merchant steels** or engineering steels with round, square, rectangular, hexagonal, octagonal, L-shaped, [-shaped, I-shaped cross sections smaller than 1600 mm<sub>2</sub> and **concrete reinforcing bars** (re-bars) with round cross sections, 6 to 40 mm diameter, mostly with ribs on their surface.

Bar rolling mills are similar to the first sections of wire rod rolling mills. They have generally single strand 2-high mills with roughing, intermediate and finishing groups followed by serás that cut the hot rolled product to long bars, which are then conveyed to a cooling bed. High capacity mills are all continuous with alternating horizontal and vertical stands, while the front groups of lower capacity mills are of the 'open' type.

After cooling the bars are cut to commercial lengths and may be straightened at a cold straightening machine.

Re-bars are often heat-treated in-line by intensive water-cooling to obtain high tensile strength (TEMPCORE® process). A different way for increasing the tensile strength of re-bars is a mechanical treatment after cooling: The bars are deformed by torsion beyond their yield strength until the desired tensile strength is obtained.

### **Cold Drawing of Steel Bars**

Cold drawing concerns the manufacture of steel bars or sections by cold drawing, grinding or peeling of hot rolled steel bars into so called 'bright steel bars', having form and characteristics required by the users. Cold finishing during cold drawing operations hardens and increases the tensile strength of the steel, while at the same time reducing the ductility, which may require an annealing treatment of the product after drawing. Bright steel bars are mainly of circular,





square, rectangular or hexagonal cross-section, but all kinds of cross-sections can be produced according to demand. Products are non-alloy steel bars, alloy steel bars of different grades including high-speed steel and other tool steel and shapes and sections of different steel grades.

Bright steel bars are used by industries such as the manufacture of motor vehicles, machinery, electrical goods and other industries, where high quality basic material is compulsory.

### 2.7.1.5 Structural/Section Mills

As most other types of mills, section rolling mills are divided into roughing, intermediate and finishing stands, preceded by a descaling machine installed between the reheating furnace and the roughing mill.

Roughing stands are generally reversing, 2-high stands. The rolls have several sets of profiles, which are used in sequence. The upper roll can be moved vertically in order to progressively reduce the gap between the rolls and thus to reduce the passing section.

Cropping shears or hot saws are generally installed between the different sections of the mills and are used to provide a clean cut bar end to facilitate the introduction into the following rolling stand.

On leaving the finishing stand or train, the bars are divided to cooling bed length or to commercial length by saws. After cooling on the cooling bed, the bars are straightened on mechanical or hydraulic straightening machines and cut to length by saws as required.

To yield the different profile shapes required for sections/structurals, either duo-stands with 2 grooved rolls or 'universal' stands with 2 horizontal and 2 vertical rolls are used as shown in Figure .2.5



Figure 2.5 : Profiled rolls for sheet piling sections





Geometry control is of utmost importance in section rolling since rather tight tolerances are common for hot rolled sections. Measuring devices applying sophisticated techniques including laser beam technology and radioactive sources are of common use.

Section mills increasingly use near-net-shape, continuously cast semis called beam blanks (see Figure 2.6 ) to increase productivity and decrease energy input.



#### Figure 2.6 : Examples of beam blanks cross sections

If the production rhythm and the manufacturing programme allow, hot charging of continuously cast semis - from the casting machine run-out area to the reheating furnace of the rolling mill - is more and more applied. Considerable savings in energy consumption may be achieved, but this depends on the proximity of the rolling mill to the continuous casting plant.

### 2.7.1.6 Tube Mill

#### Seamless tube

Seamless tube production consists basically of the following manufacturing steps:

- Heating of the input.
- Piercing (press-piercing or oblique rolling).
- Elongation/Stretching.
- Final Rolling.
- Heat Treatment.

The most important types of plants used today are mandrel mills, plug mills, push bench mills and pilger mills. Figure 2.7 show some typical tube mill designs.

Raw material for the production of unalloyed and medium-alloy steel tubes are continuously cast round billets or blooms, although sometimes billets with square cross sections are used. The raw material for high-chrome steel tubes are mainly round bars, rolled from cast billets. The input is heated to rolling temperature in rotary hearth furnaces fired with natural gas or oil. Then a hollow billet (ingot) is produced by piercing. The most important hole-piercing process uses inclined rollers. The hole is produced by two inclined rolls rotating in the same direction, so that the ingot is rolled with a screw motion over a piercer plug to form a hollow bloom. The piercer plug is fixed to a freely rotating rod supported by a thrust bearing on the exit side.







#### Figure .2.7: Mandrel mill

Longitudinal rolling, transverse rolling, or presses are used for the elongating stage. The most important one is the continuous tube rolling process, as it is one of the most efficient and productive processes.

Several rolling stands are used simultaneously, usually 6 -8 two-high stands per group, at an angle of 90  $_{0}$  to each other. The reduction of the wall thickness takes place between the rolls and a cylindrical lubricated mandrel.

Rolling to the finished size is carried out without an inner mandrel in sizing mills or stretchreducing mills. Sizing mills have 2 - 10 stands, and can have two or three rolls per stand. As the circumference is reduced, the wall thickness is increased. In stretch reducing mills, which normally have three rolls per stand, and up to 30 stands, an increase of wall thickness is avoided, as tensile forces are applied between the stands during the process.

Tubes for undemanding applications can be shipped immediately after rolling. For more exacting quality requirements, especially good toughness properties, separate heat treatment is usually carried out after rolling. This can include normalising and tempering.

#### Welded tubes

Welded tubes are produced from cold rolled or hot rolled steel strip; hot rolled wide strip; or thick plate. In principal the production sequence comprises bending of the strip or plate to an open tube and closing the gap by welding. Figure 2.8 shows a schematic of continuous tube production (Fretz-Moon process).







Figure .2.8 : Flow sheet for continuous tube production

In the Fretz-Moon process (pressure welding) coils of hot-rolled strip are heated to a high temperature in a tunnel furnace. The edges of the strip are heated to welding temperature by additional burners. The strip is formed into a tube with a longitudinal gap. A two-roll compression device at 90  $_{\circ}$  then reduces the gap and presses the edges together so they become welded.

The semi-finished tube passes without further heating through a stretching mill, where the dimensions are reduced as required. A flying saw cuts the continuous tube into lengths, which are then cooled on a cooling bed.

Alternative welding processes are resistance pressure welding, in which the required welding heat is generated by high-frequency alternating current, conduction or induction. The properties of the welded seams can be improved, either by continuous heat treatment or by separate heat treatment of the individual tube. Fusion Welding is mainly used to produce steel pipes with large diameters (> 457.2 mm). Figure 2.9 shows the main tube welding processes.







Figure 2.9 : Tube welding processes

## 2.7.2 Surface Rectification and Conditioning of Input

Slabs, blooms and billets can have surface defects, like cracks, folds or seams. Surface preparation of rolling stock is necessary to ensure flawless surfaces of the rolled product. Surface defects of semi-finished products, can also be removed by the following processes.

## Scarfing

Scarfing removes surface defects of carbon steel grades by an oxy-fuel flame. The flame is used to rapidly melt and oxidise the steel surface while a separate supply of high pressure oxygen to the cutter propels the slag product from the surface. Scarfing is either done by hand (for small lot sizes) or by machine.

The scale from machine scarfing is washed from the steel surface by high pressure water and led to a water pit where the scale is removed by crane. The water is treated and recirculated.From manual scarfing operation scrap collection is carried out by means of magnets.

Dust emissions from scarfing operation are collected and, usually, abated by electrostatic precipitators (wet or dry).





### Grinding

For stainless steels and special steel grades, thermal removal of the surface defects is not possible. Therefore defects have to be eliminated by grinding. The grinding process is either carried out manually or by machines. Manual grinding is performed by use of hand held power tools, in some cases booths equipped with fume extraction to bag filter units. Grinding machines are equipped with a roller table on which the work piece is supported and on which it can be moved. The grinding wheel is mounted on a carriage that permits it to be moved back and forth over the work piece. The unit is positioned in an enclosure, which collects the dust generated during grinding and ducts it to a bag filter before discharge to atmosphere.

### Cutting to-size slabs

In some cases the slabs have to be cut to the appropriate size. Wedge-type slabs, which result from adjustment of the width in the continuous casting plant (mould adjustment) and from change of the lot size, have to be conditioned by torch cutting to obtain the desired geometrical shape.

## 2.7.3 Reheating- and Heat Treatment Furnaces

For hot rolling the steel input has to be heated to appropriate rolling temperature between 1050 and 1300 °C and a uniform temperature distribution has to be ensured.

Depending on the charge material and the hot rolling process, reheating is done in different types of furnaces such as pit furnaces, pusher type furnaces, walking beam furnaces, rotary hearth furnaces or others. These furnaces are fired directly, usually by oil, natural gas or plant gases such as COG and BFG. Depending on the heating media, different waste gas emissions will occur (mainly SO<sub>2</sub> and NOx).

## 2.7.3.1 Batch Furnaces

Batch type furnaces are often used for speciality steels and forgings. A typical example of the batch type furnace is the **soaking pit**, used to reheat ingots, slabs and other feedstock. It consists of refractory lined chambers in which the input is placed vertically (ingots) or horizontally (slabs). A moveable cover allows the input to be charged and removed for rolling. Cast ingots can be charged immediately after stripping to conserve energy. The typical soaking pit capacity is 50 to 170 tonnes with a thermal input of 9.5 MW (Th) and a heating rate of 10.7 t/h.

Soaking pits are no longer in widespread use as more and more steel is continuously cast, a process, which often bypasses the soaking pits. An example of the soaking pit furnace is shown in Figure 2.10.







Figure 2.10 : Pit furnace

Another type of the batch furnace is the bogie hearth furnace. The stock is carried into the furnace chamber on a bogie. The furnace chamber is closed by means of a door and the stock is heated. When the targeted temperature is reached, the door is opened, the bogie with the stock is removed and the slab or casting is taken away for further use.

### 2.7.3.2 Continuous Furnaces

Larger furnaces are usually fed continuously. The stock is pushed through the furnace by the following stock (**pusher type furnace**) or is moved through by walking beams (**walking beam furnaces**), a walking hearth or on/between rollers.

Examples of the larger size (> 20 MWTh) furnaces - the pusher and walking beam furnaces – are shown in Figure 2-11 and Figure 2.12. The largest currently in operation are walking beam furnaces of approx. 125 MW (Th) and pusher furnaces of 200 MW (Th).



Figure 2-11: Pusher type furnace







Figure 2-12: Walking beam furnace

In a **rotary hearth furnace** (see Figure 2.13) the charge material is placed onto a rotary hearth. During the furnace campaign (hearth is rotating) the material is heated and, alter completion of a rotation, discharged.



Figure .2.13: Typical design of rotary hearth furnace

## 2.7.4 Descaling

Prior to rolling adherent scale, which forms during reheating must be removed, in order to avoid a contamination of the stock surface by scale impressed by the rolls (so-called 'rolled in matter').





Mechanical descaling, where the adherent scale is mechanically broken in a light pass (mostly in two-high stands) and then sprayed off or mechanically removed (brushing), is rarely applied any more. Today, a common method of descaling is breaking and spraying off the scale by means of high-pressure water. Power water with pressures of 120 to 250 bar (exeptionally 600 bar) is applied via flat jet nozzles onto the material surface. For the cleaning effect, the impact pressure (i.e. the pressure determined by the distance of the descaling nozzles to the rolling stock) is more important than the system pressure. The following techniques are applied throughout the whole rolling process:

- Primary descaling in so-called high pressure descalers installed before the entry into the roughing train and equipped with 1 or 2 pairs, some times adjustable, descaling headers.

– Mill stand descaling by means of descaling headers arranged above and below the plate passage on both sides of reversing stand and on the entry side in case of continuous stands.

 Descaler at entry of the finishing train for removing secondary scale, i.e. the scale formed on the rough strip at the conveying roller table of the roughing train and finishing train.

- Pairs of mill stand descaling sprays at the entry of the first stand of the finishing train.

In case of production lines for long products the descaling headers are either designed as spray rings or as combination of vertical and horizontal headers, sometimes adjustable to material cross section, for proper descaling of all material surfaces.

## 2.7.5 Edging

Edging is usually applied in the manufacture of strip and plate. The slabs produced in the continuous casting plant are supplied in certain defined, stepped dimensions of widths. The width has to be reduced to the specified dimension of the rolled strip, with a trimming allowance as narrow as possible (scrap minimization and yield improvement). In most cases, this width reduction is performed on so-called edgers (vertical rolling stands) - recently even in slab presses - which are installed in front of the roughing unit. The accuracy of the width reduction and optimum adherence to the rectangular shape effect the amount of scrap arising from cropping (head and tail end) in the rolling mill and in the finishing shops (trimming).

## 2.7.6 Roughing

Roughing depicts the first bulk reduction done on the incoming hot roll stock for the production of strip, rod and sections. Generally, the roughing train consists of one or more horizontal stands for thickness reduction, including edgers (vertical stands) situated in front of the stand for width adjustment. Reversing roughing mills are sometimes equipped with edgers on both ends of the mill stand.





## 2.7.7 Strip Rolling/Finishing Train

In general, the finishing mill consists of a number of rolling stands positioned after one another. The stands have staggered roll gaps so that the thickness reduction to the requested final thickness is done in one pass of the transfer bar. The number of stands depends on the grade and material thickness of the input (slabs) as well as on the thickness range of the finished strip.

Crop shears arranged in front of the finishing stands serve to cut the ends of the rough strip, which may have the form of a tongue or fishtail. This ensures safe entry into the finishing train and avoids damage to the rolls as well as generation of scrap.

In most cases, an additional descaling device (descaling sprays) as described above is installed between crop shears and finishing train. Sometimes there is also an additional vertical stand, which is mainly used for strip guidance, but occasionally for minor width adjustments as well.

### Coilers

Hot strips with length up to 2 km and even more are wound up on so named down (sometimos up-) coilers at the end of the rolling mill by speeds up to 20 m/s and more. The hot band is guided around an expandable mandrel by special arranged wrapper rollers. After approx. 3 - 4 windings the wrapper rollers are lifted and the band is coiled onto the expanded mandrel. Alter the coiling operation is finished, the mandrel is collapsed and the hot coil is transported to a strapping station by means of a coil car.

## 2.7.8 Rod Rolling/Finishing Train

The finishing train of rod mills usually consists of rolling blocks with up to 10 sets of alternating horizontal and vertical roller pairs as shown in Figure 2.14.

Rolling speeds of more than 100 m/s are achieved at the final stages. The material used for the roughing and intermediate rolls is generally hardened steel or cast iron while the finishing rolls are made of carbide, a particularly wear resistant material. The typical calibration used for wire rod mills is a sequence of alternating round and oval calibres.







Figure 2.14: Roller arrangement of wire rod finishing section

## 2.7.9 Plate Rolling

Plate rolling by reversing operation is similar to roughing in strip production. The slabs are formed into plates in the so-called multi-stage rolling operations, where the slabs are stretched, turned by 90° by means of conical rollers on a special roller table, spread, turned again and rolled to the requested thickness.

## 2.7.10 Transport of Roll Stock between Rolling Stands

Usually, roller tables arranged along the entire strip rolling train are used as a means of transport for the rolling stock. These roller tables consist of individual metallic hollow and/or solid rollers with single drive or group drive by means of an electromotor and gear, if necessary.

In special cases, for example later modernisation of a rolling mill including increase of the weight of single products or installation of additional equipment, the distance between roughing stand and finishing stand is no longer sufficient to de-couple the two processes. So-called coil boxes - developed by STELCO, Steel Company of Canada Ltd. - are then inserted as intermediate storing devices.

## 2.7.11 Cooling Lines

In connection with an appropriate temperature control within the finishing trains, the cooling line provides the desired mechano-technological parameters to the material. The steel is rapidly cooled using either water sprays, water walls or laminar flows (see Figure 2.15).



Figure 2.15: Different types of water cooling





Widest spread nowadays is the use of laminar flow cooling on run out tables. Usually, the spray headers (arranged on top and bottom of the passline) are grouped into sections, sometimes of different water flow volume. Each section and/or each header is individually controllable so that desired cooling temperature may be realised. Cooling lines and the individual sprays are computer controlled, whereas the spray headers are switched on and off in accordance to complex mathematical-empirical models, supported by peripheral temperature measurements.

## 2.7.12 Sheet and Plate Production

For sheet production the hot produced coils are decoiled by means of uncoiling reels and supplied to a shearing line which is equipped with levellers to straighten the strip. The rolled sheets with desired length are piled and stored in the storage yard.

Plate production is carried out on shearing lines following the rolling process. The plates are trimmed on both sides, cropped and cut to desired length. Cutting to size for special blanks is done by CNC-cutting equipment (torch-, plasma- or laser beam-cutting units). The internal quality of plates may be determined by ultrasonic techniques. Automatically working devices may be installed on the shearing line run out table.

Finishing operations are computer controlled in the most installations. Consideration is also being given to the in-line quenching and heat-treatment of plates following the last rolling pass as a means of conserving energy.

## 2.7.13 Plate Heat Treatment

Finished plates are partly subject to heat treatment. In **annealing** steel is heated to a subcritical temperature to relieve stresses. For **normalising** steel is heated above its critical temperatura and air-cooled. The purpose is to refine grain sizes and to obtain a carbide distribution, which will dissolve more readily, austenite. **Quenching**, **tempering** and other methods may also be applied.

Several different types of furnaces are used for these purposes, such as walking beam type, roller hearth or car bottom furnaces. The heating and combustion system of such furnaces are may be used for firing the treatment furnaces.

## 2.7.14 Roll Shop

The workrolls as well as the back-up rolls for both finishing and roughing mills are conditioned according to well-defined specifications, depending on the product to be rolled. Conditioning of the rolls is performed at the roll shop where typical machine shop techniques are applied, Duch as machining and grinding.

A roll shop generally includes the following:

- Cooling area where work rolls are cooled either in open air or by water sprinkling.





– Preparation area where the shocks are dismantled and set-up (In some cases the roll shop machines allow reconditioning of rolls without prior dismantling).

 Cleaning area where the rolls to be reconditioned are cleaned from deposits and lubricants, (The cleaning techniques include steam cleaning, application of alkali degreasing solutions, application of organic solvents).

 Typical machine shop equipment including lathes and grinding machines which have individual cooling system where the cooling liquid is continuously processed in order to separate turnings and grinding sludge.

# 2.8 Cold Rolling Mills

## 2.8.1 Process Overview

In cold rolling the properties of hot rolled strip products, e.g. thickness, mechanical and

technological characteristics, are changed by compression between rollers without previous heating of the input. The input is obtained in form of coils from hot rolling mills.

The processing steps and the sequence of processing in a cold rolling mill depends on the quality of the steel treated. Low alloy and alloy steel (carbon steels) processing usually follows the order: pickling, rolling, annealing, temper rolling/skin pass rolling and finishing.

The process route for **high alloy steel** (**stainless steel**) requires an initial annealing step prior to pickling due to the hardness of the steel quality and, further more, several additional annealing and/or pickling steps during rolling may be necessary.

Cold rolled products are mainly strips and sheets (thickness typically 0.16 - 3 mm) with high quality surface finish and precise metallurgical properties for use in high specification products.

## Cold Rolling Mills (CR Strip Mills)

Typical layouts for cold rolling mills are shown in (Figure 2.16), the plants usually comprise:

- **Continuous pickling line**, where the oxide layer formed during the hot rolling is removed by pickling with sulphuric, hydrochloric or a mixture of nitric and hydrofluoric acid. A stretcher leveller or an in-line skin-pass may be used to improve the shape of the strip and provide mechanical breaking of the oxide layer.

- Cold rolling mill generally consisting of a 4-stand or a 5-stand four-high tandem mill or of a four-high reversing mill. Cold rolling reduces the initial thickness of the hot rolled strip by typically 50 to 80 %.





 Annealing facilities to restore the ductility of the steel strip that is lost as the result of work hardening during the cold rolling.

- **Temper mills** to give the annealed material the required mechanical properties (prevents the formation of Lüders lines during drawing). The material is subject to a slight skin pass rolling typically on a four-high skin pass mill. The roughness of the work rolls of the mill is transferred to the strip by the roll pressure.

- **Inspection and finishing lines,** here coils with different length may be welded together to meet the required weight or may be slit to required width. Also coils are cut into sheets with required length and width. At the same time defective sections of strip can be discarded.

- Packaging lines for coils or sheets according to the destination and/or the means of

transport.

 Roll shop, where the work rolls and the backup rolls for the cold rolling mill and the temper mill are prepared.







Figure 2.16: Typical configurations of cold rolled strip mills

For electric furnace steel sheet production the mill design is quite similar to those described above. The rolling mill usually comprises a four-high reversing mill stand, which is enlarged to rolling and alternative skin pass rolling operation (rough pass up to 7 % deformation). For higher Si-contents, flash butt welding of head and tail of the coils to an endless strip has to be replaced by 'agraphing' the ends of the coils.

## 2.8.2 Pickling of Low Alloy and Alloy HR Steel

The entire surface of the hot rolled coil is covered with a thin layer of scale containing oxides, which must be removed prior to cold rolling. This is done by pickling with hydrochloric acid or sulphuric acid, at temperatures typically ranging from 75 °C to 95 °C.

Once the strip or sheet is pickled, it must be thoroughly rinsed with de-mineralised (or equal quality) water and subsequently dried. Oiling is done either with rolling oil or anticorrosive oil.

### **Pickling lines**

Pickling can be done as a batch (usually for bars, rods or tubes), semi-batch or as a continuous process and can also involve a number of stages using several acid baths. The following process description refers to continuous pickling lines on which steel is pickled in coiled shape. Each of the pickling steps described below can also be performed as an individual batch process. A typical pickling plant may incorporate:

 Anticoil break equipment on the decoiler to avoid the occurrence of flow lines (Lüders' lines) on the entering hot rolled coil.

- Welding of the hot rolled coils to continuous strip to ensure defined constant pickling times.

- Straightening equipment prior to the entry of the hot rolled strip into the pickling tanks. The flatness of the hot rolled strip is increased by straightening, and the capacity for pickling is improved by the scale breaking effect of straightening.

- Chemical pickling zone; deep tank or shallow tank (turbulent) pickling equipment.
- Rinsing zones to remove remaining acid on the strip surface.
- Trimming of the strip to obtain cut edges and exact widths.
- Inspection of the strip for dimensional tolerances, surface defects and residues.
- Oiling of the strip (Note this may not be required in a combined pickling and rolling line).

The pickling is carried out in totally enclosed equipment or tanks fitted with hoods. In both cases the units are under continuous extraction to remove any fumes generated.

Modern pickling plant design comprises pickling tanks equipped with external pumps. Instead of simply passing the steel strip continuously through an acid bath, the acid is pumped via a





circulation system through nozzles mounted in the bath itself. The turbulence resulting from this promotes the pickling reactions.

Large continuous pickling lines can have capacities of up to 2.4 million t/a. Figure 2.17 shows the operational steps in continuous pickling lines.



Figure 2.17 : Schematic of a continuous pickling line

## 2.8.3 Initial Annealing and Pickling of High Alloy HR Steel

The coils of stainless steel strip produced by hot rolling are known as 'hot band' coils. Due to the presence of an oxide scale and chromium depleted layer formed during the hot rolling the steel must also be descaled / pickled prior to cold rolling. In addition, the greater hardness of the steel compared with carbon steels necessitates an initial annealing. The annealing process has three components, heating to annealing temperature, temperature equalisation and cooling. Both continuous and batch annealing processes may be used.

### Annealing

Ferritic grades are generally annealed as tightly wound coils in a batch heat treatment

facility. Such installations may be used for the full heating, temperature equalisation and cooling cycles. One or more coils are placed on the furnace base and covered to form a closed furnace chamber. Heating may be achieved via gas firing or electrical heating. An inert protective atmosphere (nitrogen/hydrogen) is required for metallurgical reasons. Ferritic steels are generally annealed at steel temperatures of up to 800°C.

For **continuous annealing** of **austenitic steels** the steel coil is unwound and passed through one or more heat treatment furnaces. These furnaces typically consist of a refractory (or other form of insulation) lined steel structure and are usually directly fired by gaseous fuels. An oxidizing atmosphere is needed to form a scale, which is rich in oxygen to allow a better pickling. The waste gases are exhausted via flues under natural or forced draft. Strip temperatures typically up to 1100°C are necessary for annealing austenitic steels. The steel strip then passes through the cooling section and may be cooled using gas jets, air, water





sprays or water quenching. Continuous annealing is generally combined with a descaling/pickling plant as described above to form a continuous annealing and pickling line.

#### **Descaling and Pickling**

After annealing the steel is descaled to produce a steel surface suitable for cold rolling.

Mechanical descaling such as shot blasting or scale breaking may be used prior to chemical pickling to remove the heavy scale burden. However, careful control of such mechanical processes is necessary to minimize damage to the strip surface, which could affect the final product quality.

Final scale removal including the removal of the chromium depleted layer beneath the scale is generally done by pickling in a mixture of nitric and hydrofluoric acids at temperatures of up to 70°C. The acid concentrations employed depend on the material being processed but are normally in the range 10 - 18 % nitric acid and 1 - 5 % hydrofluoric acid.

The chemical reactions that take place during the pickling of stainless steels are complex and involve the removal of the adherent scale layer by the combined action of the acids used. The dominating chemical reaction during pickling is the dissolution of metals by the nitric acid. As a by-product of these reactions both nitrogen monoxide and nitrogen dioxide are formed. The reactions shown below are for the dominant metal iron but similar reactions also occur for the alloy elements present in the stainless steel such as nickel and chromium.

Fe + 4H<sub>+</sub> + NO<sub>3-</sub> = Fe<sub>3+</sub> + NO + 2H<sub>2</sub>O Fe + 6H<sub>+</sub> + 3NO<sub>3-</sub> = Fe<sub>3+</sub> + 3NO<sub>2</sub> + 3H<sub>2</sub>O

The NOx generated is partially soluble in the acid but once the limit of solubility is reached the NOx fumes transfer to the gaseous phase and are released from the pickling tanks. The rate of formation of NOx increases with increasing temperature.

The metal ions formed in the dissolution reactions then react with the hydrofluoric acid leading to the formation of metal complexes.

2HF + Fe<sub>3+</sub> = FeF<sub>2+</sub> + 2H<sub>+</sub> 3HF + Fe<sub>3+</sub> = FeF<sub>3</sub> + 3H<sub>+</sub>

The combination of these two sets of reactions results in the consumption of both nitric and hydrofluoric acids. To maintain the optimum conditions for descaling regular additions of fresh have a limited solubility and if the concentration of iron is allowed to reach 5 % (40 g/l) then precipitation of iron fluoride will commence. This precipitation causes the formation of large quantities of a hard crystalline sludge.

Pickling line design is usually the same as for pickling of low alloy steels. Except, that on exit from the last pickling tank the steel strip is rinsed with water to remove traces of acid, dried, but no application of oil is necessary because of the corrosion resistance of the steel.

## 2.8.4 Cold Rolling of the Pickled Hot Rolled Strip





## 2.8.4.1 Low Alloy and Alloy Steel

In cold rolling the pickled hot rolled bars, sheets or strips are passed through sets of rolls on reversing mills or on continuous in-line mills. Low carbon steels which are less hard, are generally rolled in multi-stand tandem mills due to a higher capacity of these mills. They consist of a series of four or six-high stands. The strip enters the first stand and undergoes an initial thickness reduction, further reductions are achieved in each subsequent stand until the final gauge is attained.

For low carbon strip generally an emulsion of 0.5 to 4 % (10 – 20 % for direct application) of oil in water is necessary for

- Lubrication.
- Cooling of the strip, work and back-up rolls.
- Removal of Fe-particles.

In the rolling process the wide strip is mainly deformed in a longitudinal direction, with transverse deformation being practically negligible. The thickness reduction of the material is obtained by the influence of the rolling forces and the strip tensions (forward and back) applied. The cold forming process leads to a corresponding hardening of the material. Exact mass flor control (control of rolling force and/or position), assisted by laser control of the strip speed and tension, may be used. Additional automatic control loops for flatness (roll bending, zone cooling, etc.) are used to obtain the required flatness of the strip. The roughness texture of the strip surface is applied in the last stand of the tandem mill.

For optimum strip surface cleanliness it is important to avoid contamination of the tandem emulsion by the hydraulic oil, by the Morgoil oil, by grease or by the cooling water (used to cool the emulsion). Precautions taken to avoid any contamination may include:

- Continuous monitoring of oil levels.
- Monitoring of the oil concentration.
- Regular control of hydraulic equipment and bearings.
- Monitoring of emulsion parameters such as temperature, pH value, saponification index,

acid value, conductivity.

 Filtering of the tandem emulsion (using techniques such as magnetic filters, paper filters, precoat filters).

To clean the strip and remove any remaining soap or oil, it may be subjected to chemical and/or electrochemical degreasing. For this purpose, cleaning zones are installed on the entry side of the downstream processing plants such as hot dip galvanising plants or continuous annealing plants.

#### **Conventional discontinuous rolling**





The pickled hot rolled strip is fed into the cold rolling mill coil by coil. This results in a variation in the strip thickness corresponding to the geometrical conditions of the line at the strip ends during threading and at the exit of the coil end.

To produce 'mill clean sheet', often a thin emulsion with a maximum concentration of 1 % can be used on the last stands of the tandem mill. The emulsion is usually applied via spray nozzles onto the rolls and the strip. Sometimes higher concentrations are used in direct application systems.

Discontinuous rolling offers a high degree of process flexibility to account for variations in product mix. The technique is preferable for certain steel qualities.

#### **Continuous Rolling**

To achieve the narrowest possible thickness tolerances, maximum output and optimum

productivity figures, a shallow tank turbulence pickling plant can be coupled with a tandem mill, which is enlarged by one stand. Usually an accumulator and a welding machine before a tandem has the same good results and a bigger increased capacity. The use of a welding machine and the accumulator allows coils to be joint and the strip to be fed to the mill continuously.

On a tandem line, the entering pickled hot rolled strip is reduced to the desired final thickness on a single pass through the line. Owing to the installation of several separate emulsion systems, a special emulsion can be applied in the last stand to increase the cleaning effect. For this purpose, either a detergent or a thin emulsion (1 % oil content) can be used.

Continuous rolling can allow good control of the strip thickness for coil ends and of surface quality. This can have a beneficial effect on material yield. In addition it allows oil consumption to be optimised.

## 2.8.4.2 High Alloy Steel

After the initial annealing and pickling the steel is generally rolled to the required thickness on reversing cluster mills for a number of passes until the desired dimensions are achieved or until work hardening necessitates further annealing.

The process of cold reduction generates heat, part of which is transferred to the rolling oil which is sprayed onto the steel and rolls for cooling as well as lubrication. This heat is subsequently dissipated through heat exchangers to cooling water systems. Mineral oils are generally used as rolling oil and close control of the oil cleanliness is necessary

for optimum performance. This may be achieved using oil filtration circuits, which incorporate media element filters or powder pre-coat filter systems. Although the use of mineral oils predominates, emulsion cooling systems similar to those used for carbon steels may be employed. In such cases additional precautions must be taken to control oil cleanliness in order to avoid strip marking.





Collection hoods are fitted to the mill and operate under continuous extraction to remove oil mist that is generated.

## 2.8.5 Annealing of Low Alloy and Alloy Steel

The basic stages of the annealing process comprise:

- Heating to annealing temperature (above 650 °C).
- Holding at annealing temperature.
- Cooling.

This annealing process may be carried out in batch furnaces or continuous furnaces. The annealing cycle has a significant influence on the mechanical properties and, consequently, on the formability of the steel strip. The main parameter controlling the annealing cycle is the temperature profile. It varies, depending on whether the annealing is carried out in a continuous or batch furnace, and depending on the required strength or hardness of the product. The annealing cycle depends on a number of parameters including the actual material analysis, the reduction realised during cold rolling, the required mechanical properties and the required surface cleanliness, the type of protective gas, etc.

Continuous annealing and batch annealing are considered to be complementary processes and not fully interchangeable. Production related issues are integral to the selection of the annealing technique.

#### 2.8.5.1 Batch Annealing Degreasing /Cleaning by means of alkali

Prior to the annealing process the strip may be cleaned (degreased) to produce a cleaner surface. The cleaning serves to remove oil residues from the steel surface. The process is similar to that used for acid pickling except for the chemicals that are used. The most frequently used clearing agents are phosphates, alkaline silicates, caustic soda and soda ash. Electrolytic cleaning and brushes are also used in some cases to remove iron fines from the strip surface.

The steel sheet is unwound from the coil and passed through cleaning tanks, which may be stirred to improve the cleaning effect. Subsequently, the steel is rinsed with water and recoiled. The degreasing solution can be regenerated and recycled.

#### Annealing

The cold rolled coiled strip is stacked in a hood furnace for annealing (see Figure 2.18). The combustion chamber (space between heating and protecting hood) is heated by oil or gas burners. Heat passes through the protective hood into where the steel coils are stacked. A circulating fan provides as uniform temperature distribution as possible. The atmosphere in





conventional plants is usually HNX gas (a nitrogen-hydrogen mixture with a hydrogen content close to the flammability limit). The atmosphere can also be 100 % H<sub>2</sub> as in parts of the working cycle of high convection furnaces.



Figure 2.18 : Schematic of a hood-type annealing furnace

The heat passes into the coils through their outer edges, so that these areas are always hotter than the inner windings, especially during heating up. The heat treatment causes the organic residues of the emulsion to partly burn off; partly a distillation process takes place. Products of the reactions taking place are CO/CO<sub>2</sub>, H<sub>2</sub>, FeOx and CH<sub>4</sub>. The strip is heated to recrystallisation temperature, and annealed at about 700 ° C resulting in complete recrystallisation of the cold rolled steel. For cooling the coils, the heating hood is removed. The cooling effect can be enhanced by spraying water on the protecting hood; by covering it with a cooling bell and blowing air on it or by using a cooling by-pass system which cools the protective atmosphere under the protective hood. The time necessary for annealing depends on the annealing temperature and the weight of the charge and can take 2 to 7 days.

Annealing in this type of furnace is very slow and also the cooling rate is not suitable for certain steel grades. Therefore an annealing process in a 100 % hydrogen atmosphere was Developer yielding in shorter annealing times and more rapid cooling.

## 2.8.5.2 Continuous Annealing

For continuous annealing the coils are welded together on the entry side of the plant and subjected to the following process steps:





- Alkaline/electrolytic cleaning of the strips.
- Heating and holding at the required annealing temperature.

 Cooling (slow jet cooling, high gas jet cooling (using cooling rates up to 150 °C/s, hot water quench (HOWAQ), overaging, roll cooling, final cooling, misting jet cooling).

The continuous annealing is carried out by passing the steel strip through a multi-zone heating furnace with heating chamber, annealing chamber, cooling zone, tempering zone and a second cooling zone. The steel is heated to a range between 650 °C and 830 °C and then cooled by gas jets, gas-water sprays, contact rolls or water quenching, depending on the desired metallurgical properties. These furnaces are usually fired by gas (direct or indirect) or electrically heated. The steel can be protected by an inert gas atmosphere or a reducing gas atmosphere in parts of the furnace. The principle operational steps for continuous annealing are shown in Figure 2.19.



Figure 2.19 : Example of a continuous annealing furnace

Continuous annealing gives a shorter processing time (about 10 minutes), less intermediate storage, uniform mechanical properties and a superior surface cleanliness. Continuous annealing is more appropriate for the production of higher strength steels. The layout of the furnace facilitates energy recovery from the exhaust gas.

## 2.8.6 Final annealing and Pickling of High Alloy Steel

#### Degreasing





Prior to the final annealing process, degreasing of the strip may be required to remove any contaminants from the steel surface. This can be achieved using an alkali based clearing systems, which may be incorporated in the entry section of continuous annealing lines.

The steel coil is unwound and passed through a series of tanks containing the cleaning solutions. Agitation of the solution is usually incorporated to enhance the cleaning. Afterwards the strip is rinsed with water. De-mineralised water can be used for the final rinsing step.

#### Annealing

The process route for final annealing and pickling is dictated by the surface finish required. Examples of this are EN standard finish '2R' which requires a bright annealing treatment and surface finish '2B' which requires annealing and pickling.

Bright annealing is generally conducted in an electrically heated or gas fired furnace with a protective inert atmosphere of nitrogen and/or hydrogen. Both batch annealing and continuous discolouration.

Material with a '2B' surface finish is generally processed on continuous annealing and pickling lines. The furnace design and operation is generally similar to that for the annealing of hot band material described above. The steel is unwound and passed through one or more furnaces, which are usually gas fired. Annealing takes place in an oxygen rich atmosphere. This is necessary to ensure that the scale generated in the furnace is of a composition that is readily removable by the downstream chemical pickling processes.

#### Pickling

Unlike the descaling of hot band material described above, mechanical descaling techniques cannot be employed to assist in the removal of this scale due to the surface damage which would result for the final cold rolled strip. Therefore only chemical pickling is applied. This is done in the same manner as described above for hot band pickling.

Scale of high alloy steel, due to the presence of oxides of alloying elements, cannot always be removed in just a single acid descaling step. Additional treatment or pre-treatment processes may be necessary. These may include scale removal by an initial electrolytic descaling process (using e.g. sodium sulfate) installed prior to the mixed acid section. Generally these facilities operate with neutral salts or acids as the electrolyte. It is appropriate to consider the electrolytic process as a pre-pickling system as satisfactory descaling cannot be achieved with this section alone. However the length of mixed acid section required (and hence the acid consumption and environmental impacts) is considerably reduced. Furthermore the combination of electrolytic and mixed acid can provide an improved surface finish.

## 2.8.7 Tempering of Cold Rolled Strip

#### Low Alloy and Alloy Steel

After annealing the surface finish and mechanical properties of the steel are modified in line with the customer requirements. This is done by temper rolling which consists of subjecting





the strip to a light rolling pass with a thickness reduction between 0.3 and 2 %. Before tempering the strip temperature must be less than 50 °C.

Temper rolling is carried out in the temper mill which comprises typically one or two four-high stands, although two-high or six-high stands are also possible. For tin plate production two tour high stands is common. The rolls for these stands have an extremely precise surface finish in order to control the final roughness of the strip in line with the end use of the finished product. Tempering also improves strip flatness.

To avoid residues from the rolling process remaining on the strip cleaning agents, (a wet temper rolling agent), can be used during tempering. The rolls may also be brushed with mechanical polishing equipment and an associated extraction system.

#### **High Alloy Steel**

Similar to the process route for carbon steels temper rolling or skin pass rolling is completed in order to attain the desired surface finish on the steel. This cold rolling treatment, comprising a minimal reduction in gauge (up to 2 %) is generally performed dry without application of oil for cooling. The temper mill usually comprises a single two or four high stand with precision ground rolls.

### 2.8.8 Finishing

Finishing comprises slitting into coils of different width strip and transversal shearing to obtain sheet. Additional steps such as straightening, sampling, oiling and marking are also completed. In general the techniques used are similar for both low alloy and high alloy steels, however oiling is not required for stainless steels.

The finishing process comprises the following operations:

- Dimensional control (width, thickness and length).
- Inspection for surface defects and their removal.

 Sampling to determine the mechanical and technological properties, the strip roughness structure and the content of residue of particles from roll wear and carbon on the strip surface (statistical sampling).

- Trimming the coils to exact width.
- Straightening the strips to optimum flatness.

- Oiling the strips with electrostatic oiling machines or with oiling machines equipped with sprays or rolls oiling machines (anticorrosive oils or prelubes).

- Marking the finished products with coil number, production date, etc.
- Welding of different smaller coils to bigger coils.

In the finishing shops the coil weights used for maximising productivity are cut into the coil weights ordered by the customers. Defective coil parts are eliminated or if necessary, the





material is subjected to additional treatment for removal of the defects. This can incluye additional annealing, temper rolling or straightening.

#### Strip grinding

Grinding of the steel surface may be used to generate a uniform surface quality as well as rectifying defects. The strip is usually decoiled on dedicated process lines, sprayed with oil and ground with belts of varying surface roughness. Mineral oil is generally used for this process and filtration circuits employed to separate the swarf generated during grinding.

#### Parking

The material, now in its final form, is usually packed ready for despatch to the customer. The packaging is designed to ensure that no damage occurs either during storage or transport to the end user. Control measures also have to be taken to prevent damage from mechanical and climatic sources. In addition the lifting and transport equipment in the production plant should also be designed and operated to minimize damage to the steel. After finishing, packing of the individual items ordered by the customers is done. The packing materials used includes: steel bands, paper, plastic, wood, seaworthy packing, special packing.

## 2.8.9 Roll Shop

The activities generally consist of the dismantling of the chocks, the grinding of the rolls, the texturing of the work rolls and the reassembling of the rolls.

To satisfy the required strip tolerances and surface standards the rolls must be regularly reground. During this grinding operation the rolls are usually cooled and lubricated with a grinding emulsion. The spent emulsion can be recirculated and filtered, but partial replacement is required periodically. In addition, used oil and grinding sludge are produced which require disposal.

The principal roll texturing systems used include:

 SBT (Shot Blast Texturing): This is a mechanical application of the texture onto the roll using grit blasting.

 EDT (Electron Discharge Texturing): The work rolls are textured by spark generation in an oil bath.

- EBT (Electron Beam Texturing): In this system the roll is placed in a vacuum chamber and the texture is applied by means of an electron beam gun.

- Laser Tex (Laser Texturing): The roll is textured to predetermined roughness by Laser gun.

Pretex (Premium Texturing): The roll is textured by a rough electrolytical chromium plating.
The chromium plating process is fully enclosed and fitted with an exhaust gas system using a wet scrubber. The whole process operates without an effluent discharge, because of the evaporative losses.





## 2.8.10 Wire drawing plants

## 2.8.10.1 Wire Drawing Process Overview

Wire drawing is a process in which wire rods/wires are reduced in size by drawing them through cone-shaped openings of a smaller cross section, so called dies. The input usually is wire rod of diameters raging from 5.5 to 16 mm obtained from hot rolling mills in form of coils. A typical wire drawing process line comprises the following steps:

- Pre-treatment of the wire rod (mechanical descaling, pickling).
- Dry or wet drawing (usually several drafts with decreasing die sizes).
- -- Heat treatment (continuous-/discontinuos annealing, patenting, oil hardening).
- Finishing.

Wire is manufactured in different grades of steel: low carbon steel with carbon content of up to 0.25 %, high carbon steel with a carbon content of over 0.25 %, stainless and other alloy steel. Non-alloy steel wire can be uncoated or coated with zinc, copper, brass, tin, nickel, chrome, plastic or varnish. Wire is send in coil form to further processing, like coating and manufacturing of finished products (e.g. cable, mesh, barbed wire, wire fencing, grill, springs, nails).











Figure 2.21 : Production of high carbon galvanized wire

Because of the huge variety of wire products, many different processing schemes exist, dictated by wire diameter and required mechanical and other quality specifications. The process schemes shown in Figure 2.20 and Figure 2.21 cover the majority of galvanized wire that is produced in Europe (and worldwide). A fraction is sold as such; a fraction is processed further by wet drawing or by processes that fall out of the scope of the BREF, such as welding, electroplating, weaving, cabling, bunching, painting, plastic coating, cutting to length, etc.

## 2.8.10.2 Wire Rod Preparation

Air-cooling after rolling produces an iron oxide-layer (scale) on the wire rod surface. This layer is very hard, brittle and not deformable and must therefore be removed before any further processing can take place. In most cases, this is done by the wire industry. For stainless steel however, this is typically done by the steel mill.





Two techniques for descaling wire rods are applied: mechanical descaling and chemical pickling. Some categories of end products can only be produced from mechanically descaled wire at a reduced drawing speed (needing more drawing machine capacity, meaning higher investment costs). The decision on the descaling technique is therefore done by each individual plant, based on product qualities and economical considerations.

### **Mechanical Descaling of Wire Rod**

In the most common mechanical descaling method applied: wire bending, the wire is bend to cause the brittle scale to peel off. Other descaling techniques, like sanding, brushing or shot blasting, are used as a finishing step after wire bending to remove loose scale or are used as stand-alone techniques.

Batch shot blasting is a common technique for mechanical descaling of heavy diameter wire rod (e.g. used for cold heading applications). However mechanical descaling is generally done in a continuous way.

Depending on the finish of the wire rod and the quality requirements of the product, descaling by reverse bending is completed or possibly replaced by an abrasive method such as sanding, brushing, shot blasting or stream descaling. By combining reverse bending with one of these auxiliary methods, complete removal of the oxide layer can be achieved, reaching a similar surface cleanliness as with chemical pickling.

Compared to chemical pickling of wire rod, mechanical descaling has the advantage that one production step is eliminated as the descaling unit is normally coupled directly to the drawing machine. On the other hand, it is difficult to obtain the same level of drawability with mechanical descaling.

### Chemical Descaling (Pickling) of Wire Rod

In chemical descaling the mill scale is removed by dissolving in acid. Acids used are:

- Sulphuric or hydrochloric acid for low carbon wire.
- Hydrochloric acid for high carbon wire.

Pickling is mostly done in a batch process. Each roll of wire rod is immersed in the acid bath. The acid slowly dissolves the oxide layer by transforming it into iron chlorides or sulphates. When pickling in HCl an H<sub>2</sub>-inhibitor is used to suppress the reaction:  $2 \text{ HCl} + \text{Fe} \rightarrow \text{FeCl}_2 + \text{H}_2$  and reduce the unwanted loss of iron.

After pickling the wire rod coils are rinsed in water. This is usually done in cascade rinsing (e.g. rinsing 3 times) to yield maximum rinsing efficiency and minimum water consumption.

### Application of Soap (Lubricant) Carrier

In some cases, soap carrier is applied to enhance the adhesion of the lubricant to the wire. A wide range of soap carriers is available. Selection is made on economical basis and on required properties in downstream processes. Traditional soap carriers include lime, borax and Znphosphate. Modern soap carriers are typically mixtures of soluble salts, e.g. sodium and





potassium sulphate, chloride, borax, phosphate or silicate. They are adapted to a particular soap and a particular drawing situation.

Soap carrier is applied before drawing by dipping the wire in a watery soap carrier solution. This can be done in a batch process, usually associated with chemical descaling, or continuous in association with mechanical descaling.

## 2.8.10..3 Drawing

#### Dry Drawing of Wire

Dry drawing is typically used to draw wire rod (> 5.5 mm) to a product diameter of 1 - 2 mm and some times even lower. The diameter of wire is reduced by passing it through a series of dies with diminishing diameter. Before entering the dies, the wire is passed through a dry lubricant. In most cases, soap-based lubricants are used with the soap formulation depending on choice of fats from which the soap is produced, choice of fillers or choice of additives. In exceptional cases (e.g. special steels, wire with special metal coatings) other lubricants like pastes or oils can be used.

The drawing operation heats both (wire and drawing die) through friction of the wire. Cooling is done indirectly, by cooling the capstans in contact with the wire with water.

#### Wet Drawing of Wire

Wet drawing is typically used to draw wire with an intermediate product diameter of 1 - 2 mm to final diameter. The wire is also passed through a series of dies with diminishing diameter, but wire, dies and capstans are immersed in a lubricant liquid that provides lubrication and cooling. Typically, soap or oil emulsions (for some applications plain oil) are used. The heat resulting from drawing operation is taken up by the lubricant, which is cooled indirectly with water.

### 2.8.10.4 Heat Treatment of Wire

Heat treatment of wire has different goals. Therefore different types of heat treatment are available depending on the type of steel (low carbon / high carbon / stainless) and the final use (desired ductility and strength). Heat treatment also thermally removes soap and lubricant residues.

A considerable percentage of the output of the wire industry does not need any heattreatment. The heavy deformation of the metal crystal structure caused by drawing is mostly a positive property, as it increases the hardness and the strength of the wire in the axial direction.

### 2.8.10.4.1 Batch Annealing of Low Carbon Steel Wire





Drawing profoundly deforms the shape of the metal crystals of the wire. Annealing is one of the different methods to re-obtain a suited crystal shape. Batch annealing, typically used for low carbon steel wire to obtain a very soft and ductile end product, is done in bell or pot furnaces.

Batch annealing is done by putting coils of drawn wire in chambers (called "pots" or "bells"), filled with a protective gas. The protective gas is either neutral or reducing. The most common protective gasses are nitrogen, hydrogen, nitrogen/hydrogen mixtures and partly oxidized natural gas (or similar fuel). The chambers are heated from outside, typically by gas or fuel. The warming up from room to peak temperature (roughly 700 °C) takes several hours; also cooling down again takes several hours. In order to keep an over-pressure in the "pots" or "bells", a fraction of the protective gas is continuously purged.

In some cases, the wire is oiled immediately after annealing.

## 2.8.10.4.2 Continuous (In-Line) Annealing of Low Carbon Steel Wire

Continuous annealing or strand-annealing (explained in the following paragraphs) has a similar goal as batch annealing (explained in section 2.8.5.1): restore a suited crystal texture to the steel in the wire after drawing. But the desired crystal shape and metal properties are different from those that are desired when batch-annealing is applied. Continuous annealing is a typical heat treatment method for low carbon products.

Strand-annealing is a fast continuous process. The wire is heated up to the recrystallisation temperature (500 - 700  $^{\circ}$ C), is kept at this temperature for a few seconds, and is cooled down again by quenching in a water bath.

A typical line is equipped for 15 - 50 wires and is characterised by a particular v x d (wire speed x wire diameter). This means that wires of different diameters can be processed together at the same line, but the higher the diameter of a wire, the lower its speed. Modern lines have a v x d of 100 - 200 m/min x mm (in other words, a 1 mm wire is processed at speeds of 100 - 200 m/min). For specialities, lines with a few or only one wire and/or operating at a lower v x d, are used. Strand-annealing is often combined in one production line with other unit processes e.g. with hot-dip coating.

Commonly the wire is heated by passing through a molten lead bath. A fast heat-up is essential for strand–annealing. Due to a very high heat transfer coefficient of lead ( $3000 \text{ W/m}_2$ .K) equilibrium between wire and lead-bath temperature is reached after a few seconds. Other methods such as an oven or inductive heating are alternatives, only in some niches e.g. one-wire lines, lines operating at low speed or lines designed to run with only one diameter at a time.

After the heat-treatment, the wire is generally quenched in water. This can be followed by inline pickling with warm or cold HCl to remove oxides which also partly dissolves the potentially dragged lead. Other acids or electrolytically assisted pickling can be used as well. Pickling is followed by a rinsing cascade. At some plants, pickling is done as the first operation





of the next process step. Often pickling is omitted after heat treatment under protective atmosphere.

## 2.8.10.4.3 Continuous (In-Line) Annealing of Stainless Steel Wire

Stainless and high alloyed steel wire is continuously annealed to obtain suited metal cristal properties for (further) drawing operations. For stainless steel, the heat-treatment is done Ander a protective gas atmosphere. If no protective atmosphere would be used, the stainless steel wire would be oxidized; removal of these oxides would require pickling with special acids such as HNO<sub>3</sub>, HNO<sub>3</sub>/HF,... (cfr. production of stainless steel strip). The temperature profile used, varies with the type -content of Ni, Cr or other alloying elements- of stainless steel that is processed ( $700 - 1100 \ ^{\circ}C$ ).

The wire is passed through tubes or a muffle, under a protective gas. The purge of protective gas is similar to what is described for batch-annealing. The first part of the tubes or muffle is placed in an oven (indirect heating of the wire); the second part is cooled indirectly, e.g. by cooling with water. The heating can be done by electricity (resistance heating, inductive heating) or by combustion.

## 2.8.10.4.4 Patenting (special heat treatment)

Patenting is a heat-treatment method typically used for high-carbon and alloyed steel products to create a special crystal structure, which allows easy further deformation. In contrast to annealing where iron and iron/carbon compounds tend to be separated, patenting yields a structure where the carbon is homogeneously distributed in the iron.

Patenting is done by heating the wire to 850 - 1000 °C, then cooling fast to 450 - 600 °C and keeping the wire for a while a this temperature, and finally quenching in water. Patenting is usually done continuously and often combined with other unit processes, e.g. hot dip coating.

Heating to 850 - 1000 °C is done in an oven where the wire is in contact with the combustion gasses. Intermediate cooling and keeping at 450 - 600 °C is done in a lead bath. For small lines designed for specialities (e.g. fine diameters or mono-wire lines) other heating methods such as heating under protective gas atmosphere and electric ovens can be used. For the patenting of thick diameters, sometimes a molten salt bath is used.

In the fuel fired oven, a slight substoichiometric mixture is used in the burners. In this way, all  $O_2$  is excluded from the oven atmosphere, in order to minimize the formation of iron oxides at the wire surface. Excessive formation of iron oxide leads to high losses of wire material and to excessive consumption of pickling acid, and leads to excessive dragout of lead.

Final cooling is done by quenching in a water bath followed by the same procedure as in continuous annealing.

For a patenting line consisting of a furnace with direct contact between wire and combustion gases, a lead bath and a quench bath, wastes and emissions are as follows:





Air emissions arise from the furnace. The furnace is heated to 850 - 1000 °C using natural gas (or a similar sulphur-free fuel) and with a slight O2-shortage. Fresh air is mixed with the hot exhaust gas of the oven in order to convert the CO to CO2, prior to emission into the atmosphere. NOx and SO2 are negligible in this stream: reducing atmosphere/fuel is free of sulphur.

The lead bath is used for cooling; in contrast to a lead bath used for annealing, there is no burning of residual lubricant, so the emissions to air are limited to dust (bath cover material, containing traces of Pb).

Solid waste is generated by the lead bath as lead oxides and spent bath cover material. Waste water is formed in the quench bath. Some installations need cooling water for cooling of moving parts that are in contact with the hot wire.

## 2.8.10.4.5 Oil Hardening and Tempering (Oil Tempering)

Oil hardening and tempering creates a special crystal structure in the steel with a high percentage of martensite, resulting in increased hardness and wear resistance combined with good thoughness. First, the wire is heated to 850 – 1000 °C, followed by rapid cooling.

Heating is typically done under protective atmosphere using electricity (radiation, inductive heating) or combustion. The purge of protective gas is similar to what is described for batchannealing. Quenching is traditionally done in oil, but also other quenching media can be used such as water or water with additions. (Note: although it is not unusual to quench in other media than oil, the normal way of referring to this process step is still oil-hardening).

Oil-hardening is always followed by a tempering or stress-relieving step, in order to remove the stresses caused by the extremely fast cooling. This is done by heating the wire again to 300 - 500 °C. Typically a normal oven is used, with electrical heating or direct heating with a typical combustion gas, but also inductive heating can be used.

## 2.8.10.4.6 Stress-relieving

The goal of stress-relieving is to remove internal stresses in the wire caused by a previous processing steps, without changing the shape and structure of the steel crystal. The internal stresses can be caused by deformation (mechanical stresses) or by fast cooling (termal stresses). Stress-relieving as a stand-alone heat-treatment step is a typical process step for the production of PC-strand (wire for prestressed concrete).

Stress-relieving can be done at various temperatures (200 - 500 °C), dependent on the desired characteristics of the final product. Typically a normal oven is used, with electrical heating or direct heating with a typical combustion gas, but also inductive heating can be used. Alter stress-relieving, the wire is cooled relatively slowly in air or water.

## 2.8.10.5 In-line Pickling





In-line pickling is a typical operation after heat-treatment and/or before hot-dip coating of wire. It is used to clean the wire and to remove metal oxides. The wire is passed continuously through one or more acid baths. The most common acid is HCl, but other acids can be used. The pickling takes place in a very short time (a few seconds), therefore the acid is often heated and/or used in concentrated form. After pickling the wire is rinsed in water.

Finishing of wire includes the application of metallic or non-metallic coatings.

# 2.9 Continuous Hot Dip Coating Process

In the hot dip coating process, the steel is continuously passed through molten metal. An alloying reaction between the two metals takes place, leading to a good bond between coating and substrate.

Metals suitable for the use in hot dip coating are those, which have a melting point low enough to avoid any thermal changes in the steel product, like for example aluminium, lead, tin, and zinc.

The principal hot dip coatings for steel sheet are shown in Table 2-1. Wire is hot dip coated with zinc (galvanized) or tin. Zinc coating is mainly applied as corrosion protection. Tin gives the wire a shine appearance and also provides a solder adhesive layer.

Coating Base	Bath	Coating	
		Туре	Name
Zinc base	Zn	Zn	Galvanised
	Zn	Zn-Fe	Galvannealed
	Zn	Lead free	
	Zn-Al	99 %Zn, 1 %Al	Crackfree
	Zn-Al	95 %Zn, 5 %Al	Galfan
Aluminium	Al-Zn	55 %Al, 43.5 %Zn,	Galvalume
Base	Al	1.5 % Si	Type I
	Al-Si	Al	Type II
		Al 87 %, Si 13 %	
Lead base	Pb-Sn	8.25 % Sn	Terne
		75 - 92 % Pb	

Note: Source of data [EUROFER CC], [Com-CC-2]

Table 2-1: Main hot dip coatings for steel sheet

In general **continuous coating lines for sheet** comprise the following steps:

□ Surface cleaning by means of chemical and/or thermal treatment.





- □ Heat treatment.
- □ Immersion in a bath of molten metal.
- □ Finishing treatment.

#### Continuous wire galvanizing plants involve the following steps:

- □ Pickling.
- □ Fluxing.
- □ Galvanizing.
- Finishing.

## 2.9.1 Galvanizing of Sheet (Zinc and Zinc Alloy Coating)

In continuous hot dip galvanizing steel strip is coated with a zinc or zinc alloy layer as corrosion protection. Figure 2.22 shows the layout of a continuous galvanizing line (without pickling).

Plant layouts may vary in the design of the entry section (with/without pickling or alkaline degreasing), in the design of the annealing furnaces (vertical or horizontal) or the post-dipping treatment (galvannealing etc.)

Hot dip galvanizing of cold rolled strip is more common than galvanizing hot rolled strip. The processing is similar, except that for hot rolled products additional descaling (pickling) is necessary.

### 2.9.1.1 Pickling

Pickling operation for descaling is only necessary for galvanizing hot rolled products to remove hot mill scale. Pickling of unannealed cold rolled coil is done for activation. Both processes are done in hydrochloric acid, followed by rinsing. The technology is the same as the pickling process described in the cold rolling section of this BREF.

### 2.9.1.2 Degreasing

It is essential that the surface of the steel coil is free of impurities such as grease, oil or abraded iron fines to ensure the entire surface is exposed to the coating product and strong adherence is achieved. Although degreasing is not necessary when the strip is subsequently heat treated, it is often applied in any case. The cleaning process involves several or all of the following steps:

□ Alkaline degreasing via immersion or by spraying; maybe coupled with brushing.





- □ Alkaline degreasing by an electrolytic system; maybe coupled with brushing.
- $\hfill\square$  Rinsing with water with intermediate brushing between rinsing tanks.
- Drying.

Figure 2-22 shows two possible layouts for modern degreasing lines.



Figure 2-22: Degreasing line layouts



Figure .2-23: Typical layout for a hot dip zinc coating line




The degreasing agent is usually a non-siliceous alkaline solution with a concentration of 25 g/l and a temperature between 70 and 95 °C. Aqueous systems are now standard and solvent degreasing is obsolete.

The same aqueous solution containing mainly sodium hydroxides, orthophosphates and surfactant compounds is used in spray degreasing and in electrolytic degreasing. Once the solution in the electrolytic degreasing section has reached a certain oil level, it is re-used on the spraying section (cascade use). It is also possible that the solution is treated in an emulsion separation centre and then biological treated. When the solution has reached the maximum oil content it is regenerated, usually off-site.

Fumes generated in degreasing and brushing are collected and scrubbed prior to release, using water or caustic soda solution and/or led through a demister for cleaning. Spent degreasing agent and waste water from the rinsing and brushing operations are sent to waste water treatment before release.

# 2.9.1.3 Heat Treatment

Hot and cold rolled steel coil are passed through a furnace with controlled atmosphere prior to galvanization to degrease and dry the surface, to improve the adhesive properties of the surface, to obtain the required mechanical properties of the steel and to allow the steel to reach the required temperature before dipping. The following types of furnaces are used:

## Sendzimir Furnace

This type of furnace is no longer used in modern coating lines, but some older plants might still operate this horizontal continuous furnace, which comprises a directly heated preheating furnace (oxidizing zone) and indirectly heated reduction and holding zones with reducing  $H_2/N_2$  atmospheres, followed by cooling zones. In the preheating part of the furnace, the temperature is 450 - 550 °C. The strip is cleaned by burning off the oil the oil emulsion residues. In the

reduction zone, at a temperature of 980 °C and in an inert atmosphere the oxides are reduced.

The holding zone allows for recrystallisation and normalisation. The strip is then cooled to a temperature slightly above that of the molten metal (ca. 500 °C) and is fed into the zinc bath, under protective gas, by means of a so-called snout.

## Direct Flame Furnace (D.F.F)

The direct flame furnace (Non Oxidizing Type) can be divided into different sections:

A warming-up section where the strip is preheated using the gas flow coming from the furnace, temperature raises from 20 °C to approximately 250 °C).

The furnace itself, where the coil is heated directly by means of a naked flame, reaching a temperature between 560<sup>o</sup>- 750 °C.

The annealing zone where electric or radiant elements heat the strip up to 830  $^{\circ}$ C and maintain this temperature under reducing atmosphere (HNx atmosphere, 3 –20 % hydrogen).





Two cooling areas, with different cooling rates, where the temperature of the steel is reduced by jet cooling down to 450<sup>o</sup>- 480 °C.

The exit area where the steel goes towards the galvanising bath.

This type of furnace cleans the coil surface and does not require any prior degreasing of the metal, but air emissions are generated as the remaining oil from the surface is burnt. Furthermore combustion products,  $H_2$  and  $N_2$  arise from the furnace (fired by natural gas or desulphurised coke gas).

## **Radiant Tube Furnace (R.T.F.)**

The radiant tube furnace is a variation with indirect heating. The combustion gases circulate through radiant tubes and do not get in contact with the strip. The soaking zone can be fitted with radiant tubes or electric heating. Alkaline degreasing and radiant tubes or electric heating are required for very high quality standards and for improving the adherence of the following metallic coating. The fast cooling areas are similar to those of a D.F.F. The annealing furnace is combined with an alkaline degreasing equipment.

Fuels used are desulphured coke oven gas and natural gas. Energy conservation is a primary consideration in modern furnace designs. Recuperative features, such as infrared waste gas preheaters, preheating of combustion air in direct fired and radiant tube furnace burners, preheating of furnace atmosphere gas and installation of waste heat boilers are generally incorporated when feasible.

# 2.9.1.4 Hot Dipping (Galvanizing)

The galvanizing bath consists of one or more tanks, usually made of ceramic material. These pots, which can be either fixed or mobile, contain the molten metal at a temperature of 440° - 490 °C, through which the strip is passed. The bath contains zinc and any other required additive (i.e. antimony, lead or aluminium). The bath contains a sufficient amount of molten zinc in order to prevent the wide fluctuations in the operating temperature that may appear under maximum operating conditions. Most pots are nowadays heated by electrical induction systems. However, natural gas as fuel for heating the pots is an alternative when considering the environment as a whole and taking environmental aspects of power generation into account.

As the steel passes through the molten zinc bath the surface is coated, to some extent with layers of different iron-zinc alloys, but due to the high speed of the steel strip (max. 180 m/min) and the short exposure time, the coating mainly consist of zinc.

Temperature control of the bath is essential, as a high temperature will increase the rate of oxidation at the surface of the molten bath, resulting in increased ash generation. A low bath temperature will increase the viscosity of the molten coating metal, thus inhibiting the formation of a thin coating layer. The bath temperature is therefore optimized to meet the individual quality requirements of the final coated product.





The strip leaves the bath with some amount of liquid zinc on the surface. In order to achieve the exact thickness of coating required, the strip passes through a series of jets placed above the surface of the bath. By blowing air or nitrogen the excess of zinc is removed from the steel. The system is usually controlled by an automatic gauge, which measures the thickness of the coating using X-ray measurement technology or a similar technique.

Special galvanising processes to produce one-sided coatings are also applied. Examples are the Monogal process in which the zinc coating after normal galvanising is brushed off by rotating metal brushes and processes in which the zinc is applied by carrier rolls.

On leaving the bath, the strip is gradually cooled by air coolers, followed by a water quench tank and a drier.

# 2.9.1.5 Galvannealing

Galvannealing is a special post-treatment applied in some installations in which the strip, alter galvanizing, is heated to a temperature that allows the formation of a zinc-iron alloy (10 % iron). Galvannealing yields in a particularly smooth appearance of the product.

Galvannealing is the alloying of the zinc layer by the diffusion of iron (Fe) from the steel substrate. The Fe diffusion is obtained by maintaining the steel at a temperature of about 500 °C, for low carbon steel, to a temperature of about 540°C, for new generation High Strength Steel, during a sufficient time. Such furnaces are divided in two zones: a heating zone and a soaking zone. The available space for the furnace is limited. For a same available surface, a very quick heating from the zinc bath temperature (460°C) to the soaking temperature allows to apply a longer soaking time. Some furnaces are equipped with induction heating system in the heating zone and electrical elements or radiant tubes in the soaking zone. Induction heating technique is characterised by a short heating time, a short reaction time, and an accurate regulation of the temperature and no emissions on the site. The alloying and surface qualities are improved.

Other galvannealing furnaces are equipped in the heating zone and in the soaking zone with radiant tubes characterised by a longer heating time. In that case the site emissions and the energy consumption are improved by the use of low-NOx burners and regenerative or recuperative burner systems.

Figure 2-24 shows the schematic of view of the coating section and the galvannealing furnace.







Figure .2-24: Schematic Coating Section of a Galvannealing Line

# 2.9.1.6 Post Treatments

Following the coating, the steel strips are usually subjected to post-treatment in order to prevent surface damages and flaws, like white rust caused by water condensation in case of insufficient air access. Voluminous corrosion products as zinc hydroxides (white rust) affect further processing, such as e.g. painting. The formation of condensate during transportation and storage is to be generally prevented.

The resistance against white rust is considerably increased by the application of post treatment, like oiling, passivation, phosphating, organic coating or a combination of such treatment. In addition, the processing properties are significantly improved depending on application (e.g. oiling: deformation aid, phosphating: direct painting ensured, in combination with oiling: deformation aid).

# Oiling

To apply a wet film of oil on the surface of the strip dip spray, wingrolls or electrostatic oiling machines are used. The oiling coat is between 0.25 - 3 g/m2/side.





# Passivation

Passivation is a treatment with solvents containing chromic acids, applied by spraying or applicator-rolls. For hot dip metal-coated strip, a coat of 10 - 35 mg/m<sup>2</sup> per side is applied. Coat thickness is therefore extremely thin (few nanometer only). During passivation,  $Cr_{6+}$  is mainly conversed to  $Cr_{3+}$ . Almost all of the installations have a little heater after the treatment to make sure that the temperature rise over 120 °C which is necessary for a chemical reaction of excess  $Cr_{6+}$  with the additives of the passiving solution and become into  $Cr_{3+}$ . The strip is treated with solutions between 0.5 - 2 % of  $Cr_{6+}$  and temperatures between 70-120 °C.

# Phosphating

In phosphating a phosphate coat of approx.  $1 - 1.8 \text{ g/m}^2$  is applied. The phosphating procedure is more or less a precipitation reaction of zinc phosphate crystals at the surface of the metal coat caused by an increase in pH-value at the metal surface due to a pickling reaction. Trication phosphation process could be used (the hopeite crystal Zn<sub>3</sub>(PO<sub>4</sub>)<sub>2</sub>  $\oplus$  4 H<sub>2</sub>O incorporates approx. 1 % Ni and 5 % Mn). Thus, this process forms the same chemical structure of the phosphate coat as the high-quality phosphating processes for cars and household appliances do.

# 2.9.1.7 Finishing

To give the steel a special surface appearance, smoothness etc. as required by the customers or to meet width tolerances, the following operations may be applied:

## Mini or No Spangle Treatment

If the cooling rate of the top layer of pure zinc is sufficiently low, large crystals will form resulting in a 'spangled' appearance. Sometimes smaller zinc spangles or even no-spangle effect is requested. In that case the strip is either cooled more rapidly or the number of points of spangling are increased by steam spraying, steam spraying with a chemical additive (usually phosphate based) or spraying with zinc powder.

#### Mat Mill

The strip is skin-passed to obtain a mat finish surface.

Skin pass treatment can be done in three different ways: dry, wet (only water) or wet (with water and detergent). The 'temper mill' solution generated in the later process must be collected and sent to a waste water treatment plant when it is spent.

## Edge cutting

For certain applications, an edge cutting must be done in order to obtain the width tolerance needed and to avoid little dog bone defects. There are two places to realise this process:

In the pickling line before cold rolling.

In the hot dip coating process.





A perfect product schedule tries to reduce this process to the minimum to increase the line yield.

# 2.9.1.8 Cooling Water Circuits

In coating plants, cooling water is required to discharge excessive heat from furnaces. Part of the heat energy is emitted directly to the air (with the waste gases), via the coated strip or the shop air. The rest is transferred to the cooling water. The main cooling water consumers are the furnace (roll bearings) and final cooling of the strip.

A coating plant is supplied with cooling water re-circulated from central cooling water systems. In these systems, pumps convey the cooling water to the consumers; the heated water is returned and re-cooled again in plate heat exchangers with industrial water (e.g. from the river).

Due to the insertion of the closed re-cooling water circuits, the industrial water, even in case of leakage of a cooler, does not get into touch with the equipment of the consumers; so that, penetration of chemicals or oil into the industrial water and pollution of the sewage system is prevented.

There are several variants of re-cooling, two of them are:

re-cooling with industrial water in heat exchangers and

re-cooling by evaporation in cooling towers.

Compared to re-cooling in towers, re-cooling in plate exchangers offers the advantage that considerable amounts of chemicals for cooling water treatment (such as corrosion inhibitors, hardness stabilisers, dispersants and biocides) can be saved, and are not discharged into the sewage system. Another advantageous feature is that it is not necessary to do discharges of partial flow with a high salt content caused by the evaporation, as it happened in the case of cooling towers.

## Typical configuration of a cooling loop with cooling towers

The little discharge that is necessary for keeping low salt concentration of water to the sewer system is mostly made continuously. Algaecide (for avoiding the saturation of the contact zone between the water and the air) is dosed. The frequency is variable depending on the weather (between 1 and 3 times per week).

Other chemicals could be necessaries depending on the composition of the water used in the circuit (hardness, etc).







Figure 2-25: Typical configuration of a cooling loop with cooling towers

# Configuration for recycling water using plate heat exchanger:

Cooling water is recirculated in several closed cooling systems and heated by the heat expelled from the process (machine cooling, gas cooling, etc.). The cooling water is recooled by river water in heat exchangers. The river water on the secondary side of the heat exchanger is never in contact with the strip or harmful media and is therefore not contaminated. The water becomes only heat loaded and can be drained back to the river. The main cooling water





consumers are the preheating and annealing furnaces, the zinc pots, several roll coolings, the immersed water coolers, the activation section, the electrical equipment, the hydraulics and air conditioning.

All heat which is not removed by the cooling water has to be discharged either by waste gas or to the ambient air.

With this system, addition of algaecide and scale-prevender is avoided. The outlet water is only thermal loaded. This could be advantageous if the water of the system has no contact with pollution. There are discharges in case of system drain only.



Figure 2-26: Cooling water system with heat exchangers

# 2.9.1.9 Water Circuits/Water Management

Process water is water which is used for make-up of chemical solutions or which is in direct contact with the strip (e.g. water for direct strip cooling). It may be contaminated by the process and has then to be treated as waste water. The following process water streams are used at galvanizing lines and are finally discharged as waste water:

Make-up water (usually deionized water) for concentrate preparation of the chemical strip treatment sections (pre-treatment, electrolytic treatment, post treatment). The different concentrates are sprayed onto strip or the strip is running through the concentrate bath. The concentrates are usually recirculated by pumps. They are clarified or filtered in recycling plants





during recirculation. Only a small flow is discharged as high concentrated waste water to the water treatment plant.

Rinsing water (usually deionized water) for chemical treatment sections (pretreatment, electrolytic treatment, post treatment). The rinsing water is used for removing of remaining concentrate from the strip. The water sprayed onto strip in a cascade of rinsing sections, with the water flowing countercurrently to the strip. It is finally discharged as low concentrated waste water to the water treatment plant.

Make-up water for the water cooler. In the water cooler the strip is cooled first by recirculated spray water and finally by running through a water bath with an immersed turn back roll. The water will be contaminated by abrasion dust and has to be discharged from time to time to the skin pass mill water treatment plant.

Spray water for the skin pass mill. The water is used for keeping the working rolls clean. It is sprayed onto the rolls and contaminated by Zn-containing abrasion dust and lubricating oil and is discharged to the skin pass mill water treatment plant.





# **3** PRESENT EMISSION LEVELS AND RAW MATERIALS AND ENERGY CONSUMPTION

# **3.1** Present consumption and emission levels

# 3.1.1 Mass stream overview and input/output data

Figure 3.1.a provides an overview for the input and output of electric arc furnaces. This overview may be used for the collection of data from an electric arc furnace. Specific input factors as well as specific emission factors have been determined for electric arc furnaces. Such factors are presented in Table 3.1.a. The data are derived from various sources mentioned in the footnotes.

For the sake of comparison, Table 3.1.b shows a similar table but with the data corresponding to 7 Turkish iron and steel electric arc furnace installations. The data of these 7 installations is orientative but not completely representative of all the installations of this kind in Turkey.

Fig. 3.1 Mass stream overview of an electric arc furnace







# Table 3.1.a: Input/output data for electric arc furnaces within the EU (DRI = Direct Reduced Iron, HBI = Hot-briquetted iron)

Input			Output			
Raw materials			Products			
Metallic input: Scrap Pig iron Liquid hot	kg/t LS kg/t LS kg/t LS	039 - 1232 0 - 153	Liquid steel (LS)	kg	1000	
	ka/t I S	0 - 215				
Lime/dolomite (2)	kg/tLS	25 - 140	Air emissions			
Coal (including	kg/tlS	3-28	Off-gas flow	Million Nm <sub>3</sub> /h	1-2	
anthracite and coke)	18/ 120	5 20		Nm3/t LS	8 000 - 10 000	
Graphite	kg/t LS	2-6	Dust	g/t LS	4 - 300	
electrodes				mg/m <sub>3</sub>	0.35 – 52	
Refractory lining	kg/t LS	4-60	Hg	mg/t LS	2 – 200	
Alloys:			Pb	mg/t LS	75 – 2 850	
Carbon steel	kg/t LS	11-40	Cr	mg/t LS	12 – 2 800	
High alloy and	kg/t LS	23 – 363	Ni	mg/t LS	3 – 2 000	
stainless steel			Zn	mg/t LS	200 - 24 000	
			Cd	mg/t LS	1 - 148	
Gases			Cu	mg/t LS	11 – 510	
Oxygen	m₃/t LS	5 – 65	HF	mg/t LS	0.04 - 15 000	
Argon	m₃/t LS	0.3 - 1.45	HCI	mg/t LS	800 - 35 250	
Nitrogen	m₃/t LS	0.8 - 12	SO <sub>2</sub>	g/t LS	5 – 210	
Steam (3)	kg/t LS	33 – 360	NOx	g/t LS	13 - 460	
			CO	g/t LS	50 – 4 500	
Energy	I		CO <sub>2</sub>	kg/t LS	72 – 180	
Electricity	kWh/t LS	404 - 748	тос	g C/t LS	35 – 260	
	MJ/t LS	1454 – 2693	Benzene	mg/t LS	30 - 4400	
Fuels (natural gas	MJ/t LS	50 – 1500	Chlorobenzenes	mg/t LS	0.2 – 12	
and liquid fuels)			PAH (4)	mg/t LS	9 – 970	
			PCB (5)	mg/t LS	0.01 – 5	
Water	m³/t LS	1-42.8	PCDD/F	μg I-TEQ/t LS	0.04 - 6	
			Production residue	s (waste/by-product	s)	
			Slag from furnace	kg/t LS	60 – 270	
			Slag from ladle	kg/t LS	10 - 80	
			Dusts	kg/t LS	10 - 30	
			Waste	kg/t LS	1.6 - 22.8	
			refractories			
			Noise	dB (A)	90 - 133	
(1) Hot metal is only us	sed in very special case	s (about 275 kg/t LS), then the qua	ntity of scrap is lower.		•	

(2) Typically lime is used but in a few cases dolomite alone is used or combinations of dolomite and lime (e.g. weight proportion 63/37).

(3) Steam is generally not used within EAF steelmaking, except for plants with secondary metallurgy with vacuum treatment

(4) No consistent database, some results represent the total of 16 EPA PAH, others only a section of them.

(s) No consistent database, values represent different selections of PCB (2 of them refer to the above-mentioned Ballschmiter PCB, 3 to WHO-TEQ and 2 without further indication).

NB: — Some measuring methodologies might vary significantly from country to country and from plant to plant. Not all the

emitted substances are measured at all plants. The measuring programmes vary greatly depending on permit requirements.

- Data has been compiled from information provided by EAF melt shop operators (carbon steel, alloy steel and stainless





steel) representing 37.4 Mt of steel produced. This represented close to 50 % of the total EAF steel production in the EU in 2004 in 11 different EU countries.

- LS = Liquid steel.

Source: [ 140, Eurofer 2009 ] [ 200, Commission 2001 ] [ 220, Eurofer 2008 ] [ 234, Poland 2007 ] [ 367, Prüm et al. 2005 ] [371, Eurofer 2007 ] [ 372, Czech TWG member 2008 ].

Table 3.1.b: Input/output data for 7 Turkish electric arc furnaces (DRI = Direct Reduced Iron, HBI = Hot-briquetted iron)

Input			Output			
Raw materials			Products			
Metallic input: Scrap Pig iron Liquid hot	kg/t LS kg/t LS kg/t LS	90 - 1176 0 - 150 	Liquid steel (LS)	t/year	409.000 – 1.974.000	
metal (1) DRI (HRI)	ka/t I S	0-661				
Lime/dolomite (2)	kg/tLS	10 - 0,01	Air emissions			
Coal (including	kg/tLS	8 - 25	Off-gas flow	Million Nm <sub>3</sub> /h	1 – 3 55	
anthracite and coke)	18/2 23	0 25		Nm3/t LS	11.600 - 17.700	
Graphite	kg/t LS	1,3 - 2,9	Dust	g/t LS	13 – 127	
electrodes	0.			mg/m <sub>3</sub>	0.53 – 11	
Refractory lining	kg/t LS	4 - 10	Hg	mg/t LS	14	
Alloys:			Pb	mg/t LS	56 – 97	
Carbon steel	kg/t LS		Cr	mg/t LS	7,6 - 18	
High alloy and	kg/t LS		Ni	mg/t LS	14 – 44	
stainless steel			Zn	mg/t LS	0 – 137	
			Cd	mg/t LS	2,3 - 18	
Gases			Cu	mg/t LS	13 – 34	
Oxygen	m₃/t LS	38 – 55	HF	mg/t LS		
Argon	m₃/t LS	0.16 - 2,61	HCI	mg/t LS		
Nitrogen	m₃/t LS	0.2 – 12	SO <sub>2</sub>	g/t LS	5 - 100	
Steam (3)	kg/t LS	0 - 40	NOx	g/t LS	46 - 190	
			CO	g/t LS	42 - 360	
Energy	•	•	CO <sub>2</sub>	kg/t LS	175	
Electricity	kWh/t LS	435 – 592	TOC	g C/t LS	1,35	
	MJ/t LS	469 - 1.576	Benzene	mg/t LS	17	
Fuels (natural gas	MJ/t LS	50 - 1500	Chlorobenzenes	mg/t LS		
and liquid fuels)			PAH	mg/t LS	93 - 103	
			РСВ	mg/t LS		
Water	m³/t LS	0,2 – 2,85	PCDD/F	μg I-TEQ/t LS	0,09 – 1,23	
			Production residue	s (waste/by-product	s)	
			Slag from furnace	kg/t LS	60 - 178	
			Slag from ladle	kg/t LS	15 – 25	
			Dusts	kg/t LS	10 - 21	
			Waste refractories	kg/t LS	1.5 – 20	
				•	•	
			Noise	dB (A)	70 – 115	
(1) Hot motal is only us	ad in yory special case	$r_{\rm r}$ (about 275 kg/t (S) then the g	uantity of scrap is lower	1		

), thên thế qu antity of scrap is lower.

(2) Typically lime is used but in a few cases dolomite alone is used or combinations of dolomite and lime (e.g. weight proportion 63/37).

(3) Steam is generally not used within EAF steelmaking, except for plants with secondary metallurgy with vacuum treatment

NB:





— LS = Liquid steel.

By far the main iron source for an EAF is scrap. Hot metal and DRI are used by a rather small number of operators, generally in a rather sporadic fashion. Thus, it is difficult to indicate representative ranges. Hot metal and DRI might be used to adjust composition for some particular steel grades. In some instances, the input of DRI or hot metal might also be due to economic reasons. HBI is basically hot briquetted DRI. It is better suited for handling and transportation and less exposed to atmospheric oxidation.

The emission factors indicated in Table 3.1 are the result of a survey. The wide ranges observed for some of the emission factors may have the following origins:

- differences in the performances of environmental protection equipment
- differences in the emission limit values prescribed by national or local authorities
- differences in the quality of measurements frequency, precision, sampling, laboratory methodologies, etc.
- differences in the input material
- differences in the plant characteristics
- type of steel produced (metals emissions)
- plant productivity.

# 3.1.2 Environmental issues for electric arc furnace steelmaking process

The electric arc furnace steelmaking process is an important source of dust and solid wastes/byproducts. Energy consumption also plays an important role for EAF steelmaking. When abatement techniques are applied to reduce emissions, cross-media effects occur. Generally, Sections 3.2 to 3.6 below describe the most relevant environmental issues in the EAF process.

# 3.2 Emissions to air

# **3.2.1** Primary and secondary emissions and treatment

Off-gas from primary and secondary collection in EAF contains dust, metals, nitrogen and sulphur oxides and organic matter (e.g. VOC, chlorobenzenes, PCB, PAH and PCDD/F). Organic matter emissions mainly depend on the scrap quality. Some scraps contain paints, oils and other organic substances.

Information about secondary emissions is limited. From charging the EAF, usually 0.3 - 1 kg dust/t LS and from tapping usually 0.2 - 0.3 kg dust/t LS are emitted (emissions before abatement). For fume leakages during EAF operations, dust emission factors between 0.5 and 2 kg dust/t LS are reported.





Emission factors as a sum of the aforementioned three sources (charging, tapping, fume leakages) are between 1.4 and 3 kg dust/t LS before abatement. This can be considered a confirmation that primary emissions are about ten times higher than secondary emissions.

Generally the treatment of different off-gas flows (i.e. primary and secondary emissions) is performed in the same device, mostly in bag filters). Only in a few cases are ESPs and wet scrubbers applied.

Table 3.2 shows examples for achieved air emissions concentrations from the EAF process after abatement with bag filters or ESP.

Paramete	r	Bag filter	Electrostatic precipitator (1)	Unit
Dust		0.35 – 3.4	1.8	mg/Nm₃
CO		88 – 256		mg/Nm₃
NOx		0.97 – 70		mg/Nm₃
SOx		8 – 17		mg/Nm₃
	Hg	0.016 - 0.019	<0.0003	mg/Nm₃
Metals:	Total (including Sb, Pb, Cr, CN, F, Cu, Mn, V, Se, Te, Ni, Co, Sn) Cr (except Cr (VI) Mn	0.006 - 0.022 0.013 0.036	0.01 – 0.07	mg/Nm3
	Ni	0.003		
PAH		<0.00001	<0.001	mg/Nm₃
PCDD/F		0.0015 – 0.1 (2)		ng/Nm₃
HF		0.085 - 0.2		mg/Nm₃
HCI		3 – 5.4		mg/Nm₃
Cl <sub>2</sub>		<3		mg/Nm₃

#### Table 3.2: Air emissions concentrations from the EAF process after abatement

(1) Values relate to one German stainless steel plant.

(2) Upper end of the range relates to measurements carried out in 1997.

 $\ensuremath{\mathsf{NB:}}$  — Values are annual averages and relate to the central deducting system.

-PAH contain benzo(a)pyrene and dibenzo-(a,h)-anthracene.

*Source:* [Plickert, *Performance values of iron and steel plants in Germany*, UBA, 2007] [Wiesenberger, *Review of the BREF Iron and Steel Production - Austrian Comments*, UBA, 2007,].

#### Dust

The off-gas contains 10 - 30 kg dust/t liquid carbon steel or low alloyed steel and 10 - 18 kg dust/t in the case of high alloyed steel before abatement. At EAFs for stainless steel, the maximum value for dust production is 30 kg dust/t. With a converter like an AOD, the off-gas (EAF and AOD) contains 10 - 46 kg/t liquid alloyed steel. The composition of the dust can be seen from the analysis of the dust separated from the off-gas in the bag filters or electrostatic precipitators (ESP). Most of the heavy metals are mainly associated with dust and, thus, are removed to a large extent from the off-gas with the dust abatement. Those heavy metals present in the gas phase, e.g. mercury, are not eliminated by filtration or ESP.





The range of dust emission factors after abatement can be seen in Tables 3.1.a and 3.1.b. About 96 % of the dust belongs to  $PM_{10}$ . The range is quite wide (three orders of magnitude), indicating a huge difference in collection and abatement efficiency. In terms of concentration, the emissions are between 0.5 - 50 mg dust/Nm<sub>3</sub> (the majority of the installations are at the lower end of the range). Normally these emission factors or emission concentrations include secondary dust emissions because primary and secondary emissions are very often treated in the same equipment.

#### Heavy metals

Some emissions in Tables 3.1.a and 3.1.b show wide ranges. Higher values can be of high environmental relevance. Zinc is the metal with the highest emission factors. Chromium and nickel emissions are, for obvious reasons, generally higher in the manufacturing of stainless steel. A part of the chromium can occur as hexavalent chromium. It is of paramount importance because it is highly carcinogenic by inhalation.

In three EU EAF plants, emissions factors for arsenic between 0.025 and 14 g/t have been measured.

Mercury emissions can strongly vary from charge to charge depending on scrap composition/quality. Mercury emissions in the sector are expected to decline due to the progressive phasing out of mercury following the full implementation of several directives already in place, such as the By-Law 27986 (dated 06.07.2011) on end-of-life vehicles, the By-Law 28300 (dated 22.05.2012) on waste electrical and electronic equipment (WEEE) and the as well as the By-Law 27537 (dated 30.03.2010) on batteries and accumulators and waste batteries and accumulators. Nevertheless, relevant exceedings of mercury ELVs have been observed, indicating that mercury-bearing components still occur in the scrap sources, and apparently they are not always removed from the shredder input. Emissions factors for mercury of 170 mg/t LS, despite efforts to reduce mercury in purchased scrap, have been observed on an annual basis and seem to be fairly similar for steel, based on domestic and imported scrap.

#### Sulphur and nitrogen oxides

The SO<sub>2</sub> emissions mainly depend on the quantity of coal and oil input but are not of high relevance. NO<sub>x</sub> emissions also do not need special consideration.

## Other inorganic pollutants

On top of the previously quoted inorganic pollutants, releases of fluoride, chloride and other relevant inorganic compounds were mentioned, but no further information was provided about them.

## voc

VOC emissions may result from organic substances adhering to the raw materials (e.g. solvents, paints) charged to the furnace. In the case of the use of natural coal (anthracite), compounds such as benzene may degas before being burnt off.

## Polycyclic aromatic hydrocarbons (PAH)





The emission factors for PAH are also relatively high (9 – 970 mg/t LS – see Table 3.1.a) but there are not many reported measurements. PAH are also already present in the scrap input but may also be formed during EAF operation. The expectation that PAH adsorb to the filter dust to a high extent (also depending on the off-gas temperature) could not be confirmed by investigations in Luxembourg, where PAH emissions remained unchanged before and after abatement in a bag filter which achieved low residual dust contents (<5 mg/Nm<sub>3</sub>) as a daily mean value. The PAH profile is dominated by the more volatile two or three ring PAH such as naphthalene, acenaphthene, anthracene and phenanthrene.

## Persistent organic pollutants (POPs)

Since the nineties increasing note has been taken of POPs. Analytical results are only available for a limited number of compounds. Organochlorine compounds, such as chlorobenzenes, PCB and PCDD/F have been measured.

There is a strong correlation between the concentrations of PCDD/F and WHO-12 PCB, with the I-TEQ of PCDD/F being approximately 16.5 times higher than that of WHO-12 PCB. This suggests that the formation mechanisms of PCB and PCDD/F are linked.

Chlorobenzenes have been determined at several EAF operations (0.2 - 12 mg/t LS - see Table 3.1.a). From measurements at one EAF plant, it is known that hexachlorobenzene is present in the emitted off-gas.

## Polychlorinated biphenyls (PCB)

Polychlorinated biphenyls (PCB) are a class of chlorinated semi-volatile organic compounds composed of 209 congeners. A group of 12 PCB, which exhibit 'dioxin-like' behaviour, has been identified by the World Health Organisation (WHO). The main contributor to the WHO-12 I-TEQ was PCB 126.

Other PCB congeners found are PCB 28, 52, 101, 138, 153 and 180 which are known as the six Ballschmiter congeners. The toxicological purpose for the determination of the two sets of PCB is not the same. A common approach for an adequate estimate of the 'total PCB'(209) is to multiply the sum of the 6 Ballschmiter/DIN PCB by five.

PCB emissions have been detected and measured at some EAFs. These measurements showed that different congeners have been determined. The Values as low as 0.01 mg/t LS and high as 5 mg/t LS have been reported. In addition, it is not known yet whether PCB can be formed by de novo synthesis during the process and/or within the off-gas devices. These uncertainties show that it is difficult if not impossible to draw general conclusions on the formation and decomposition processes of PCB in EAF off-gases.

PCB may be present in the scrap input which could be the dominant source for the measured emissions. Regulations, for example as end-of-life electric equipment management, have greatly helped to prevent the introduction of items which contains PCB (for instance small capacitors in several technical devices like washing machines, dryers, cooker hoods, oil burners, fluorescent lamps, etc). One investigation has shown that PCB are practically not abated in bag filters. A recent study performed in Sweden has shown a correlation between





dioxin-like PCB and PCDD/F but has also shown that the emission of PCB in terms of WHO-TEQ is far less important than the emission of PCDD/F.

In general, it has been concluded that typical off-gas cleaning systems (e.g. filters, ESP, scrubbers) are more efficient at removing PCDD/F emissions than PCB. The compound-specific differences can be explained by differences in volatility between the congeners of the three compound groups. The variability in efficiency may be also due to the differences in the dust separation efficiency, gas temperature and adsorption properties of the dust.

#### Polychlorinated dibenzo-p-dioxins and furans (PCDD/F)

During the thermal treatment of scrap which contains paints, oils (e.g. cutting oils), PVC (polyvinyl chloride) or other organic substances, PCDD/F are released or produced during waste gas treatment and emitted into the atmosphere along with the furnace fumes. These emissions are especially important during the beginning of the scrap melting phase at the EAF, when the temperatures are still low. Even if downstream process temperatures are sufficiently high to destroy the PCDD/F, the PCDD/F generated during that initial phase will have an influence on its downstream generation.

PCDD/F are generated as well by the combustion at low temperatures (250 - 500 °C) of organochlorinated compounds that may be present in the charge as well as by de novo synthesis, catalysed by metals (e.g. Cu and to a lesser extent Fe). Findings indicate that the temperature profile is more important than the mean temperature in determining the PCDD/F concentration in the waste gas. Regarding PCDD/F, there are many measurements available showing emission factors between 0.04 – 6 µg I-TEQ/t LS (see Table 3.1.a). Concentrations between 0.02 and 9.2 ng I-TEQ/Nm<sub>3</sub> have been measured.

PCDD/F are normally expressed as International Toxicity Equivalents (I-TEQ) according to NATO/CCMS, 1988. This is also the case for the existing legislation and actual permits. The revised IPPC permits for IS plants in the Walloon Region of Belgium are formulated in WHOTEQ for PCDD/F and 'dioxin-like' PCB plus a specific limit value for 'total PCB' estimated by 5 × the sum of the 6 Ballschmiter/DIN PCB (in mass concentration).

In 1998, the WHO had developed new toxicity equivalents for PCDD/F (WHO-TEQ). Integrated into this evaluation are 12 dioxin-like PCB. In 2005, reevaluated toxicity equivalents (WHO 2005-TEQ) have been presented and accepted by the WHO.

The total level of PCDD/F including PCB expressed as WHO 2005-TEQ varies between 11 % lower and 21 % higher than the PCDD/F expressed as I-TEQ. The average of all presented measurements is 2 % lower for the values of PCDD/F as WHO 2005-TEQ including PCB compared to PCDD/F as I-TEQ.

The total level of PCDD/F including PCB is 12 - 24 % lower when expressed as WHO 2005- TEQ compared to WHO 1998-TEQ.

According to information provided by Eurofer, the dioxin emissions from stainless steel production are lower than in the case of carbon steel. However this affirmation has only been verified in a few plants.





Table 3.3 shows specific and annual emissions of PCDD/F and PCB to air from Swedish EAFs steel plants estimated from production in 2005. The reported values are according to the TEQ, using the latest weighting scheme by the WHO including both PCDD/PCDF and dioxin-like PCB. The contribution from dioxin-like PCB is mostly in the range of 10 - 20 %. The TEQ is reported as an interval when some toxic congeners are below the limit of detection.

Table 3.3: Specific and annual emissions of PCDD/F and PCB to air from Swedish EAF steel plants

Plant	PCDD/F (μg TEQ/t LS)	PCDD/F (g TEQ/yr)	PCB (μg TEQ/t LS)	PCB (g TEQ/yr)		
A	0.67	0.29	0.22	0.096		
В	0.41	0.025	0.04	0.002		
С	0.091	0.008	0.015	0.0013		
D	0.080	0.015	0.02	0.0034		
E	3.7	1.8	0.42	0.21		
F	0.056	0.015	0.012	0.0032		
G	2.4	1.0	0.28	0.12		
Н	0.17	0.003	0.56	0.01		
NB: LS = Liquid steel. Source: [ <b>370, Öberg 2007 ].</b>						

# 3.2.2 Emissions from secondary metallurgy processes and continuous casting

Information about emissions from secondary metallurgy (mainly dust emissions) and from continuous casting is very limited. Reports dust emission factors before abatement from seven AOD/VOD refining installations between 6 and 15 kg dust/t LS and a single low figure of 1.35 kg dust/t LS. These seven installations have a dedusting device independent from the dedusting of EAFs. The emission factors reported in Table 3.1.a include the emissions from secondary steelmaking.

The treatment of the collected off-gas flows from secondary metallurgy is performed in the same type of device, mostly in bag filters as primary and secondary emissions. Table 3.4 shows some emissions concentration values for different parts of the secondary metallurgy after abatement.

 Table 3.4: Emissions from different parts of the secondary metallurgy after abatement

Parameter	Primary dedusting of ladle metallurgy	Ingot casting and continuous casting (1)	Vacuum treatment and oxygen blow unit
	units		





PM	0.6 - 1	0.5	4.1 - 13.2			
Pb, Co, Ni, Se, Te	0.006					
Sb, Cr, CN, F, Cu, Mn, V,	0.01	0.01 - 0.03				
Sn						
(1) For stainless steel produc	tion only.					
NB: Values are annual averages and in mg/Nm3.						
Source: Plickert, Performance values of iron and steel plants in Germany, UBA, 2007.						

# 3.2.3 Emissions from scrap preheating

The scrap preheating may lead to an important generation of organic pollutants due to the possible presence of organic substances on the scrap which are combusted during preheating under very unfavourable conditions. This can result in increased emissions of VOC and PCDD/F emissions. In this case, the off-gases need further aftertreatment, i.e. post-combustion.

# **3.2.4** Emissions from slag processing

If the slag is collected in a slag pot at the EAF, it needs to be poured into outside slag basins for solidification. The cooling of the slag may be enhanced by water sprays resulting in fumes. These fumes can be highly alkaline if the slag contains free CaO. This is very often the case. Alkaline depositions from the fumes may cause problems in the neighbourhood.

If the slag is poured on the floor it is precrushed after solidification using excavators or shovel loaders and subsequently brought to an outside storage area. After a certain period of time, the slag is processed in crushing and screening devices in order to give it the desired consistency for separating metals from the slag and for its further use in construction. Slag breaking and metal recovery can create dust emissions. The emission from crushing and screening should be extracted and subsequently cleaned. Water spraying can be applied at the conveyor belts transfer points. If the processed slag is stored, heaps can be wetted. During loading of broken slag, water fogs can be used to minimise dust emissions.

# 3.3 Emissions to water

The use of water depends in principle on the cooling system of the EAF and the type of flue gas cleaning facility. Wet precipitation systems are no longer in use in major European electric steel plants mainly due to the problems arising with sludge and waste water treatment.

# 3.3.1 Waste water

Different processes in which water is used:

- 1. Cooling of the EAF
- 2. Waste water from off-gas scrubbing
- 3. Waste water from quenching





- 4. Drainage water from the scrapyard
- 5. Vacuum generation
- 6. Direct cooling in continuous or ingot casting.

According to the water management seeking optimal treatment of all waste waters, information on the flow and treated waste water of single production steps is often not available because the mixture of different waste water streams are treated together.

## 1. Cooling water

Water is used in the EAF unit for cooling the wall panels and the roof and for spraying the electrodes. The water used for the cooling of the EAF is about  $5 - 12 \text{ m}^3/(\text{m}^2\text{h})$ . For an EAF of a production capacity of 70 t/h the cooling water demand is 1000 m<sup>3</sup>/h. Since the water flows within a closed cooling cycle, no waste water is generated. Also cooling system without circulation can be used if there is no lack of good quality cooling water. This saves energy on pumping and recooling.

## 2. Waste water from off-gas scrubbing

In some cases in the EU, the off-gases are treated in a wet scrubber. There is no information available on applied treatment techniques and discharged quantities and their pollution.

## 3. Waste water from quenching

Water is used for rapid quenching. From one plant it is reported that 25  $m^3/h$  are used to quench approximately 870 000  $m^3/h$ . No waste water occurs since the used water is mostly evaporated and leaves the process with the exhaust airflow. A minor part leaves the process with the residual moisture of the dust.

## 4. Drainage water from the scrapyard

The main raw material of EAF, the different kinds of scrap, are often stored on unpaved scrapyards. Drainage water can be contaminated, especially in the case of scrap which contains oil/emulsions like turnings. There is no information available on quantities and pollution of drainage water. Usually it is at least treated in an oil separator prior to being discharged.

## 5. Waste water from vacuum generation

For vacuum treatment, the usual specific process water flow from vacuum generation ranges from  $5 - 8 \text{ m}^3/\text{t}$  LS vacuum treated. In a few cases the specific process water demand is higher, in one case 42.8 m<sup>3</sup>/t LS (see Table 3.1.a). This water is nearly fully recycled. It should be mentioned that not all of the liquid steel should be vacuum treated. Information on composition and treatment or recycling is not available. Usually this waste water is treated together with other streams from the rolling mill(s) where they are located in the direct vicinity.

## 6. Waste water from continuous and ingot casting





Continuous casting in the EAF process is similar to the basic oxygen furnace process. Specific information about input/output quantities is not available. Usually this waste water is treated together with other streams from the rolling mill(s).

#### 6.1. Description

Water is used in continuous casting machines for direct cooling of the slabs, blooms and billets. A contaminated process water flow is therefore generated. In many cases, this waste water is treated together with waste water streams from the hot rolling mills. After treatment, the water is recirculated.

The casting mould and the inner part of the rollers are usually cooled with water in a closed circuit and are not considered here.

The main pollutants are suspended solids and oil. The main measures to reduce discharges to water are a high rate of recirculation along with sedimentation and/or filtration of the bleed. Skimming tanks can be used to remove oil.

The spray water is commonly precipitated by sand filtration prior to or after cooling in an evaporative cooling tower. Sand filtration helps to ensure low levels of particulate and oil contamination to achieve satisfactorily prolonged operation of the secondary spray nozzles of the casting machine. The bleed from the open circuit to control the level of dissolved solids should be taken from downstream of the sand filtration plant to minimise the discharge of suspended solids and any oil/grease contamination. To prevent the clogging of the sand filter, oil skimming should be installed before the sand filters.

#### 6.2. Emissions

Emissions to water from continuous casting machines are generated by the direct cooling system. This is used for the direct cooling of slabs, blooms, billets and the machines. The waste water contains mill scale (1 - 3 g/l) and oil/grease. This water is very often treated together with waste water from rolling mills where they are located in the direct vicinity. The amount of waste water strongly depends on local conditions and water management. The specific water demand for continuous casting is usually between 5 and 35 m<sup>3</sup>/t LS. The amount of waste water which can arise from continuous casting is up to 2 m<sup>3</sup>/t LS.

Parameter		Corus Stelco LEW, IJmuiden, Ontario, NL (1) Canada		ArcelorMittal, Indiana Harbour Works, IN, US	
Discharge flow	m <sup>3</sup> /t cast steel	0.04	1.4	0.076	
Recirculation rate	%	98	78	99	
Suspended solid	g/t cast steel	0.8 0.2 (2)	26	1.4	

Table 5: Overview of specific emissions to water from direct cooling systems at continuous casting





Zinc (Zn)	mg/t cast steel	<1	_	8.0
Lead (Pb)	mg/t cast steel	<1	-	8.7
Oil	mg/t cast steel	20	2000	160

(1) Data refer to 2004.

(2) Data for 2007 indicate a trend downwards.

*Source:* [Dutch Notes on BAT for the Production of Primary Iron and Steel, Spatial Planning and the Environment, Directorate for Air and Energy, Department of Industry, 1997.] ['Specific emissions to water from direct cooling at continuous casting', Personal Communication, 2009].

## 7. Waste water flow from pickling and plating

Waste water flow from pickling and plating should be reduced as far as possible. Discharges of metals from pickling plants should be limited as follows: Ni = 1 mg/l; Cr-tot = 1 mg/l; Cr (VI) = 0,1 mg/l; Zn = 2 mg/lS; S Cd = 0,2 mg/l.

# 3.4 Solid waste and by-products. Landfills

# 3.4.1 Process residues such as wastes and by-products

The various solid residues such as wastes or by-products from EAF steelmaking are compiled together with their specific quantities in Table 3.6.

Table 3.6: Kind and specific quantity of solid wastes/by-products from electric arc furnace

steelmaking

Solid was	Specific quantity (range) (kg/t LS)	
Slags from carbon steel/low alloyed steel production:	Slag from EAF	100 – 150
	Slag from ladle	10 - 30
Slags from high alloyed steel production:	Slag from EAF	100 – 135
	Slag from ladle	30 - 40
	AOD slag	Approximately 160
Dusts from carbon steel/low all	oyed/high	10-46
alloyed steel production		
Refractory bricks	2 – 25	
NB: LS = Liquid steel.		

More recent data for European EAF plants can be found in Table 3.1.a.

# 3.4.2 Slags from production of carbon steel/low alloyed steel/high alloyed steel





First a slag is produced during a process of melting steel scrap in an EAF by the addition of slag formers. During one or several ensuing processes the raw steel produced in the EAF will pass subsequent treatments in converters and/or ladles. In this (these) process(es) ferroalloys are added to the liquid metal, and together with some additives (e.g. lime) basic slags are formed. In contrast to EAF slag from carbon steel production, EAF slags from stainless steel production can have higher contents of heavy metals, which are, e.g. used as an alloying addition.

The chemical composition of EAF slags from the production of carbon/low alloyed steel and stainless/high alloyed steel can be seen in Table 3.7.

Table 3.7: Chemical composition of EAF slag from the production of carbon/low alloy steel and stainless/high alloy steel

	Carbon/low alloyed steel (1)			Stainless/high alloyed Steel (2)		
Component (wt-%)	Typical concentration	Lower limit	Upper limit	Typical concentration	Lower limit	Upper Limit
CaO	28	15	64	50	17	68
SiO <sub>2</sub>	19	4	26	23	2	42
MgO	7	0.5	15.5	6	1.5	25
Al <sub>2</sub> O <sub>3</sub>	7	1	16.5	2.5	<0.1	30
FeO	32	10	63	2	<0.1	39
Cr2O3	1.8	<0.1	11	2	<0.1	22
F				2	<0.1	9
MnO	5	0.5	19.5	1	<0.1	21
TiO <sub>2</sub>				0.8	<0.1	3.5
Zn				<0.1	<0.1	2
P2O5	0.4	<0.01	2		<0.1	
Na <sub>2</sub> O	0.2	<0.01	2			
K2O	0.14	<0.01	2.5			

(1) Carbon/low alloyed steel: EAF C EINECS No: 294-410-9 CAS No: 91722-10-0.

(2) Stainless/high alloyed steel: EAF S EINECS No: 294-410-9 CAS No: 91722-10-0.

NB: — The analytical information on ferrous slags is usually given in the form of oxides although components may occur in different mineral phases and different oxidation states.

Components which usually have maximum concentrations <1 wt-% are not specified.</li>

- The analysis relates not to aqua regia dissolution but to total digestion (see e.g. EPA 3052 or EN 13211:2001).

- In traces, other elements such as Pb, As, Sb, Hg, Cl, F and hexavalent chromium may also be present

The rate of landfilling or recycling varies in the different EU Member States depending on legal requirements, availability of landfills, taxes, market situation, costs and possibilities to reuse processed slags. In the EU, a growing amount of slags from carbon and low alloyed steelmaking are used as secondary raw materials, mainly for road construction and for infrastructural measures in several applications. Slags from stainless steel production are generally less suitable for such uses and need to be landfilled. The percentage of the on-site recycling of slags from the production of high alloyed steels is significantly higher than for slags from carbon and low alloyed steelmaking. But still one third is landfilled and stored (see Table 3.8).





Kind of steel	Total On-site slag recycling		External use		Sold		Landfilled and stored		
	(kt/yr)	(kt/yr)	(%)	(kt/yr)	(%)	(kt/yr)	(%)	(kt/yr)	(%)
Carbon steels (1)	958	-	-	164	17.1	362	37.8	432	45.1
Carbon steels (2)	1796	45.1	2.5	494.8	27.6	13.7	0.8	1242	69.2
Low alloyed steels (2)	444	-	-	61.6	13.9	108.0	24.4	261	58.9
High alloyed steels (2)	461	81.4	17.7	68.0	14.8	160.0	34.7	156	33.9
Total EAF slags (2)	2701	126.5	4.7	624.4	23.1	281.7	10.4	1659	61.4
Total EAF slags (3)	4408		- f - l //		2000				

(1) Data from 11 plants producing 958 kt/yr of slags (131.7 kg/t LS) in 2008.
(2) Data from 57 plants producing 2.7 million t/yr of slags (133 kg/t LS) in 1996.

(3) Data from 2004 and related to the following EU countries: AT, BE, DE, DK, ES, FR, FI, LU, NL, UK, SE, SK.

Slags from four EAF plants were analysed for PCDD/F and PCB. Table 3.9 shows concentrations and annual mass flows of PCDD/F and PCB in slag for these steel plants in which scrap was used as a raw material. The concentrations found are below the limit value of 15  $\mu$ g TEQ/kg specified in the European Regulation (EC) No 850/2004 of 29 April 2004 on persistent organic pollutants.

Table 3.9: Concentrations and annual mass flows of PCDD/F and PCB in slag from steel plants using scrap as a raw material

Plant	PCDD/F	PCDD/F	РСВ	РСВ		
	(µg TEQ/kg)	(g TEQ/yr)	(µg TEQ/kg)	(g TEQ/yr)		
А	<0.004	<0.56	0.0002	0.029		
В	0.014 - 0.015	0.053 – 0.058	0.0014	0.0069		
I	0.002	0.14	0.0004	0.027		
J	0.002	0.09	0.00005	0.002		
Source: Öberg, 'Emissions of persistent organic pollutants from Swedish steel mills', 2007						

# 3.4.3 Dusts from off-gas treatment

The treatment of off-gases (mostly primary off-gases together with secondary off-gases) is very often performed in bag filters. The chemical composition of dusts from the production of carbon, low alloyed and high alloyed steel can be seen in Table 3.10.





Table 3.10 : Chemical composition of EAF dusts from the production of carbon steel/low alloyed steel and high alloyed steel/stainless steel

Component	Dust from	Dust from alloy steel	Dust from stainless
	carbon/low alloyed	production	steel production
	steel production	(wt-%)	(wt-%)
	(wt-%)		
Fetot	10 – 45	17 – 37	20 – 65
SiO2	0.6 - 5.1	1.7 – 5	3 – 9
CaO	3 – 17	2 – 16	8-20
Al <sub>2</sub> O <sub>3</sub>	0.3 – 3	1-4	0.4 - 2
MgO	0.5 – 6	1.2 – 3	1-5
P2O5	0.1-0.37	0.01-0.1	0.03 - 0.1
MnO	1.1-6	1.5 - 6.9	2.2 - 6.3
Cr <sub>2</sub> O <sub>3</sub>	0.13 – 2	0.12 - 6	9 – 20
Na2O	0.3 – 3	NA	0.6 - 2
K2O	0.5 – 2.3	NA	0.7 – 3
Zn	21 - 43	2 – 15	2 – 25
Pb	0.4 - 10	0.05 - 3.6	0.2 - 4.5
Cd	0.02 - 0.18	0.01 - 0.04	0.01 - 0.08
Cu	0.08 - 0.5	0.01-0.8	0.015 – 0.5
Ni	0.01-0.8	0.01-0.5	1-8
V	0.01 - 0.09	0.01-0.2	0.05 - 0.12
W	NA	0.5 – 1.5	NA
Со	0.001-0.01	0.01-0.2	0.02 - 0.04
As	0.001-0.02	0.001-0.01	0.01
Hg	0.0001 - 0.005	0.05 - 0.7	0.0002 - 0.015
Cl	0.8 – 5	0.7 - 1.7	0.8 - 1
F	0.02 - 0.9	0.01 - 0.65	0.3 - 2.4
S	0.1 - 3	0.25 - 1.42	0.2 - 0.5
С	0.4 - 3.3	0.5 - 3.1	0.05 - 1.3
Basicity	2.0 - 6.5	NA	NA
Moisture	6 - 16	NA	NA
NB: NA = Data not available.			

Dust from six plants were analysed for PCDD/F and PCB. Table 3.11 shows concentrations and annual mass flows of PCDD/F and PCB in dust for four of these plants in which iron scrap was used as a raw material.

Table 3.11: Concentrations and annual mass flows of PCDD/F and PCB in dust from four steel plants using scrap as a raw material

Plant	PCDD/F (μg TEQ/kg)	PCDD/F (g TEQ/yr)	PCB (μg TEQ/kg)	PCB (g TEQ/yr)
А	0.16	1.0	0.014	0.089
В	0.21	0.11	0.015	0.0075
Ι	0.035	0.20	0.0020	0.011
J	0.16	1.0	0.0042	0.026
NB: LS = Liquid steel.				
Source: [Öberg 2007, `Emissions of persistant organic pollutants from Swedish steel mills', 2007 ].				





In recent years the percentage of dust put into landfills has been dramatically reduced, following regulation on waste management. A vast majority of dust is recovered to operations for non-ferrous metals (Zn and Pb mainly in the case of carbon steel dusts and Cr and Ni in the case of stainless steel dusts).

Different technologies exist for treating EAF dust which contains from 18 - 35 % zinc. These are well-established processes in use in the non-ferrous metals production industries. However, the zinc industry normally uses raw materials which have a higher zinc concentration. As a result, EAF dust undergoes a further process before the zinc can be recovered from it. These processes raise the zinc content to 55 - 65 %.

According to a survey carried out in 2006 covering 36 EAF plants and 34 2949 tonnes of dust, EAF dust is mainly used in three different ways:

- 34% Recovery through other processes
- 34% Landfilling
- 32% External recovery by Waelz process

# **3.4.4 Refractory bricks**

Refractory bricks are used for lining in the different vessels. Until recently, spent refractory bricks were sent to landfill. In recent years, the recovery of usable magnesia, dolomite and alumina bricks has been introduced and landfilling has been used only for fractions that are not suitable for recovery. Bricks are mostly reused in steel production for the same purpose or another purpose not requiring such a high quality brick.

In an EAF plant with a capacity of approximately 400 000 tonnes of stainless steel per year, the spent refractory amounts up to about 9000 tonnes per year. Table 3.12 shows the annual amount relating to different process steps.

Refractory used	EAF	Steel ladle	Ladle furnace RH degaser	Strand caster	Ingot Casting
Magnesite	1200	3800	600 (1)	2400	
Dolomite		600			
Mullite (clay)					500
(1) Chromium magnecite					

Table 3.12: Example of annual amount of spent refractory material in one installation

(1) Chromium magnesite.NB: Values in tonnes per year.

*Source:* [ Cores et al. Efficient itilisation of raw materials used in secondary steelmaking as flux in steelmaking furnaces, 2005 ].

# 3.5 Noise emissions

# **3.5.1** Techniques concerning noise aspects





Noise is a significant workplace problem within the iron and steel industry, especially when electric arc furnaces are in use. Typical noise levels historically for electric arc furnaces, given by the sound power level, are between 125 and 139 dB(A). This sound level is relatively independent of the furnace capacity. Often, the noise emitted from an EAF is also stated by the average sound pressure level, measured at a certain distance from the furnace. This figure is always 8-20 dB smaller than the sound power level.

The total noise resulting from electric steelmaking plants, perceived at a certain location, origins from several sources and depends on several factors. Relevant parameters are the installed transformer capacity, the size of the furnace, existing enclosures of the EAF and the melting shop, the operating conditions, the distance between emission and immission location, the way of propagation, the weather situation, and the conditions at the immission location. Further factors to take into account include the periods of operation of the plant (day/nighttime) and the existing background noise at the immission site.

Main noise sources within an electric steelmaking plant are the EAF itself (including the encapsulated transformer), the reloading works at the scrap yard, the gas cleaning system (precipitator including the fan motor), the water cooling system, and the traffic related to the transportation of the inputs and outputs.

The identification of factors that influence the noise emitted by several sources within an electric steelmaking plant usually helps to show potentials for the reduction of noise emissions. Furthermore, besides the investigation of the several emission sources, also the spectral composition of the noise is an important topic. Impulses or tonal components, i.e. the "information" contained in the noise, and not its level, frequently cause complaints at the receptor's site.

# **3.5.2** Aspects of relevant noise sources

A general approach to isolate the influence of certain emission sources on the overall emission level is inter alia to perform systematic measurements and to collect the data obtained in emission inventories. In recent years, some research on the acoustic characteristics and the decisive factors for noise creation in electric steelmaking plants has been done.

For the electric arc furnace itself investigations showed the following factors to be relevant for noise creation: Electrical power supply, related to the time elapsed since the beginning of the melting phase, the condition of the inputs, the physical state of the EAF (like the type of the brickwork, the sealing of hood and door, and electrode or other openings), the stage of the melt, and the configuration of the furnace. Different types of scrap also have an impact on the noise creation within the EAF. Smaller and more homogeneous pieces of scrap support a more stable burning of the arc and a lower noise level. The noise creation of the gas cleaning system is mainly influenced by its capacity, which is at last determined by the furnace size, the suction system (4th hole, secondary dedusting), the precipitation system (electrostatic precipitator, bag filter), and the design of the precipitator (pressure-, suction filter-, cleaning equipment). Main emission sources within the precipitation system are the waste gas fans, which emit





sound power levels up to 120 dB(A), and auger-type or endless chain drives for the drag-out of dust, often causing squeaking sounds.

# 3.5.3 Main noise sources

The following are the main noise sources in EAF steelworks:

- the melting shop including the EAF
- the scrapyard
- the primary dedusting
- the roof hood dedusting
- water management equipment
- the transport of slag pots
- the transport of products, e.g. with wheel loaders
- slag processing in crushers, magnetic separators and screening devices.

Conventional EAFs show average sound levels (melting and treating) of LWA = 118 - 133 dB(A) for furnaces >10 t and LWA = 108 - 115 dB(A) for furnaces <10 t; the specific transformer power determines the level of noise emissions. In electric steelworks, sound levels of up to LWA = 127 dB(A) can appear (measurement includes melting and treating). The main share of noise emissions are contributed by the melting shop including EAF, the scrapyard and primary dedusting.

\* Lwa = Sound power level

#### Further aspects:

The condition or shape of the inserted scrap also affects the noise created in the EAF. However, due to quality, process, and economic reasons it is not possible to charge light and homogeneous scrap just in order to reduce noise emissions by the EAF. Significant reductions for the workers and also for the surroundings in the sound level can be achieved by an encapsulation of the furnace. But this may lead to handling problems, if the encapsulation fits to tight to the furnace. Another option is to separate the melt shop from the casting bay, which can reduce the sound level up to 30 dB. The sound proofing of the buildings that contain the steelworks, in particular by using soundproof materials in construction and taking special care for acoustically weak points like doors or gates, has been common within the last years. Electric steelmaking plants that have been erected within the last years have been put up with separate melt shops including a roof hood suction system. The sound power of a melt shop that is sound proven in a suitable manner can be reduced to 90 to 100 Db.

Bag house fans also may produce a considerable level of noise. Fans operating with a pressure increase of 300 dePa and an air flow of 500,000 to 1,500,000 m3(STP)/h produce a sound power level of 125 to 135 dB(A) in the inlet and outlet duct. The casing of the fan itself produces levels between 117 and 127 dB(A). Enclosures for the fan with an insertion loss of 20-40 dB can reduce the problem. In some cases, there may be the necessity to encase the





baghouse, eg. if the distance to the neighbours is short and the impulses by the bag cleaning system are audible.

European electric steelmaking plants are subject to regulations concerning the limitation of noise immissions imposed on the neighbourhoods. The plants usually have to comply with requirements that are set by licensing authorities. Standard values, that are the basis for actual requirements are shown in Table 3.13.g

Table 3.13: Standard values for maximum noise immissions at the immission site

Area of application	Day-time	Night-time
Areas, which only accommodate industrial installations or housing	70 dB(A)	70 dB(A)
for		
owners and managers of installations and supervisory staff or stand-		
by staff		
Areas, which mainly accommodate industrial installations	65 dB(A)	50 dB(A)
Areas, which mainly accommodate industrial installations or housing,	60 dB(A)	45 dB(A)
but		
within which neither industrial installation nor housing are located		
mainly		
Areas, which mainly accommodate housing	55 dB(A)	40 dB(A)
Areas, which only accommodate housing	50 dB(A)	35 dB(A)
Dedicated health resorts, hospitals, nursing homes	45 dB(A)	35 dB(A)
Housing, that is directly connected to the installation	40 dB(A)	30 dB(A)



Eşleştirme Projesi TR 08 IB EN 03 IPPC – Entegre Kirlilik Önleme ve Kontrol T.C. Çevre ve Şehircilik Bakanlığı



#### Example of values for emissions noise sources inside the factory



# 3.6 Soil contamination

The potential soil contaminants can occur in the following locations:

# 3.6.1 Storage and handling of input materials

Airborne dust from the stockyards and conveyor belts, including transfer points, can be a significant source of emissions. When material including leachable compounds and materials such as hydrocarbons from mill scale or scrap is stored in unpaved stockyards, attention also should be paid to soil and groundwater pollution and to runoff water. In some countries, material with leachable components should be stored on grounds with adequate soil protection.

Some techniques for improving the use of scrap include:

- Specification of acceptance criteria suited to the production profile in purchase orders of scrap.
- Having a good knowledge of scrap composition by closely monitoring the origin of the scrap; in exceptional cases, a melt test might help characterise the composition of the scrap.
- Having adequate reception facilities and check deliveries.





- Storing the scrap according to different criteria (e.g. size, alloys, degree of cleanliness).
- Storing of scrap with potential release of contaminants to the soil on impermeable surfaces with drainage and collection system; applying a roof which can reduce the need for such a system.

In many cases the scrapyard is unpaved and uncovered. Contamination of soil may arise from the storage of scrap contaminated by mineral oil/emulsions or other compounds. In this cases, there is no information available about the extent and the impact of such soil contamination.

If the yard for slag processing is unpaved and the raw slag contains free CaO, alkaline water may enter the soil.

# **3.6.2** Drainage water from the scrapyard

The main raw material of EAF, the different kinds of scrap are often stored on unpaved scrapyards.

Drainage water can be contaminated, especially in the case of scrap which contains oil/emulsions like turnings. There is no information available on quantities and pollution of drainage water. Usually it is at least treated in an oil separator prior to being discharged.

# 3.7 Raw materials consumption

The direct smelting of materials which contain iron, such as scrap is usually performed in electric arc furnaces (EAF) which play an increasingly important role in modern steelworks concepts. Today the percentage of electric arc furnace steel of the overall steel production in the EU-27 is 41.8 %. With 61 % in Italy and 77 % in Spain, the production of EAF steel is significantly higher than steel production via the blast furnace/basic oxygen furnace route.

The major feedstock for the EAF is ferrous scrap, which may be comprised of scrap from inside the steelworks, cut-offs from steel product manufacturers (e.g. vehicle builders) and capital or post-consumer scrap (e.g. end-of-life products). Direct reduced iron (DRI) is also increasingly being used as a feedstock due to its low gangue content, variable scrap prices and lower content of undesirable metals (e.g. Cu). Ferroalloys may be used as additional feedstock in greater or lesser quantities to adjust the desired concentrations of non-ferrous metals in the finished steel.

In the EAF slag from carbon steel production is produced during a process of melting steel scrap by the addition of limestone and/or dolomite as fluxes at temperatures around 1600 °C. The production of high alloy steel comprises various processes during which several slags are produced as by-products.





# 3.8 Energy consumption

The energy consumption has been constantly reduced by introducing energy-saving equipment in steel manufacturing processes and improving the efficiency of energy conversion facilities such as power plants. Energy-saving equipment includes waste energy recovery equipment. Another measure is the optimisation of energy consumption and costs by the implementation of a total energy management system.

Electricity and natural gas are the most important energy sources in EAF operations.

During the melting process some the following types of energy concur:

- 1. thermal energy from the electrical arc.
- 2. thermal energy from the combustion of natural gas or other gaseous or liquid fuels.
- 3. chemical energy from the exothermic reactions occurring in the furnace by metal oxidation.

The energy consumption of the furnace is the balance of the three aforementioned inputs. In an example is shown for an EAF with a comparably low input of 380 kWh/t electrical energy, 210 kWh/t through fuel combustion and 100 kWh/t through metal oxidation which corresponds to a total of 690 kWh/t of LS. From this input, 370 kWh/t are needed to melt and superheat the scrap to tap temperature, 37 kWh/t to liquefy and superheat the slag, 100 kWh/t are furnace losses and 140 kWh/t are as sensible heat in the off-gas.

The utilisation of the 140 kWh/t of sensible heat in the off-gas has developed over the last 40 years and is today a proven tool to reduce the total energy requirements in the EAF operations. One option is to use the sensible heat for scrap preheating. The scrap can be preheated to approximately 800 °C prior to the melting process in the furnace vessel which reduces the total energy consumption by up to 100 kWh/t LS.





# **4** BATs FOR THE PRODUCTION PROCESSES

# 4.1 General considerations

The BATs which are mentioned and described in this chapter have been extracted basically from two documents, the BREF for iron and steel production (published in 2012) and the BREF for the ferrous metals processing industry (published in 2000).

Throughout this chapter, the BAT Conclusions from the BREF for iron and steel production (published in 2012) are included within a square like the one below:

The BATs and associated emission levels which do not appear inside such a square correspond to the other BREF document.

The electric arc furnace iron and steel installations **are not obliged to implement all the BATs**: Depending on the characteristics of each facility (type of fuel, used systems) each electric arc furnace iron and steel installation can choose to implement one, several or no techniques at all, as a function of the amount of changes which entail the emission limit values and other conditions stated in the corresponding integrated environmental permit. The emission values which will be established in the future integrated environmental permits will take as reference those values associated to the BATs, which are mentioned in the BREF documents. The values indicated in the two BREF documents mentioned in the previous paragraph are summarized in Annex 2.

Each operator will have to identify within its application for the integrated environmental permit the techniques that are used in it which are considered as BATs in any of the existing BREFs (naturally in the case of electric arc furnace iron and steel installations the most relevant BREFs are the two previously mentioned). In the cases where during the assessment of the permit application the Competent Authority will request to achieve a certain emission level for a certain pollutant, the operator will have to justify how he or she will achieve that goal. Some BATs have associated emission levels stated in the corresponding BREF, so if the operator uses them it will be understood that those associated emission levels will be achieved.

If the operator chooses to use techniques other than BATs to achieve the emission level required by the Competent Authority, he or she will have to justify how such techniques will achieve that goal.

# 4.1.1 Techniques to consider in the determination of BAT and BAT conclusions





This chapter describes techniques (or combinations thereof), and associated monitoring, considered to have the potential for achieving a high level of environmental protection in the activities within the scope of this document.

It covers process-integrated techniques and end-of-pipe measures. Waste prevention and management, including waste minimisation and recycling procedures are also considered. Furthermore, techniques for reducing the consumption of raw materials, water and energy are covered.

The BAT conclusions adopted for iron and steel production according to Directive 2010/75/EU, which shall be the reference for setting the permit conditions, are also explained in the following sections of this chapter. The competent authority shall set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the decisions on BAT conclusions. Unless otherwise stated, the BAT conclusions presented in this section are generally applicable.

This chapter does not necessarily provide an exhaustive list of techniques which could be applied in the sector and other techniques may exist or may be developed, which could be considered for the determination of BAT for an individual installation.

As far as possible, a standard structure as shown in Table 4.1 is used to outline the information gathered concerning each technique, to enable a comparison of techniques and the assessment against the definition of BAT given in the Directive. In practice, the most important information corresponds to the sections "description", "achieved environmental benefits" and "operational data". For some of the techniques not all of the sections described in Table 4.1 are provided, because in those cases the information gathered from EU installations when preparing the BAT Conclusions was not enough.

Type of information	Type of information included	
considered		
Description	Brief technical description using, as appropriate,	
	pictures, diagrams and flow sheets.	
Achieved environmental	Main potential environmental benefits to be	
benefits	gained through implementing the technique	
	(including energy, water, raw material savings, as	
	well as production yield increases, energy	
	efficiency, etc.).	
Cross-media effects	Potential environmental side effects and	
	disadvantages to other media due to	
	implementing the technique, including details of	
	the environmental effects of the technique in	
	comparison with others (advantages and	
	disadvantages supported by data if available) in	
	order to assess the impact of the technique on the	
	environment as a whole. This may include issues	
	such as:	

Table 4.1: Information breakdown for each technique described in this section



Г



	<ul> <li>- consumption of raw materials and water</li> <li>- energy consumption and contribution to climate change</li> <li>- stratospheric ozone depletion potential</li> <li>- photochemical ozone creation potential</li> <li>- acidification resulting from emissions to air</li> <li>- particulate matter in ambient air (including microparticles and metals)</li> <li>- eutrophication of land and waters resulting from emissions to air or water</li> <li>- oxygen depletion potential in water</li> <li>- persistent/toxic/bioaccumulable components in water or to land (including metals)</li> <li>- creation or reduction of (waste) residues</li> <li>- ability to reuse or recycle (waste) residues</li> <li>- noise and/or odour</li> </ul>
Operational data	Actual performance data (including reference conditions, monitoring periods and monitoring methods) on emission levels, consumption levels (raw materials, water, energy) and amounts of waste generated. Any other useful information on how to operate, maintain and control the technique.
Applicability	Indication of the type of plants or processes in which the technique may or cannot be applied as well as constraints to implementation in certain cases, considering, e.g. plant age (new or existing), factors involved in retrofitting (e.g. space availability), plant size (large or small), techniques already installed and type or quality of product.
Economics	Information on costs (investment and operating) and any possible savings (e.g. reduced raw material or energy consumption, waste charges) or revenues including details on how these have been calculated/estimated. Economic information relevant to new build and retrofit to existing installations will be included. This should allow for identifying, where possible, the overall economic impact of the technique
Driving force for implementation	Specific local conditions, requirements (e.g. legislation, safety measures) or non- environmental triggers (e.g. increased yield, improved product quality) which have driven or stimulated the implementation of the technique to date.
Example plants	Reference to the plant(s) where the technique has been implemented and from which information has been collected and used in writing the section. Indication of the degree to which the technique is in use in Europe or worldwide.
Reference literature	Literature or other reference material (e.g. books,




reports,	stu	dies, v	websites	) tha	t was	used in
writing	the	sectio	n and	that	contair	is more
detailed	infor	rmatior	n on the	techn	ique.	

## 4.2 EAF process optimisation

#### Description

The EAF process has been steadily improved in order to become optimised and to increase productivity which correlates to the decrease of specific energy consumption. The most important measures/techniques which are briefly described in this section are

- [ 312, Dr. Michael Degner et al. 2008 ]:
- (ultra) high power operation (UHP)
- Water-cooled side walls and roofs
- oxy-fuel burners and oxygen lancing
- bottom tapping system
- foaming slag practice
- ladle or secondary metallurgy
- automated sampling and the addition of alloying elements
- increased energy efficiency
- computer-based process control and automation.

#### (Ultra) high power operation

Efforts to reduce tap-to-tap times have led to the installation of more powerful furnace transformers. Decisive features for UHP furnaces are the specific power supply installed, mean power efficiency (0.7), and timely use of the transformer (0.7). UHP operation may result in higher productivity, reduced specific electrode consumption, and reduced specific waste gas volume, but also in increased wear of the furnace lining[ 57, Heinen 1997 ].

#### Water-cooled side walls and roofs

Since 1980, furnace walls and roofs have been lined with water cooled panels, providing the opportunity to save refractory material, to use the UHP furnace technology, and also to reuse waste heat by the application of measures for energy recovery. However, the economic viability of energy recovery should be checked on a plant by plant basis. In principle, two cooling systems can be distinguished. 'Cold or warm cooling' draws off power losses by an increase of the cooling water temperature flowing through the pipe coils. Evaporation cooling





works through the evaporation of cooling water to draw off radiation heat caused by the electric arc process. To protect water-cooled side panels from thermal strain, especially when foaming slag operation is not possible, a computer controlled regulation of the meltdown process helps to prevent tears in the panels caused by mechanical tension and also saves refractory material [75, Knoop et al. 1997].

#### Oxy-fuel burners and oxygen lancing

Oxy-fuel burners promote a uniform melting of the scrap. It also partially offsets the effect of maximum demand control on electricity supply. Usually, additional energy input by oxy-fuel burners and oxygen lancing results in a decrease in total energy input required.

#### Bottom tapping system

The practice of bottom tapping has been used since 1983 and is widely adopted nowadays, as it makes minimising the amount of oxidic slag (carryover) to the ladle during tapping possible. It also allows cost savings for the lowering of refractory material needed, for a more rapid tapping, and for reduced energy losses. Furthermore, it simplifies the capturing of fumes.

Usually most new EAFs for carbon steel are equipped with bottom tapping systems. However, some older furnaces as well as most furnaces for stainless steel are still equipped with spouts.

The reasons for this are multiple. Spouts allow the tapping of the whole melt and partial tapping.

The tapping procedure is well controlled and the maintenance of the spout is easy due to its simple construction. With stainless steel and a high degree of reduction of the slag some Cr is recovered by the steel from the slag after tapping and prior to deslagging at a deslagging station [77, Austrian TWG member 2008 ] [177, Eurofer 2009 ].

#### Foaming slag practice

Creating a foamy slag within the furnace improves the heat transfer to the charged inputs, and also protects the refractory material inside the furnace. Because of better arc stability and fewer radiation effects, foaming slag practice leads to reductions in energy consumption, electrode consumption, noise level, and an increase in productivity. It also causes positive effects on several metallurgical reactions (e.g. between slag and melt). The density of foaming slag is lower than common EAF slag which contains FeO  $(1.15 - 1.5 \text{ t/m}_3 \text{ compared to } 2.3 \text{ t/m}_3)$ . For this reason, the volume of slag arising during steelmaking increases and may require larger slag buckets. After tapping, the slag partly degases again. Information on adverse impacts of the foamy slag practice on the possibilities of using the slag have not been encountered. It should be noted that the use of the foaming slag practice is not possible for some steel grades such as stainless steel and other high alloyed steels.





#### Ladle or secondary metallurgy

Some production steps need not be carried out in the EAF itself and can be performed more efficiently in other vessels (like desulphurisation, alloying, temperature and chemistry homogenisation). The technique of shifting specific activities to ladles, ladle furnaces, or other vessels was introduced c. 1985 [ 36, EPRI 1992 ] [ 57, Heinen 1997 ]. The reported benefits of this development are energy savings (net savings of 10 - 30 kWh/t), a reduction of tap-to-tap times of about 5 – 20 minutes, increased productivity, a better control of the steel temperature of the heat delivered to the continuous casting, a possible reduction of electrode consumption (up to 0.1 - 0.74 kg/t), alloy savings, and a decrease in the emissions from the EAF itself [ 36, EPRI 1992 ]. A possible drawback of using ladles or other vessels with respect to air pollution control is the increase in the number of emission sources, requiring higher investments for air pollution control equipment as additional fume capturing devices like hoods.

#### Increased energy efficiency

The EAF power demand (electrical voltage) has been significantly increased since 1995, resulting in electric networks being more and more disturbed, which implies electric energy losses. Electric energy inputs are an important lever for action. Improving power supply by means of efficient power electronics allows for increasing productivity and a reduction in the overall energy demand. Specific electricity consumption of 360 kWh/t has been achieved with a 100 MW DC EAF at ArcelorMittal, Esch-Belval, Luxembourg. For AC EAFs, one study has shown that improved power supply can lead to a productivity gain of approximately 7 % and associated gains in energy efficiency [ 252, France 2007 ].

#### Computer-based process control and automation

Computer-based control in EAFs has become necessary and has been commonly used approximately since 1982, as the high throughputs require efficient control systems to manage the material and data flows arising in the raw material selection, EAF, ladle furnace, and continuous caster. Efficient control systems in particular enable optimisation of the energy input in the furnace and permit an increase in productivity and also a decrease in dust emissions [86, Linninger et al. 1995] [312, Dr. Michael Degner et al. 2008].

#### Achieved environmental benefits

The achieved environmental benefits are mentioned above under the description heading.

#### **Cross-media effects**

Oxy-fuel burners increase the off-gas flow but on the other hand they decrease the overall energy demand.





Water-cooled side walls and roofs need an additional energy consumption of about 10 - 20 kWh/t but may be compensated for by advantages in the field of plant availability and maintenance. Water-cooled side walls and roofs have inter alia provided the opportunity to apply modern technology like high power or UHP furnaces.

#### Applicability

The described techniques are applicable to both new and existing plants but should be checked on a plant by plant basis.

#### Driving force for implementation

The high market competition and the need to increase productivity/to reduce costs pushed the introduction of the described techniques.

#### **Example plants**

Many plants in the EU are equipped with the described techniques and are operated with optimised conditions.

#### **Reference literature**

[ 16, Rentz 1997 ] [ 252, France 2007 ] [ 260, Germany 2007 ] [ 273, Eurofer 2007 ] [ 312, Dr. Michael Degner et al. 2008 ]

## 4.3 BATS ON AIR EMISSIONS

## **4.3.1** Advanced emission collection systems

#### Description

The primary and secondary emissions to air are of high relevance. Both primary and secondary emissions should be collected as much as possible, preferably at the source of origin and then abated. The combination of 4th hole (in case of three electrodes, e.g. AC) or 2nd hole (in the case of one electrode, e.g. DC), the direct extraction with canopy hood systems (or furnace enclosures) or total building evacuation are the preferred systems.

With a 4th or 2nd hole (see Figure 4.1), the primary emissions generated during the melting and refining periods can be collected almost completely. This type of direct extraction technology is state of the art in modern EAF steelmaking for the collection of primary emissions. It can also be applied to secondary metallurgy vessels.

In a canopy hood system (see Figure 4.1), one or more hoods over the furnace indirectly collect fumes escaping from the furnace during charging, melting, slag-off, and tapping steps (up to 90 % of primary emissions and also secondary emissions [ 22, EC EAF 1994 ]). Hood systems are commonly used within the electric EAF industry. Combined with direct extraction systems, the collection efficiency of primary emissions and also secondary emissions and also secondary emissions improves





by up to 98 %. Hoods are also installed to collect emissions arising at secondary metallurgy vessels, hoppers and conveyor belts.

Furnace enclosures, also called doghouses (see Figure 4.1), usually encapsulate the furnace, its swinging roof, and also leave some working space in front of the furnace door. Typically, waste gases are extracted near the top of one of the walls of the enclosure, and make-up air enters through openings in the operating floor [36, EPRI 1992 ]. More complex handling steps, causing time losses and possibly higher investments (e.g. the need for additional door opening and closing mechanisms and procedures in order to charge and empty the furnace) are drawbacks of this type of collection technology. Collection rates of doghouses are similar to or usually slightly higher than those of hood-complementary hole combinations. A positive effect of furnace enclosures is a reduction in the noise level if they are constructed in a suitable manner. Noise abatement at an EAF plant by sound protecting enclosures can reduce the average sound pressure level between 10 and 20 dB(A) [ 79, Kuhner et al. 1996 ]. Furnace enclosures may also be applied at secondary metallurgy processes [ 22, EC EAF 1994 ] but a treatment of the shop walls is needed to eliminate reverberation.



Figure 4.1 Collection systems at EAF

Source: based on [ 140, Eurofer 2009 ] [ 373, Eurofer 2007 ]

Another way to collect secondary emissions from the furnace and other installations is a complete enclosure of all plants in one sealed building.

The erection of such buildings and the additionally required large dedusting installations in order to achieve complete dedusting impose considerable costs on the operators. For this reason, the costs and benefits need to be weighed carefully for every special plant before this option is considered. A positive effect of this measure is a reduction in the noise level penetrating the outside. Usually, the pressure in the enclosing building is below atmospheric pressure to prevent the escape of fumes through occasional door openings.





For a high collection rate, a sufficient extraction volume should be ensured. Depending on the collection system, exhausting volumes are often in the range of  $600\ 000 - 1.2$  million m<sub>3</sub>/h.

#### Achieved environmental benefits

The combination of direct fume extraction and a hood system is often used. This combination achieves a collection of about 98 % of the primary emissions. In addition, a significant share of charging and tapping (secondary) emissions can be collected, too, though this depends on the type and the number of hoods [ 22, EC EAF 1994 ]. A combination of a direct extraction device and a furnace enclosure can even achieve collection rates from 97 % – 100 % of the total dust emissions [ 57, Heinen 1997 ]. Total building evacuation also achieves practically 100 % emission collection.

In one case, the emission collection system was newly designed and optimised. This included the increase of the exhaust gas volume from 630 000 to 1 250 000 Nm<sub>3</sub>/h, a new lining of the roofs of the steelwork and the melt shop, renewal of the primary waste gas duct from the EAF and the addition of a bag filter, three fans and a new stack.

A comparison of dust emissions from the steelwork stacks before and after retrofitting is shown in Table 4.2.

Parameter	Measured values				
	Concentration	Mass flow			
Dust emissions from the steelwork stacks, daily	4.5 – 5 mg/m³	3.25 kg/h			
average values until August 2006					
Dust emissions from the steelwork stacks, daily average values from September 2006	0.35 mg/m <sup>3</sup>	0.44 kg/h			
Achieved improvement by the retrofitting	- 93 %	- 87 %			
Source: [ 355, Plickert 2007 ].					

#### Table 4.2: Comparison of dust emissions from the steelwork stacks before and after retrofitting

This measure has also improved the working environment significantly and reduced the diffuse dust emissions via roof fans from  $6.35 \text{ mg/m}_3$  to  $2.5 \text{ mg/m}_3$  which corresponds to a reduction of approximately 60 % [ 355, Plickert 2007 ].

#### Cross-media effects

(one steel work in Germany)

The emission collection systems need energy, especially the fans.

#### Applicability

This technique is applicable both to new and existing plants.





#### Driving force for implementation

The main driving force is to reduce particulate emissions.

#### **Example plants**

Many plants in Europe have a combination of direct off-gas extraction and hoods.

The following German plants are equipped with only doghouses or with a combination of doghouse and direct hole extraction: Benteler AG, Lingen; ThyssenKrupp Nirosta, Bochum; ThyssenKrupp Nirosta, Krefeld; Mannesmannrohr GmbH, Bous/Saar; TSW, Trier; Stahlwerke Thüringen GmbH, Unterwellenborn, Elbe and Stahlwerke Feralpi, Riesa.

Total building evacuation: ArcelorMittal, Schifflange; Differdange and Belval, all in Luxembourg.

#### **Reference literature**

[ 16, Rentz 1997 ] [ 22, EC EAF 1994 ] [ 57, Heinen 1997 ]. [ 208, Lindfors et al. 2006 ] [ 366, Dornseiffer et al. 2007 ] [ 373, Eurofer 2007 ]

## **4.3.2** Abatement techniques for primary and secondary emissions to air from electric arc furnaces

Abatement techniques for primary and secondary emissions to air from EAFs (for example PCDD/F concentrations in air emission) refer to the total primary and secondary emissions.

Therefore if primary and secondary emissions are treated separately, the concentration indicated as achievable performance should be compared with the weighted average of concentrations in primary and secondary emissions, both measured downstream of the dust collection system.

#### 4.3.2.1 Dust abatement by means of a bag filter and an electrostatic Precipitator

#### Description

By far the most common dust abatement technique in electric arc furnace (EAF) operations is the bag filter (also called bag house) which is particularly suited to the type of dust generated in the EAF. Bag filters are very effective in capturing all particle-bound pollutants, e.g. heavy metals as well as organochlorine pollutants such as PCDD/F particularly if adsorption agents are used.

The off-gas flow from primary and secondary exhausting depends on the collection system.

Exhausting volumes are often in the range of  $600\ 000 - 1.4\ million\ m_3/h$ . For large bag filters as generally required in EAF steelmaking plants, a design with tubular fabric bags of around 6 m long and about 200 mm in diameter is chosen. A very important design parameter for bag





filters is the air-to-cloth ratio which is, in the case of the EAF process, often between 1 and 1.3  $(m_3/min/m_2)$ .

A typical filter material for the application in EAF is a spark-resistant polyester or a PTFEcoated needle felt. However, an important issue for a sound bag filter operation is to prevent incandescent particles from reaching the filtering medium and thus burning holes into it. For this purpose, spark arresting devices, such as cyclones are often installed in the raw gas ducts.

Cleaning of the fabric, i.e. removing the dust periodically that has accumulated on the fabric surface is performed either by mechanical shaking or with a continuous, fully-automated online pulse jet (compressed air) cleaning system which means that the process flow continues during cleaning. The dust cakes falling from the bags are collected in dustbins below the bags and are carried outside the filter by a conveying system.

In some rare EAF plants, ESPs are used but with a slightly less performance abatement efficiency.

#### Achieved environmental benefits

Figure 4.2 shows the dust emissions profile from one EAF plant for three years (2004 – 2006).

The data show that with well designed and well operated bag filters, annual dust emission values of 1 mg/Nm<sub>3</sub> are achievable. A well designed and well maintained bag filter has a residual emission of less than 5 mg/Nm<sub>3</sub> (daily average).



Figure 4.2: Daily average dust emissions from an EAF plant over three years

Source: [ 366, Dornseiffer et al. 2007 ]





The detailed results from the continuous dust measurements in the aforementioned three EAF plants over three years are shown in the Table 4.3.

Measurement	EAF A	EAF B	EAF C	Unit
result				
Mean	0,84	0,85	0,53	mg/Nm₃
Standard	0,47	0,40	0,58	mg/Nm₃
deviation				
Minimum	0,30	0,05	0,01	mg/Nm₃
Maximum	7.82	4,35	7,36	mg/Nm₃
Number of values	902	716	1054	
Source: [ 366, Dornseiffer et al. 2007 ].				

#### Table 4.3: Daily average dust emissions from three EAF installations (2004 – 2006)

Table 4.4 shows the results from seven dust and heavy metals measurements carried out in Germany and Austria and two in the Netherlands.

#### Table 4.4: Residual dust and heavy metals concentrations from nine EAF installations after

#### Abatement

Parameter		Bag filter	Electrostatic precipitator (1)	Unit
Dust		0.35 – 3.4	1.8	mg/Nm₃
Metals:	Hg	0.001 - 0.019		mg/Nm₃
	Sum of Sb, Pb, Cr,	0.006 - 0.022	<0.0003	mg/Nm₃
	CN, F, Cu, Mn, V,			
	Se, Te, Ni, Co, Sn			
	Cr (except Cr (VI))	0.013	0.01 - 0.07	mg/Nm₃
	Mn	0.036		mg/Nm₃
	Ni	0.003		mg/Nm₃
(1) ESP applied in stair	less steel production			

(1) ESP applied in stainless steel production.

 $\ensuremath{\mathsf{NB:}}$  — Values are annual averages and relate to the central deducting system.

-PAH contains benzo(a)pyrene and dibenzo(a,h)anthracene.

Source: [ 191, Infomil 2010 ] [ 244, Plickert 2007 ] [ 277, Wiesenberger 2007 ] [ 355, Plickert 2007 ].

#### Cross-media effects

Bag filters capture essentially dust including all of the heavy metals that are present as particulates at the filtering temperature as well as the organic substances that are adsorbed to the dusts, among them PCDDs and PCDFs. Bag filters play an essential role in PCDD/F abatement

#### **Operational data**

Higher emissions may occur when, for instance, parts of the bag filters are destroyed. This can be avoided by good operation which consists of the continuous monitoring of dust emissions and consequent replacement of all destroyed bag filters. Good design consists of well





dimensioned bag chambers thus minimising mechanical wear, spark arrestors and temperature control and the detection of excessive dust accumulations.

There are different types of fabric used for the manufacturing of filter bags. Some allow maximum temperatures of 125 - 130 °C, others may be used at temperatures up to 250 °C. The fabrics suited for low-temperature filtration tend to have higher abatement efficiencies. The offgas flow should be cooled down to the suitable temperature. This is often done by mixing the primary and secondary flows. If the resulting temperature is still too high, and in case of separate filtering of the primary and the secondary flow, additional cooling devices need to be installed in the primary off-gas flow.

Electricity consumption is approximately 20 - 28 kWh/t liquid steel for bag filters and whole building evacuation.

#### Applicability

Waste gas treatment with a bag filter is applicable for new and existing plants.

#### **Example plants**

Most European EAF steelmaking plants use fabric filters for dust abatement.

Examples of the aforementioned technique are given in Table 4.5.

Example plants	Description
Luxembourg	Three EAFs plants
Böhler	The EAF plant produces high alloyed steel with a
Edelstahl,	total capacity of 180 000 tonnes per year. The
Kapfenberg	steelwork includes an EAF with 50 tonnes per
Austria	charge, ladle metallurgy with an AOD converter
	and a special steelwork with vacuum treatment
	and remelting units. For primary dedusting, main
	emission sources (EAF and AOD converter) are
	enclosed. The waste gas extracted from both
	emission sources is treated by a bag filter. Waste
	gas volume is about 900 000 Nm <sub>3</sub> /h
Marienhütte,	EAF plant producing about 365 000 t/yr carbon
Graz,	steel, which is processed into steel bars and
Austria	reinforcing steel. The EAF has a capacity of 35 t.
	During the melting process, primary emissions are
	extracted from the 4th hole of the EAF.
	Secondary emissions are collected by a roof hood
	extraction. Primary and secondary emissions are
	conducted through a mixing chamber and treated
	together in a bag house filter. Total waste gas
	volume is about 1 million Nm <sub>3</sub> /h
Elbe Stahlwerke	The off-gas volume is about 1 250 000 Nm <sub>3</sub> /h; the
Feralpi, Riesa,	filter area is 19 270 m <sub>2</sub>
Germany	
BSW, Kehl,	The off-gas volume is approximately 1 800 000

#### Table 4.5: Example plants using dust abatement techniques





Germany	Nm <sub>3</sub> /h; the filter area is 38 000 m <sub>2</sub>		
Ovako Imatra,	The off-gas volume is approximately 620 000		
Finland	Nm <sub>3</sub> /h, the filter area is 9400 m <sub>2</sub> . Filter material is		
	PTFE-coated needle felt, filter cleaning with a		
	pulse-jet system, and continuous monitoring by		
	two systems: the tribumetric measuring system by		
	SINTROL® and the optical measuring system SICK®		
Source: [ 208, Lindfors et al. 2006 ] [ 277, Wiesenberger 2007 ] [ 360, Sick-Maihak 2006 ] [ 366, Dornseiffer et al.			
2007 ] [ 355, Plickert 2007]			

#### **Reference literature**

[ 140, Eurofer 2009 ] [ 208, Lindfors et al. 2006 ] [ 244, Plickert 2007 ] [ 277, Wiesenberger 2007 ] [ 355, Plickert 2007 ] [ 366, Dornseiffer et al. 2007 ] [ 367, Prüm et al. 2005 ] [ 375, IISI 1998 ] [ 388, Fisher et al. 2005 ]

## **4.3.2.2** Reduction of PCDD/F by means of post-combustion and quenching in combination with a bag filter

#### Description

Post-combustion in a combustion chamber aims primarily at the full combustion of CO and H<sub>2</sub> remaining in the off-gas in order to avoid uncontrollable reactions in the gas cleaning equipment.

Secondarily, this post-combustion, when it is well optimised (i.e. when the temperature and the residual time are adequate) reduces the emission of organic and organochlorine compounds such as PAH, PCB or PCDD/F. Post-combustion with the additional aim of minimising organic micropollutants needs an adequate retention time, turbulence and temperature (the three Ts).

The heat produced by this combustion is generally not recovered unless recovery from cooling water is possible.

To prevent the de novo synthesis of PCDD/F, it is essential to have a rapid cooling (quenching) of the fumes as soon as possible after post-combustion to a temperature of below 250 °C at which all risk of de novo synthesis is excluded. In some cases, this might be obtained by dilution of the secondary circuit; mostly, however this cooling is obtained by water injection in a quenching tower. Figure 4.3 shows the post-combustion of the primary off-gas from an EAF with subsequent rapid cooling.







Figure 4.3: Post-combustion of the primary off-gas from an EAF with subsequent rapid cooling *Source:* [16, Rentz 1997]

#### Achieved environmental benefits

Figure 4.4 shows the PCDD/F concentrations measured at two EAFs with post-combustion and rapid quenching were between 0.102 and 0.7 ng I-TEQ/Nm<sub>3</sub>. The main reasons for the observed lack of reliability of this technique are considered to be:

- insufficient temperature level reached in the post-combustion chamber during the first few minutes of the EAF melting process, exactly the time when probably the highest load of organic pollution is carried from the furnace.

- the distance between the post-combustion chamber and the quenching tower, in this specific case due to the retrofitting situation, was long and thus there was a permanent potential for the de novo synthesis. A quenching system right next to the post-combustion chamber would most likely have given much better results.







Figure 4.4: Average annual dioxin emission concentrations from two EAFs with post-combustion

and rapid cooling (1997 - 2000)

Source: [ 375, IISI 1998 ]

Table 4.6 shows the results from seven dust, PAH and PCDD/F measurements put through in Germany and Austria.

Parameter	Bag filter	Unit			
Dust	0.35 – 3.4	mg/Nm₃			
РАН	<0.00001	mg/Nm₃			
PCDD/F	0.0015 - 0.1 (1)	ng I-TEQ/Nm3			
(1) Upper end of the range relates to measurements carried out in 1997.					
NB: — Values are annual averages and relate to the central dedusting system.					
—PAH contains benzo(a)pyrene and dibenzo(a,h)anthracene.					
Source: [ 244, Plickert 2007 ] [ 277, Wiesenberger 2007 ] [ 355, Plickert 2007					

Table 4.6: Dust. P	AH and PCDD/F	emissions	concentrations	after abatement
		•••••••		

In general with proper post-combustion followed by rapid cooling (by dilution with air or water quenching) emission concentrations of PCDD/F of lower than <0.1 ng I-TEQ/Nm<sub>3</sub> can be achieved. In some cases, for the aforementioned reasons higher PCDD/F concentrations can occur.

The following Table 4.7 shows additional results for dust and PCDD/F measurements from four EAFs with post-combustion and rapid quenching in Germany.





#### Table 4.7: Performance of post-combustion and rapid cooling at four German EAF

PLANT																	
	EAF 1		EAF 2			EAF 3		EAF 4	4 (1)								
Features			•														
Tapping weight (t)	105		138	138		85/85	5	150									
Power supply (MVA)	105		96	96		57/68	3	135									
Collection of emissions	4th hol	e, hood	4th hol	4 <sub>th</sub> hole, hood		4th hole, hood		4th hole, hood		4 <sub>th</sub> hood	hole,	e, 4th hole, (prim.) doghouse with two exhausts (sec. 1 and 2)					
Post- combustion (PC)	PC (air)	chamber	PC in c	luct		PC cha (air)	amber	PC in	duct								
Waste gas cooling	Injecti water	on of	Water of was	conditior te gas	ning	Spray coolin syster (quen	ng n ching)	Air-co heat	ooled exchangei	r							
Off-gas cleaning system	Bag fil	ter	Electro precip	ostatic itator		Bag fi (1 for	lter both)	Bag filters		ag filters							
Number of measurements	1	2	1	2	3	1	2	1	2	3	4		5	6			
at the plant																	
Gas concentrations: (2)																	
Dust in crude gas (prim.)	3398	14246	4200	12500	3600	-	-	-	-	-							
Dust in crude gas (sec.)	148	273	Prim. togeth	and er	sec.												
	0,76	1,05	15	15	18	1,45	1,1	<1,1									
Dust in clean gas (sec.)	Avera	ge (3)	Avera	Average (3) Average (3)		ge (₃)	0.54 (4) 1.8 (4)										
PCDD/F (prim.)	-	-	-	-	-	-	-	0,09	0,047	0,084	0,022		0,02	0,0	)8		
PCDD/F (sec.)	-	-	-	-	-	-	-	-	0.025 0.015	0.043 0.024	0.009 0.08	0.0 0.0	)13 )4	0.013 0.08	3		
PCDD/F (Mix, prim. and sec.)	0.016	0.021	0.01	0.02	0.01	0.13	0.1	-	-	-	-		-	,	-		
<ul> <li>(1) Measurements v</li> <li>(2) Crude and clean</li> <li>(3) Average of two r</li> </ul>	vere carr gas dust neasurei	ied out in 2 concentra nent spots	2008. tions in n	ng/Nm3; P	CDD/F co	ncentrat	ion in ng	I-TEQ/I	Nm3.								

(4) Two values refer to secondary 1 and secondary 2.

NB: – = Not relevant or no information available.

(prim.) = Concentrations after dedusting device for primary off-gases.

(sec.) = Concentrations after dedusting device for secondary off-gases.

Source: [ 16, Rentz 1997 ] [ 137, Theobald 1995 ] [ 177, Eurofer 2009 ] [ 189, N.N. 2008 ].

#### **Cross-media effects**

Post-combustion with additional burners consumes considerable quantities of energy (in the order of 30 kWh/t). Since the hot off-gases need to be quenched to prevent de novo synthesis of PCDD/F, the energy cannot be recovered.





#### **Operational data**

The water consumption for quenching can be up to 40 tonnes per hour.

The thermal combustion before quenching can be obtained with natural gas burners in postcombustion chambers.

#### Applicability

The post-combustion unit at BSW, Kehl, Germany operates without significant problems.

In principle, post-combustion can be applied to both new and exiting plants but in existing ones the local circumstances and possibilities (like available space, given off-gas duct system, etc.) should be checked on a plant by plant basis.

#### Economics

The investment costs for a quenching tower were about EUR 1.2 millions in 1997. More economic data are not available. This represents a higher investment compared to an adsorption process.

#### Driving force for implementation

The main driving force for the implementation of post-combustion and subsequent rapid cooling are the environmental and health concerns for reducing PCDD/F emissions.

#### Example plants

BSW, Kehl, Germany; Salzgitter AG, Peine, Germany; B.E.S., Brandenburg, Germany; HSE. Henningsdorfer Stahl Engineering GmbH, Henningsdorf, Germany; DEW, Witten, Germany; ArcelorMittal, Hamburg, Germany; Gerlafingen Stahl AG, Gerlafingen, Switzerland; ArcelorMittal, Differdange and Esch-Belval, both in Luxembourg.

#### **Reference literature**

[ 68, Karcher et al. 1996 ] [ 73, Knapp 1996 ] [ 167, Werner 1997 ] [ 366, Dornseiffer et al. 2007 ] [ 367, Prüm et al. 2005 ] [ 373, Eurofer 2007 ] [ 375, IISI 1998 ]

#### 4.3.2.3 Reduction of PCDD/F by means of adsorbent materials in combination with bag filters

#### Description

In order to reduce persistent organic pollutants, especially PCDD/F, in the total off-gas (primary and secondary emissions), adsorbents (e. g. activated carbon, pulverised activated lignite coke or mixtures of these with lime) can be dosed to the exhaust duct before the dust abatement device. The necessary amount depends on the type and size of the adsorbent. Usually it is between 20 and 150 mg/Nm<sub>3</sub> off-gas. The size of pulverised activated lignite coke is typically between 0 and 0.4 mm, on average 0.63 um. Being milled, the average size is about 24 um which leads to lower dosing rates. Carbonaceous adsorbents used have an average grain size of around 25 um.





Adsorption takes place in three steps; first, when the stream of adsorption agent hits the raw gas flow, secondly as the adsorbent-enriched raw gas travels to the filtering device, and thirdly, (especially with the use of bag filters) as the gas phase crosses the adsorbent-enriched dust coating layer on the filter medium [ 63, Wirling, J. 2007 ].

The carbon to which the PCDD/F molecules are adsorbed is separated from the gas phase together with the EAF dust contained in the raw gas in the subsequent bag filters.

Figure 4.5 shows a schematic of an adsorbent injection system.



Figure 4.5: Schematic of an adsorbent injection system

Source: [ 375, IISI 1998 ]

#### Achieved environmental benefits

Residual PCDD/F emission concentrations of 0.01 - 0.1 ng I-TEQ/Nm<sub>3</sub> are achievable in practice. Some calculations show these emissions values to correspond to 0.01 - 0.14 ng WHO-TEQ PCDD/F (including dioxin-like PCB). The removal efficiency is quite stable and reliable.

Besides PCDD/F adsorption, activated carbon and pulverised activated lignite coke have shown a high efficiency of separation of heavy metals and a certain efficiency in removing mercury from the gas phase. Table 4.8 shows the PCDD/F reduction as a result of pulverised activated lignite coke injection.

Table 4.8: PCDD/F reduction as a result of pulverised activated lignite coke injection

EAF	Gas flow	Addition of	PCDD/F	PCDD/F





plant	(1000 Nm₃/h)	lignite coke adsorbent (kg/h)	Emission concentration without adsorbent injection (ng ITEQ/ Nm3)	Emission concentration with adsorbent injection (ng ITEQ/ Nm <sup>3</sup> )
A	750	100 (1) 35 (2) 25 (2)	0.178 – 1.44	0.085 - 0.226 0.003 - 0.008 0.023 - 0.092
В	850	40 (2)	0.072 - 0.722	0.007 - 0.032
С	770	50 (2)	0.040 - 0.714	0.005 – 0.075
D	690	15 (2)	<2.0	<0.05
E	840	20 (2)		0.002 - 0.007
F	1250			0.015 - 0.04

(1) Standard quality lignite coke; particulate size 63 ]m (300 m<sub>2</sub>/g).

(2) Supermilled activated lignite coke; particulate size 24 ]m (1200 m<sub>2</sub>/g); considered to have a high pyrophoric index.

NB: Data from 1999 – 2004.

Source: [ 260, Germany 2007 ] [ 277, Wiesenberger 2007 ] [ 367, Prüm et al. 2005 ] [ 368, Prüm et al. 2004 ] [ 375, IISI 1998 ].

Table 4.9 shows the results of the dioxin measurements according to the progress after gradual retrofitting and optimisation of the abatement system of an EAF plant by installation of a second injection systems for activated coal in the collection ducts prior to the bag filter. The volume of the exhausted waste gas is approximately 1 250 000 Nm<sub>3</sub>/h.

Table 4.9: Progress in PCDD	F abatement after installation of	a second carbon injection system
-----------------------------	-----------------------------------	----------------------------------

	PCDD/F Emission			
	concentration			
After start up of first injection system for activated coal				
Average concentration of three measurements in	0.04 ng I-TEQ/Nm <sup>3</sup>			
September,				
October and November 2006				
After start-up of second injection system for activated coal				
Measurement 06 – 08 March 2007	0.015 ng ITEQ/			
	Nm <sup>3</sup>			
Source: [ 355. Plickert 2007 ].				

Investigations show that the persistent organic pollutants, such as PCDD/F, adsorbed on activated lignite coke are bonded irreversibly due to the high bonding forces and are reliably destroyed or catalytically decomposed during the thermal treatment of dust.

#### **Cross-media effects**

The amount of energy needed for pulverised activated lignite coke dosage is not considerable.

The filter dust contains the lignite coke powder and slightly increased PCDD/F amounts but this does not interfere with dust treatments for the recovery of non-ferrous metals.





#### **Operational data**

Attention should be paid to the final carbon content of the dust mixture abated at the bag filter.

In order to prevent the risk of ignition, the carbon content of the EAF dust should stay below 4 %.

The use of activated carbon or lignite coke differs in grain size and in the effective adsorption surface area and consequently in the amount of injection required. Activated coal has the highest specific free surface and shows a very good adsorptive effect. Activated lignite coke is a more economic alternative than activated coke and the supermilled lignite coke with a diameter of 0.024 mm also shows a very good adsorptive efficiency and leads to half the dosing rates necessary compared to standard lignite coke [ 367, Prüm et al. 2005 ]. Sometime inerts have to be added to the injected carbon-based materials to prevent ignition. Table 4.10 shows the characteristics of different adsorbents and absorbent materials.

Adsorption and absorption material	ls	Grain size (mm)	Surface area BET (1)	Precipitative pollutants	
Standard powdered activated lignite	Carbon	0.063	(m2/g) 300 - 400	Organics, heavy metals	
Supermilled powdered activated lignite coke	Carbon	0.024	1200		
Powdered activated (charcoal) carbon	Carbon		500 - 1600		
Zeolite	Z		4 – 90		
(1) BET: Abbreviation created from the initials of the family names of the people who developed this theory as a rule for the physical adsorption of gas molecules on a solid surface.					

Comprehensive investigations have shown that only a very short contact time is required to have PCDD/F adsorbed on activated lignite coke. However, the separation efficiency depends on the probability of contact between the sorbent and the pollutant molecule. The distribution of the adsorbent in the waste gas flow plays a major role here. An important precondition for achieving optimum separation efficiency is the presence of a homogeneous and, at the same time, turbulent mixture already at the injection point where the first pollutant separation step takes place. A significant factor in selecting the adsorbents is an optimum pore radius distribution for pollutant molecule adsorption.

Provisions should be taken to prevent sparks from reaching the bag filters in order to prevent possible glow fires, since the increased carbon content of the separated dust may increase its





ignitability. The explosion risk has been assessed to be low. Fire and explosion protection is achieved through a combination of prevention measures (e.g. adsorbent inertisation, avoidance of entry of sparks, limiting the amount of adsorbent in the filter dust). Some techniques applied are the use of spark detectors, nitrogen flooding systems, temperature surveillance in the bag house, and detection of dust accumulations in the bag house collecting bins. Spontaneous ignition reactions of the filter dust are reliably prevented through consistent avoidance of large volume deposits in the plant section subjected to hot gas flows.

The low PCDD/F emissions in the clean gas attainable with dosing rates of  $25 - 35 \text{ mg/Nm}_3$  illustrate the high adsorptive effect of lignite coke adsorber.

#### Applicability

This technique is applicable to both new and existing plants.

#### Economics

Investment for the total off-gas flow (primary and secondary off-gases) from an EAF plant producing about 1 Mt steel/yr is about EUR 500 000.

#### Driving force for implementation

The main driving forces for the implementation of this technique for reducing PCDD/F are environmental and health concerns and, in the case of Feralpi in Riesa, Germany, the increase in production capacity.

#### **Example plants**

The technique has been implemented in several European EAF plants since 1997.

ArcelorMittal, Esch-Belval, Differdange and Schifflange, all in Luxembourg; Swiss Steel, Gerlafingen, Switzerland; Stahlwerk Thüringen, Unterwellenborn, Germany; Elbe Stahlwerke Feralpi, Riesa, Germany; ArcelorMittal, Genk, Belgium.

#### Reference literature

[ 260, Germany 2007 ] [ 277, Wiesenberger 2007 ] [ 355, Plickert 2007 ] [ 366, Dornseiffer et al. 2007 ] [ 367, Prüm et al. 2005 ] [ 368, Prüm et al. 2004 ] [ 373, Eurofer 2007 ] [ 375, IISI 1998 ]

## 4.3.3 Reducing of dust emissions from slag processing

#### Description

If the slag is collected in a slag pot at the EAF, it needs to be poured into outside slag basins for solidification. The cooling of the slag may be enhanced by water sprays resulting in fumes.

If the slag is poured onto the floor, it is precrushed after solidification using excavators or shovel loaders and is subsequently brought to an outside storage area.





After a certain period of time, the slag is processed in crushing and screening devices in order to give it the desired consistency for separating metals from the slag and for its further use in construction. Slag breaking and metal recovery can create dust emissions.

In order to minimise dust emissions, the crushing and screening devices can be enclosed and extracted. The emission from crushing and screening are subsequently cleaned by means of a bag filter. The conveyor belts should be enclosed; transfer points can be wetted. If the processed slag is stored, heaps should be wetted. During the loading of broken slag, water fogs can be used to minimise dust emissions [ 85, VDI/DIN 2006 ] [ 260, Germany 2007 ] [ 273, Eurofer 2007 ] [373, Eurofer 2007 ].

#### Achieved environmental benefits

With this technique a residual dust concentration of <10 - 20 mg/m<sub>3</sub> can be reached.

#### Applicability

The technique is applicable to both new and existing plants.

#### Driving force for implementation

The main driving force is to reduce particulate emissions.

#### **Example plants**

BSW, Kehl, Germany

Georgsmarienhütte, Osnabrück, Germany Lech-Stahlwerke (LSW), Meitingen, Germany.

#### **Reference literature**

[ 85, VDI/DIN 2006 ]





## 4.3.4 Adopted BAT Conclusions

The following conclusions have been adopted :

4.1.4.1 Diffuse dust emissions from materials storage, handling and transport of raw materials and (intermediate) products

\* BAT is to prevent or reduce diffuse dust emissions from materials storage, handling and transport by using one or a combination of the techniques mentioned below.

If abatement techniques are used, BAT is to optimise the capture efficiency and subsequent cleaning through appropriate techniques such as those mentioned below.

Preference is given to the collection of the dust emissions nearest to the source.

I. General techniques include:

- the setting up within the EMS of the steelworks of an associated diffuse dust action plan;

- consideration of temporary cessation of certain operations where they are identified as a source of PM10 causing a high ambient reading; in order to do this, it will be necessary to have sufficient PM10 monitors, with associated wind direction and strength monitoring, to be able to triangulate and identify key sources of fine dust.

II. Techniques for the prevention of dust releases during the handling and transport of bulk raw materials include:

- orientation of long stockpiles in the direction of the prevailing wind

- installing wind barriers or using natural terrain to provide shelter

- controlling the moisture content of the material delivered

- careful attention to procedures to avoid the unnecessary handling of materials and long unenclosed drops

- adequate containment on conveyors and in hoppers, etc.

- the use of dust-suppressing water sprays, with additives such as latex, where appropriate rigorous maintenance standards for equipment

- high standards of housekeeping, in particular the cleaning and damping of roads

- the use of mobile and stationary vacuum cleaning equipment

- dust suppression or dust extraction and the use of a bag filter cleaning plant to abate sources of significant dust generation

- the application of emissions-reduced sweeping cars for carrying out the routine cleaning of hard surfaced roads.





III. Techniques for materials delivery, storage and reclamation activities include:

- total enclosure of unloading hoppers in a building equipped with filtered air extraction for dusty materials or the hoppers should be fitted with dust baffles and the unloading grids coupled to a dust extraction and cleaning system

- limiting the drop heights if possible to a maximum of 0.5 m

- the use of water sprays (preferably using recycled water) for dust suppression

- where necessary, the fitting of storage bins with filter units to control dust

- the use of totally enclosed devices for reclamation from bins

- where necessary, the storage of scrap in covered, and hard surfaced areas to reduce the risk of ground contamination (using just in time delivery to minimise the size of the yard and hence emissions)

- minimisation of the disturbance of stockpiles

- restriction of the height and a controlling of the general shape of stockpiles

- the use of in-building or in-vessel storage, rather than external stockpiles, if the scale of storage is appropriate

- the creation of windbreaks by natural terrain, banks of earth or the planting of long grass and evergreen trees in open areas to capture and absorb dust without suffering long-term harm

- hydro-seeding of waste tips and slag heaps

- implementation of a greening of the site by covering unused areas with top soil and planting grass, shrubs and other ground covering vegetation

- the moistening of the surface using durable dust-binding substances

- the covering of the surface with tarpaulins or coating (e.g. latex) stockpiles

- the application of storage with retaining walls to reduce the exposed surface

- when necessary, a measure could be to include impermeable surfaces with concrete and drainage.

IV. Where fuel and raw materials are delivered by sea and dust releases could be significant, some techniques include:

- use by operators of self-discharge vessels or enclosed continuous unloaders.

Otherwise, dust generated by grab-type ship unloaders should be minimised through a combination of ensuring adequate moisture content of the material is delivered, by minimising drop heights and by using water sprays or fine water fogs at the mouth of the ship





#### unloader hopper

- avoiding seawater in spraying ores or fluxes as this results in a fouling of sinter plant electrostatic precipitators with sodium chloride. Additional chlorine input in the raw materials may also lead to rising emissions (e.g. of polychlorinated dibenzodioxins/furans (PCDD/F)) and hamper filter dust recirculation

- storage of powdered carbon, lime and calcium carbide in sealed silos and conveying them pneumatically or storing and transferring them in sealed bags.

V. Train or truck unloading techniques include:

- if necessary due to dust emission formation, use of dedicated unloading equipment with a generally enclosed design.

VI. For highly drift-sensitive materials which may lead to significant dust release, some techniques include:

- use of transfer points, vibrating screens, crushers, hoppers and the like, which may be totally enclosed and extracted to a bag filter plant

- use of central or local vacuum cleaning systems rather than washing down for the removal of spillage, since the effects are restricted to one medium and the recycling of spilt material is simplified.

VII. Techniques for the handling and processing of slag include:

- keeping stockpiles of slag granulate damp for slag handling and processing since dried blast furnace slag and steel slag can give rise to dust

- use of enclosed slag-crushing equipment fitted with efficient extraction of dust emissions and bag filters.

VIII. Techniques for handling scrap include:

- providing scrap storage under cover and/or on concrete floors to minimise dust liftoff caused by vehicle movements

IX. Techniques to consider during material transport include:

- the minimisation of points of access from public highways

- the employment of wheel-cleaning equipment to prevent the carryover of mud and dust onto public roads





- the application of hard surfaces to the transport roads by concrete or asphalt to minimise the generation of dust clouds during materials transport and the cleaning of roads
- the restriction of vehicles to designated routes by fences, ditches or banks of recycled slag
- the damping of dusty routes by water sprays, e.g. at slag-handling operations
- ensuring that transport vehicles are not overfull, so as to prevent any spillage
- ensuring that transport vehicles are sheeted to cover the material carried
- the minimisation of numbers of transfers
- use of closed or enclosed conveyors

- use of tubular conveyors, where possible, to minimise material losses by changes of direction across sites usually provided by the discharge of materials from one belt onto another

- good practice techniques for molten metal transfer and ladle handling

- dedusting of conveyor transfer points.

#### 4.1.4.2 Prevention of mercury emissions

\* BAT for the electric arc furnace (EAF) process is to prevent mercury emissions by avoiding, as much as possible, raw materials and auxiliaries which contain mercury (check "4.4 BATs on raw materials and fuel and energy" and "4.4.3 Adopted Bat conclusions")

The implementation of this BAT will be important in order to achieve afterwards the BATassociated emission level for mercury indicated in 4.1.4.3.

#### 4.1.4.3 Primary and secondary dedusting

\* BAT for the electric arc furnace (EAF) primary and secondary dedusting (including scrap preheating, charging, melting, tapping, ladle furnace and secondary metallurgy) is to achieve an efficient extraction of dust emissions from all emission sources by using one of the techniques listed below and to use subsequent dedusting by means of a bag filter:

I. a combination of direct off-gas extraction (4th or 2nd hole) and hood systems

II. direct gas extraction and doghouse systems

III. direct gas extraction and total building evacuation (low-capacity electric arc furnaces (EAF) may not require direct gas extraction to achieve the same extraction efficiency).





The overall average collection efficiency associated with BAT is >98 %.

The BAT-associated emission level for dust is <5 mg/Nm3, determined as a daily mean value.

The BAT-associated emission level for mercury is <0.05 mg/Nm3, determined as the average over the sampling period (spot measurement, for at least four hours).

\* BAT for the electric arc furnace (EAF) primary and secondary dedusting (including scrap preheating, charging, melting, tapping, ladle furnace and secondary metallurgy) is to prevent and reduce polychlorinated dibenzodioxins/furans (PCDD/F) and polychlorinated biphenyls (PCB) emissions by avoiding, as much as possible, raw materials which contain PCDD/F and PCB or their precursors and using one or a combination of the following techniques, in conjunction with an appropriate dust removal system:

I. appropriate post-combustion

Applicability of BAT I

In existing plants, circumstances like available space, given off-gas duct system, etc. need to be taken into consideration for assessing the applicability.

II. appropriate rapid quenching

III. injection of adequate adsorption agents into the duct before dedusting.

The BAT-associated emission level for polychlorinated dibenzodioxins/furans (PCDD/F) is <0.1 ng I-TEQ/Nm3, based on a 6 – 8 hour random sample during steady-state conditions. In some cases, the BAT-associated emission level can be achieved with primary measures only.

#### 4.1.4.4 Dust emissions from slag processing

\* BAT for on-site slag processing is to reduce dust emissions by using one or a combination of the following techniques:

I. efficient extraction of dust emissions from the slag crusher and use of screening devices with subsequent off-gas cleaning, if relevant

II transport of untreated slag by shovel loaders

III. extraction or wetting of conveyor transfer points for broken material

IV. wetting of slag storage heaps

V. use of water fogs when broken slag is loaded.

In the case of using BAT I, the BAT-associated emission level for dust is <10 - 20 mg/m3, determined as the average over the sampling period (spot measurement, for at least half an





hour).

## 4.4 BATS ON EMISSIONS TO WATER AND WASTEWATER

## 4.4.1 Treatment of waste water from continuous casting

#### Description

Water is used in continuous casting machines for direct cooling of the slabs, blooms and billets.

A contaminated process water flow is therefore generated. In many cases, this waste water is treated together with waste water streams from the hot rolling mills. After treatment, the water is recirculated.

The casting mould and the inner part of the rollers are usually cooled with water in a closed circuit and are not considered here.

The main pollutants are suspended solids and oil. The main measures to reduce discharges to water are a high rate of recirculation along with sedimentation and/or filtration of the bleed.

Skimming tanks can be used to remove oil.

The spray water is commonly precipitated by sand filtration prior to or after cooling in an evaporative cooling tower. Sand filtration helps to ensure low levels of particulate and oil contamination to achieve satisfactorily prolonged operation of the secondary spray nozzles of the casting machine. The bleed from the open circuit to control the level of dissolved solids should be taken from downstream of the sand filtration plant to minimise the discharge of suspended solids and any oil/grease contamination. To prevent the clogging of the sand filter, oil skimming should be installed before the sand filters.

#### Achieved environmental benefits

In Table 4.11 an example of the composition of waste water from direct cooling in the continuous casting process and hot rolling mill process is given.

 Table 4.11: Composition of the waste water flows from direct cooling at BSW, Kehl, Germany after waste water treatment (2008)





	Units	Continuous casting after sand filtration ( <sup>1</sup> )	Hot rolling mill after sand filtration ( <sup>1</sup> )	
Flow	m³/h	421	802	
Temperature	°C	39	30	
Suspended solids	mg/l	30.8	4.8	
TOC	mg/l	1.33	1.85	
AOX	mg/l	<0.01	< 0.01	
Fe	mg/l	0.053	<0.1	
Zinc	mg/l	<0.05	<0.05	
Ni	mg/l	<0.02	<0.02	
Copper	mg/l	<0.02	<0.02	
Mineral oil hydrocarbons (mg/l)	mg/l	<0.1	<0.1	
( <sup>1</sup> ) 24-hour random sample. Source: [178, N.N. 2008].				

#### Applicability

A high recirculation rate and a treatment of the bleed can be applied at both new and existing plants.

#### Example plants

BSW, Kehl, Germany

TSW, Trier, Germany

#### **Reference literature**

[178, N.N. 2008]

## 4.4.2 Closed loop water cooling system

#### Description

Generally, water is only used in the EAF steelmaking processes in connection with non-contact cooling, and only if a wet scrubbing technique for off-gas cleaning is used. As wet scrubbing is only applied in few cases, this topic is not further investigated in this section. The most relevant use of water considered here is the water used for the cooling of the elements of the furnace.

Additionally, some water may be used for the cooling of waste gas or in the secondary metallurgy step. The water needed for the cooling elements amounts to  $5 - 12 \text{ m}_3/\text{m}_2\text{h}$  [ 16,Rentz 1997 ].





#### Achieved environmental benefits

By application of this technique no discharge of waste water occurs.

#### **Cross-media effects**

The closed loop system requires additional energy for water pumping and water recooling.

#### Applicability

This technique can be applied at both new and existing plants.

#### Driving force for implementation

Legal requirements and limited availability of cooling water are the driving forces for the implementation of this technique.

#### **Example plants**

Preussag Stahl AG, Peine, Germany; BSW, Kehl, Germany and many other plants in the EU.

Almost all EU EAF plants use closed loop water cooling.

#### **Reference literature**

[ 16, Rentz 1997 ]

## 4.4.3 Adopted BAT conclusions

The following conclusions have been adopted :

\* BAT for waste water management is to prevent, collect and separate waste water types, maximising internal recycling and using an adequate treatment for each final flow. This includes techniques utilising, e.g. oil interceptors, filtration or sedimentation. In this context, the following techniques can be used where the prerequisites mentioned are present:

- avoiding the use of potable water for production lines

- increasing the number and/or capacity of water circulating systems when building new plants or modernising/revamping existing plants

- centralising the distribution of incoming fresh water
- using the water in cascades until single parameters reach their legal or technical limits

- using the water in other plants if only single parameters of the water are affected and further usage is possible

- keeping treated and untreated waste water separated; by this measure it is possible to dispose of waste water in different ways at a reasonable cost

- using rainwater whenever possible.





### Applicability

The water management in an integrated steelworks will primarily be constrained by the availability and quality of fresh water and local legal requirements. In existing plants the existing configuration of the water circuits may limit applicability.

\* BAT is to minimise the water consumption from the electric arc furnace (EAF) process by the use of closed loop water cooling systems for the cooling of furnace devices as much as possible unless once-through cooling systems are used.

\* BAT is to minimise the waste water discharge from continuous casting by using the following techniques in combination:

I. the removal of solids by flocculation, sedimentation and/or filtration

II. the removal of oil in skimming tanks or in any other effective device

III. the recirculation of cooling water and water from vacuum generation as much as possible.

The BAT-associated emission levels, for waste water from continuous casting machines, based on a qualified random sample or a 24-hour composite sample, are:

- suspended solids <20 mg/l</li>
- iron <5 mg/l
- zinc <2 mg/l
- nickel <0.5 mg/l
- total chromium <0.5 mg/l
- total hydrocarbons <5 mg/l</li>

## 4.5 BATS ON SOLID WASTE AND BY-PRODUCTS.

## 4.5.1 EAF dust processing for the recovery of heavy metals

#### Description

Depending on the type of steel produced, about 10 - 30 kg/t steel of dust are separated from the off-gas.





Separated dusts obtained by the gas cleaning facilities usually contain a significant share of heavy metals. In the case of carbon steel, essentially zinc and, to a lesser extent, lead are present

and in the case of stainless steel, substantial amounts of chromium and nickel are present apart from zinc.

Processes for zinc recovery and recovery or removal of other heavy metals are suitable options for reclaiming valuable resources that have already been mined and treated at least once.

Pyrometallurgical and hydrometallurgical options exist for the recovery of zinc, in principle. For dusts from the production of carbon/low alloyed steel, different techniques exist and are operated mostly by companies that have close links to the non-ferrous metals production sector.

For the recovery of EAF dusts it is desirable to have high concentration levels of heavy metals to operate economically. In order to increase the zinc content of their dust, some EAF operators recycle part of the generated dust back into the furnace.

#### Achieved environmental benefits

These heavy metals are toxic and might be leachable, necessitating special care for further processing and possibly the landfilling of the dusts.

Quantitative recovery of dust and the recycling of heavy metals can be achieved. The options described are desirable to different degrees according to their potential to satisfy the aim of prevention and control of environmental pollution. The use of the iron and heavy metal content of the dust is preferred compared to landfilling.

#### Cross-media effects

The recycling of precipitated EAF dusts for zinc enrichment by returning them to the EAF results in certain impacts on the steelmaking process, such as increased energy consumption.

Also the method of dust addition to the furnace might affect the performance of the furnace.

In the case of pelletisation of the dust before transport/recycling, additional energy is needed since pelletisation and additional dust emissions may occur.

#### Applicability

This technique is applicable to both new and existing plants.

#### Driving force for implementation

The main driving forces for the implementation of this technique are limited space for landfilling, stringent standards for landfilling and cost aspects like taxes on landfilled wastes.

#### **Example plants**

There are many plants in the EU that have examples of dust recovery to external plants.





One example is the EAF Marienhütte, Graz, Austria where about 6.9 tonnes of dust per year arise from waste gas treatment of the EAF. The dust with a zinc content of about 38 % is treated externally in order to recover the zinc.

#### Reference literature

[ 16, Rentz 1997 ] [ 69, Kemeny 1994 ] [ 116, Rentz et al. 1996 ] [ 373, Eurofer 2007 ] [ 391, Tavernier et al. 2004 ] [ 394, Colletta et al. 2002]

## 4.5.2 EAF slag processing

#### Description

In an EAF operation, some 60 – 270 kg of slag per tonne of steel are generated according to a tight specification, with the aim of performing metallurgical work. Solidified EAF slag from carbon steel production can be regarded as an artificial rock, similar to natural rock, consisting of iron oxides (FeO), lime (CaO), silicon dioxide (SiO<sub>2</sub>), and other oxides (MgO, Al<sub>2</sub>O<sub>3</sub>, MnO). EAF slags are characterised by high strength, good weathering resistance, and also high resistance against abrasion. They also have properties that make them suitable for use in hydraulic engineering [ 57, Heinen 1997 ]. An important criterion for the use of EAF slag in general is the consistency in volume, which depends on the presence of free lime.

Most of the slags from low carbon steel grades are relatively low in free lime and are suitable for various applications like road construction, earthfill and hydraulic engineering. EAF slags from carbon steel production typically meet the specifications of aggregates used in construction. The deciding factors with respect to these uses are environmental acceptability and structural suitability. If the required legal conditions for use in construction are met, the EAF slag should be crushed, screened, and sized for use. Ferrous slag components are separated via magnetic separators. The treated slag is used in various construction purposes, also dependent on the grain size. Figure 4.6 shows a processing scheme for a German plant for slag preparation. In 1994, about 90 % of EAF slags generated by the production of non-alloyed and medium-alloyed steel in certain EAFs were used [ 57, Heinen 1997 ].

Slags arising at high grade steel production are only used to a limited extent, so far. Possible uses may be also in road construction, after a preparation treatment.

E.g., at Böhler Edelstahl, Kapfenberg, Austria about 270 kg slag arise per tonne steel produced.

This EAF slag is not considered suitable for the construction industry due to the slag composition and properties (e.g. expansion of the slag). Most of the slag arises from the EAF (approximately 70 %) and the secondary metallurgy (approximately 30 %). The previously mentioned slags are disposed of at the internal landfill site.

Nevertheless, there are also examples where parts or even the total amount of stainless steel slag is used as a construction material in particular in cases of lower structurally engineered requirements (e.g. noise protection berm).





Recyclability of slags from high alloy steel or stainless steel production should either require better assessment or some special treatment depending on the properties of such slag (e.g. expansivity).

Options for using the wide spectrum of secondary metallurgy slags are limited. Grain size and expansion coefficients are decisive factors for the use of secondary metallurgy slags. They sometimes may be used in the construction area. But a significant share of the arising slags has to be landfilled, as hardly any options for prevention, reduction, or utilisation exist.



Figure 4.6: Processing scheme of a plant for slag preparation

Source: [ 16, Rentz 1997 ]

#### Achieved environmental benefits





Slags from EAF that produce carbon or low alloyed steel can be treated with subsequent recycling in road construction.

#### Cross-media effects

The treatment of slags requires energy. Attention should be paid to alkaline fumes when the slag contains free CaO.

#### Applicability

This technique is applicable both to new and existing carbon steel plants. Further processing may procure a better suitability for use as construction material.

#### Driving force for implementation

The main driving forces are limited space for landfilling and cost aspects like taxes on landfilled wastes.

#### **Example plants**

BSW, Kehl, Germany (treatment of slag with subsequent use for construction purposes).

Georgsmarienhütte GmbH, Georgsmarienhütte, Germany (selling of slag for external preparation with subsequent use in road construction; slag from EAF and secondary metallurgy are mixed); Salzgitter Stahl AG, Peine, Germany (treatment and use in the construction sector) ArcelorMittal in Schifflange, Differdange and Belval, all in Luxembourg (high-performance road surfacing, hydraulic engineering and other applications).

#### **Reference literature**

[ 16, Rentz 1997 ] [ 277, Wiesenberger 2007 ] [ 373, Eurofer 2007 ]

## 4.5.3 Treatment of high alloyed and stainless steel EAF slags

#### Description

Some techniques for slag treatment are given below:

a) the treatment of liquid slag during tapping with residues which contain Al<sub>2</sub>O<sub>3</sub>.

b) the reduction of the slag during tapping with aluminium

c) optimisation of oxygen blowing and use of some reduction agents

d) prevention of dust formation when emptying slag pots. The highly basic slag from stainless steel plants contains Ca<sub>2</sub>S, which undergoes a phase transformation during cooling. The transformation includes a certain increase in volume. By quenching the slag, the phase transformation can be suppressed and no dusting will occur. At Sandvik Materials Technology, Sandviken, Sweden, the problem with dust formation has been solved by emptying slag pots filled with hot and partially liquid slag into a box surrounded by a retaining dike. Then 12 m<sub>3</sub> of water is flooded over the slag. The quick drop in temperature together with the binding of





small particles with water has proven to eliminate the spreading of dust over large areas. The water itself is recirculated via a basin.

e) techniques for stainless steel slag are:

\_ the stabilisation of the slag by the use of a stabilising agent to prevent pulverisation

\_ the control of the slag composition

\_ the minimisation of the leaching of chromium from slag materials, nearly no Cr occurs in the eluate (Cr below the detection limit value of 0.01 mg/l)

\_ control of the slag cooling

\_ metal separation by crushing, screening, gravity and magnetic separation.

#### Achieved environmental benefits

These techniques can improve the properties of EAF slags by fixing the chromium in a stable slag lattice and can reduce the content of Cr in the eluate.

For technique d) according to estimations from the early implementation of the technique, the dusting was reduced by more than 90 %. Since only the slag from the pot from the teeming ladle is not processed in an optimal way, the reduction in dusting is probably close to 100 %.

As a measuring index of the dusting problem, the numbers of cars or boats around the plant that have to be cleaned have been used. In 2002, 80 cars and boats had to be cleaned in total. With the new technique of 2004, no cars or boats were affected by dust from the emptying of slag pots. The results so far have been outstanding in terms of environmental and goodwill aspects.

For technique e) the dusting efforts at the dumping station and slag yard can be reduced, the amount of waste is significantly reduced and natural resource can be saved.

#### Cross-media effects

For technique d) the amount of recirculated water is increased.

For technique e) additional stabilisation agents are needed in the process.

#### Applicability

For technique d) the described technique can be used whenever the slag is hot enough to not yet have undergone the dust forming phase transformation (i.e. it is used for all slag pots, EAF and AOD, except for the one in which the remaining ladle slag from the continuous caster is emptied). All in all, 90 % of the produced slag is processed using the described technique.

Pots with slag from the teeming ladle are put into watering equipment, i.e. the pots are filled with water and are then left until they are cooled down and the slag is soaking wet.

Technique e) can be applied at both new and existing plants.

#### Driving force for implementation





With technique e) the energy consumption and the whole environmental impact can be reduced.

Due to an efficient material flow there is a low bloom stock level and an increased productivity.

#### Example plants

Technique d): Sandvik Materials Technology, Sandviken, Sweden

Technique e): Outokumpu Stainless Tornio Works, Tornio, Finland.

#### **Reference literature**

[ 208, Lindfors et al. 2006 ] [ 245, Kuhn et al. 2004 ]

## 4.5.4 Adopted BAT conclusions

The requirements adopted by the Council Regulation 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste (see Annex 3) will also be considered BAT conclusions on by-products.

The following conclusions have been adopted :

\* BAT for solid residues is to use integrated techniques and operational techniques for waste minimisation by internal use or on-site recycling.

Description

Techniques for the on-site recycling of iron-rich residues include specialised recycling techniques such as the OxyCup<sup>®</sup> shaft furnace, the DK process, smelting reduction processes or cold bonded pelletting/briquetting as well as techniques for production residues.

\* BAT is to maximise external use or recycling for solid residues which cannot be used or recycled on-site wherever this is possible. BAT is to manage in a controlled manner residues which can neither be avoided nor recycled.

#### Description

Techniques for the external recycling of iron-rich residues include specialised recycling techniques such as the OxyCup<sup>®</sup> shaft furnace, the DK process, smelting reduction processes or cold bonded pelletting/briquetting as well as process specific techniques.

\* BAT is to use the best operational and maintenance practices for the collection, handling, storage and transport of all solid residues and for the hooding of transfer points to avoid





emissions to air and water.

\* BAT is to prevent waste generation by using one or a combination of the following techniques:

I. appropriate collection and storage to facilitate a specific treatment

II. recovery and on-site recycling of refractory materials from the different processes and use internally, i.e. for the substitution of dolomite, magnesite and lime

III. use of filter dusts for the external recovery of non-ferrous metals such as zinc in the non-ferrous metals industry, if necessary, after the enrichment of filter dusts by recirculation to the electric arc furnace (EAF)

IV. separation of scale from continuous casting in the water treatment process and recovery with subsequent recycling, e.g. in the sinter/blast furnace or cement industry

V. external use of refractory materials and slag from the electric arc furnace (EAF) process as a secondary raw material where market conditions allow for it.

\* BAT is to manage in a controlled manner EAF process residues which can neither be avoided nor recycled.

# 4.6 BATS ON RAW MATERIALS AND FUEL AND ENERGY CONSUMPTION

## 4.6.1 Scrap preheating

#### Description

The utilisation of the sensible heat in the off-gas (approximately 140 kWh/t LS) has developed in the last 40 years and is today a proven tool in reducing the total energy requirements in the EAF operations. One option is to use the sensible heat for scrap preheating. The scrap can be preheated to approximately 800 - 1000 °C with discontinuous systems and to 300 - 400 °C with continuous systems prior to the EAF melting process which reduces the total energy consumption by up to 100 kWh/t LS.

Such preheating is performed either in the scrap charging baskets or in a charging shaft (shaft furnace) added to the EAF or in a specially designed scrap conveying system allowing continuous charging during the melting process. In some cases, even additional fossil energy is added in the preheating process [ 373, Eurofer 2007 ].




The **shaft technology** has been developed in steps. In 1988, Fuchs Systemtechnik GmbH, now SIEMENS VAI Metals Technologies, started a development to overcome the shortfalls of the scrap bucket preheaters and opted for direct charging of the scrap into a shaft that was positioned on the roof of the EAF (see Figure 4.7.a). With the single shaft furnace 100 % of the scrap can be preheated [ 125, Smith 1992 ].

A further modification is the double shaft furnace which consists of two identical shaft furnaces (twin shell arrangement) which are positioned next to each other and are serviced by a single set of electrode arms. The scrap is partly preheated by off-gas and partly by side wall burners.

A very efficient shaft furnace design is the finger shaft furnace. The finger shaft design uses a unique scrap retaining system with fingers which allows the preheating of 100 % of the scrap amount [ 162, Voss-Spilker et al. 1996 ]. The first basket is preheated during the refining of the previous heat and the second during the melting down of the first one. In 1994, the first finger shaft furnace started up at Hylsa in Monterrey, Mexico. Through the utilisation of the furnace off-gas during the heat cycle, scrap can be preheated to a temperature of approximately 1000 °C prior to the final melting in the furnace vessel. This means considerable energy and cost savings with a substantial reduction in tap-to-tap times. The 4th generation of Siemens VAI preheating Shaft technology were installed in January 2008 in Stahl Gerlafingen with an more efficient charging system into the shaft in addition to improved scrap preheating. The average additional energy savings for this system are in the range of 10 kWh per tonne of LS.

All occurring emissions from the scrap preheating systems can be combusted in a separate downstream combustion chamber.

Since the year 2000, **continuous scrap preheating** and feeding became very popular, e.g. **CONSTEEL** (see Figure 4.7.b) [ 84, Grasselli, A. and Raggio, C. 2008 ]. The scrap is charged by cranes on a special conveyor belt. In the preheating section the charge receives heat from the off-gases leaving the furnace. The scrap flow is adjusted to the power input of the EAF. The charge is melted by immersion in a molten pool, heated by the energy coming from the electric arcs and from the chemical reactions taking place in the melt, in contrast to conventional topcharge EAF where the melting is provided by direct heat transfer from the electric arc. The bath is always covered by a foaming slag which is constantly promoted by controlled carbon and oxygen injection.

Another recently developed continuous feeding scrap preheating process is the COSS technology (see Table 4.13) [ 364, Fuchs, G. 2008 ]. The Continuous Optimized Shaft System (COSS) capitalizes on the advantages of the CONSTEEL process (flat bath operation, improved power input at the beginning of the heat, low noise, smaller transformer power, less flicker control requirements and short power off times), as well as the higher scrap preheating efficiency of the shaft furnace. The EAF of the COSS system can operate with or without the shaft, which is connected to the EAF by means of a removable car. Scrap can be charged into the shaft without interrupting the power input. Less maintenance cost as compared to the CS and FS. The short power off time, the high energy input due to the flat bath operation and the





much higher scrap preheating temperatures compared to the Shaft Furnace Systems and CONSTEEL guarantee very low conversion cost figures and higher productivity.



Figure 4.7.a: Schematic of a Fuchs shaft scrap preheating system. *Source*: [Electric Power Research Institute, 1997]



Figure 4.7.b: Schematic of the CONSTEEL process *Source:* [ 84, Grasselli, A. and Raggio, C. 2008 ]

#### Achieved environmental benefits





With shaft furnaces, very high scrap preheating temperatures of up to 800 - 1000 °C can be achieved. With the described techniques for scrap preheating 70 - 100 kWh/t LS energy can be saved which is about 10 - 25 % of the overall electricity input. Calculated on the basis of primary energy, the savings might be higher considering the efficiency of energy supply. In addition, the two scrap preheating solutions reduce the tap-to-tap time since less electric energy needs to be put into the charge and downtime for batch charging is reduced.

In combination with an advanced off-gas treatment, scrap preheating plays a significant role in the optimisation of EAF steelmaking, not only related to productivity but also to the minimisation of emissions.

As a side effect, scrap preheating reduces raw dust emissions by about 20 % because the offgas has to pass through the scrap which acts as a filter. This reduction correlates with an increase in the zinc content in the dust which supports its recycling.

With the continuous feeding systems, the scrap can be heated up to an average temperature of 300 °C, thus the efficiency of the furnace is increased and energy consumption is reduced. But the continuous feeding has some additional advantages including lower noise emissions.

All CO and H<sub>2</sub> are considered to have evolved from the melting process and are burnt to CO<sub>2</sub> and H<sub>2</sub>O inside the preheater. The continuity of the process allows for achieving a stable offgas exit temperature between 800 and 1100 °C, with an oxygen excess of 8 – 10 %, which allows for the complete destruction of PCDD/F. Provided that the off-gases are rapidly cooled below 200 to 250 °C, the risk of PCDD/F formation by de novo synthesis is considerably reduced.

Nevertheless, experiences from at least two continuous charging installations showed a high emissions concentrations for PCDD/F exceeding the value of 0.1 ng I-TEQ/Nm<sub>3</sub> significantly [ 67, TSW GmbH 2005 ]. That means that additional measures for reducing PCDD/F to ensure emissions concentrations for PCDD/F below 0.1 ng I-TEQ/Nm<sub>3</sub> may be necessary also for continuous charging techniques from case to case. Table 4.12 shows the measurement results of a continuous pollution measurement from one installation for an eight year operating period.

Parameter	Units	1999 – 2007			
Off-gas flow	Nm <sub>3</sub> /h	750000-800000			
СО	mg/Nm₃	142-400			
NOx	mg/Nm₃	5-50			
PCDD/F	Ng I TEQ/Nm3	0.05 – 0.20			
Dust (PM10)	mg/Nm₃	0.40 - 0.86			
Source: [ 84, Grasselli, A. and Raggio, C. 2008 ].					





At the EAF Mo i Rana in 2008, a CONSTEEL furnace has been realised. To reduce the emissions of dust, dioxins and mercury downstream of the bag filter, a carbon filter has been installed. Measurements carried out both before and after the application of the Consteel furnace show that the dioxins and mercury have been reduced by more than 90 %.

#### Cross-media effects

Scrap preheating looks very attractive from the point of view of energy management. But the scrap preheating may lead to an important generation of organic pollutants due to the possible presence of organic substances on the scrap. Due to the process-specific low temperatures in the scrap column, the organic constituents adhering to the scrap, such as oils and greases, are only evaporated off but not thermally destroyed; one result here being the formation of volatile organic chlorinated hydrocarbon compounds and the precursor of PCDD/F [ 367, Prüm et al. 2005 ].

As mentioned before, high emissions of aromatic organohalogen compounds such as polychlorinated dibenzo-p-dioxins and -furans (PCDD/F), chlorobenzenes, polychlorinated biphenyls (PCB) as well as polycyclic aromatic hydrocarbons (PAH) and other partial combustion products may occur from scrap contaminated with paints, plastics, lubricants or other organic compounds. In one EAF with conventional scrap preheating, up to 9.2 ng ITEQ/ Nm<sub>3</sub> have been measured.

These emissions can be minimised by post-combustion of the off-gas in a specially designed post-combustion chamber equipped with fossil fuel burners. Due to the high temperature to be reached in order to destroy the POPs (persistent organic pollutants) that are present in the offgas, the amount of energy required is considerable and of the order of magnitude of the energy savings provided by scrap preheating.

#### **Operational data**

Since its start-up, no CONSTEEL furnace has been stopped. The following table shows some operational data for selected scrap preheating systems applied to EAF furnaces.

Features	Unit	Consteel Plant 1	Consteel Plant 2	Constee Plant 3	I	Fuchs- Coss Plant	SIMET Finger Plant 1	AL Shaft L	SIMETAL Finger Shaft Plant 2	
Furnace type		DC	AC	AC			AC		DC	
Heat size	t LS	109	187	73		120	126,5		80	
Transformer power	MVA	90	130	50		100	85		56	
Metallic charge mix		100 % scrap	80 % scrap 15 % pig iron	80 % scrap 20 % pig iron	80 % scrap 20 % hot metal	100 % scrap (1)	100 % scrap	80 % scrap 20 % pig iron	100 scrap	%
Tapping	°C	1650	1630	1600		NA	1620	1673	1630	

Table 4.13: Process data from selected scrap preheating systems applied to EAF furnaces





temperature									
Average	MW	55	82	37	33	NA	57	63	35
power									
Additives	kg/t LS	26	32	41	60	58	50	48	NA
Power on time	min	41	50	43	35	40	40	30	38
Power off time	min	8	15	7	7	NA	10	17	12
Electrical consumption	kWh/t LS	343	365	362	265	300	300	248	278
Oxygen consumption	Nm₃/t LS	35.5	33	34	35	38	34	37	44
Electrode	kg/t	0,8	0,9	1,4	1,2	1,2	1,3	1,1	0,8
consumption	LS								
Scrap preheating efficiency									
Scrap	°C	200 – 300	200 - 300 300 - 800 - 1000						
temperature						400			
after									
preheating									
Scrap	kWh/t	15				NA	80 - 10	00	
preheating	LS								
efficiency									
(1) Can be theoretically achieved. The Coss plant in operation is applying 60 % scrap and 40 % hot metal.									
NB: NA = Data not available.									
Source: [ 58, Kaestli, P. 2009 ] [ 84, Grasselli, A. and Raggio, C. 2008 ] [ 364, Fuchs, G. 2008 ].									

#### Applicability

The CONSTEEL process is applicable to both new and existing plants. In existing plants, the local conditions related to the space availability and limitations for the conveyor installation and the scrapyard positioning have to be considered which may sometimes prevent the installation of such a technique. Scrap preheating systems do not require specially sized scrap more than the conventional EAF. The scrapyard groundwork is equivalent compared to the buckets-operating furnaces.

#### Economics

With finger shaft EAFs, tap-to-tap times of about 35 minutes are achieved which is about 10 – 15 minutes shorter compared with EAF without efficient scrap preheating. This allows for a very short payback time which is in the order of one year.

As an example, for a new steelmaking plant, producing about one million tonnes per year, the Consteel implementation usually represents about 10-15 % of the total investment.

The cost of a revamping is in a range of EUR 5 million -10 million and varies a lot according to the size of the furnace, layout and to the extent of the required modifications.

The overall cost savings achievable with the CONSTEEL process for a melt shop of one million tonnes per year productivity is around EUR 9.5 per tonne LS.

#### Driving force for implementation





The main driving force is to increase productivity, to reach a higher charge yield and lower conversion costs combined with a lower environmental impact. In some cases, scrap preheating by means of a finger shaft furnace has been installed in combination with advanced off-gas treatment.

Another main driver is the reduction in electrical disturbances in plants where the electrical power supply network is an issue.

#### **Example plants**

- Twin-shell shaft furnace with integrated preheating in a shaft: ASW, Montereau, France
- Two-finger shaft furnaces and one shaft furnace, Zhangjiagang, P. R. China
- Three-finger shaft furnaces Severstal AG, Russia
- Two-finger shaft furnaces Habas, Aliaga, Turkey
- Finger shaft furnace, Stahl Gerlafingen, Switzerland
- Finger shaft furnace, SUEZ Steel, Egypt
- CONSTEEL at TSW, Trier, Germany
- CONSTEEL at Celsa Mo i Rana, Norway
- CONSTEEL at ORI Martin, Brescia, Italy
- CONSTEEL at Acciaierie Arvedi, Cremona, Italy
- CONSTEEL at Sovel Hellenic Steel Company, Greece.

In January 2009, 31 shaft furnaces and 35 continuously operating CONSTEEL systems were installed worldwide, including those installations under construction.

Figure 4.8 shows the numbers of installed shaft, CONSTEEL and ESC furnaces between 1988 and 2009.







#### Figure 4.8: Number of preheating installations at EAF

Source: [ 364, Fuchs, G. 2008 ]

#### **Reference literature**

[ 54, Haissig 1997 ] [ 84, Grasselli, A. and Raggio, C. 2008 ] [ 91, Memoli, F. and Ferri, M. 2007 ]
[ 94, Mc Manus 1995 ] [ 125, Smith 1992 ] [ 162, Voss-Spilker et al. 1996 ] [ 208, Lindfors et al.
2006 ] [ 260, Germany 2007 ] [ 273, Eurofer 2007 ] [ 287, MVAE 2005 ] [ 364, Fuchs, G. 2008 ] [
367, Prüm et al. 2005 ] [ 373, Eurofer 2007 ] [ 388, Fisher et al. 2005 ]

## 4.6.2 Near net shape strip casting

The techniques for continuous near net shape strip casting for electric arc steelmaking are similar to those described in Best Available Techniques (BAT) Reference Document

for Iron and Steel Production (7.3.11) for basic oxygen steelmaking.

## 4.6.3 Adopted BAT conclusions

The following conclusions have been adopted :

```
* BAT is to reduce thermal energy consumption by using a combination of the following techniques:
```





I. improved and optimised systems to achieve a smooth and stable processing, operating close to the process parameter set points by using

i. process control optimisation including computer-based automatic control systems

ii. modern, gravimetric solid fuel feed systems

iii. preheating, to the greatest extent possible, considering the existing process configuration.

II. recovering excess heat from processes, especially from their cooling zones

III. an optimised steam and heat management

IV. applying process integrated reuse of sensible heat as much as possible.

Description of BAT I.i

The following items are important for integrated steelworks in order to improve the overall energy efficiency:

• optimising energy consumption.

• online monitoring for the most important energy flows and combustion processes at the site including the monitoring for all gas flares in order to prevent energy losses, enable instant maintenance and achieving an undisrupted production process

• reporting and analysing tools to check the average energy consumption of each process

• defining specific energy consumption levels for relevant processes and comparing them on a long-term basis

• identifying cost-effective energy savings opportunities by carrying out energy audits as defined in the Energy Efficiency BREF.

Description of BAT II – IV

Process integrated techniques used to improve energy efficiency in steel manufacturing by improved heat recovery include:

• combined heat and power production with recovery of waste heat by heat exchangers and distribution either to other parts of the steelworks or to a district heating network

• the installation of steam boilers or adequate systems in large reheating furnaces (furnaces can cover a part of the steam demand)

• preheating of the combustion air in furnaces and other burning systems to save fuel, taking into consideration adverse effects, i.e. an increase of nitrogen oxides in the off-gas

• the insulation of steam pipes and hot water pipes

• recovery of heat from products, e.g. sinter





- where steel needs to be cooled, the use of both heat pumps and solar panels
- the use of flue-gas boilers in furnaces with high temperatures
- the oxygen evaporation and compressor cooling to exchange energy across standard heat exchangers
- the use of top recovery turbines to convert the kinetic energy of the gas produced in the blast furnace into electric power.

Applicability of BAT II – IV

Combined heat and power generation is applicable for all iron and steel plants close to urban areas with a suitable heat demand.

\* BAT is to reduce primary energy consumption by optimisation of energy flows and optimised utilisation of the extracted process gases such as coke oven gas, blast furnace gas and basic oxygen gas.

#### Description

Process integrated techniques to improve energy efficiency in an integrated steelworks by optimising process gas utilisation include:

• the use of gas holders for all by-product gases or other adequate systems for shortterm storage and pressure holding facilities

- increasing pressure in the gas grid if there are energy losses in the flares in order to utilise more process gases with the resulting increase in the utilisation rate
- gas enrichment with process gases and different caloric values for different

consumers

- reheating fire furnaces with process gas
- use of a computer-controlled caloric value control system
- recording and using coke and flue-gas temperatures

• adequate dimensioning of the capacity of the energy recovery installations for the process gases, in particular with regard to the variability of process gases.

\* BAT is to use desulphurised and dedusted surplus coke oven gas and dedusted blast furnace gas and basic oxygen gas (mixed or separate) in boilers or in combined heat and power plants to generate steam, electricity and/or heat using surplus waste heat for internal or external heating networks, if there is a demand from a third party (Note: the cooperation and agreement of a third party may not be within the control of the operator, and therefore may





not be within the scope of the permit).

\* BAT is to minimise electrical energy consumption by using one or a combination of the following techniques:

I. power management systems

II. grinding, pumping, ventilation and conveying equipment and other electricity-based equipment with high energy efficiency.

#### Applicability

Frequency controlled pumps cannot be used where the reliability of the pumps is of essential importance for the safety of the process.

\* BAT is to optimise the management and control of internal material flows in order to prevent pollution, prevent deterioration, provide adequate input quality, allow reuse and recycling and to improve the process efficiency and optimisation of the metal yield.

#### Description

Appropriate storage and handling of input materials and production residues can help to minimise the airborne dust emissions from stockyards and conveyor belts, including transfer points and avoid soil, groundwater and runoff water pollution.

The application of an adequate management of integrated steelworks and residues, including wastes, from other installations and sectors allows for a maximised internal and/or external use as raw materials.

Material management includes the controlled disposal of small parts of the overall quantity of residues from an integrated steelworks which have no economic use.

\* In order to achieve low emission levels for relevant pollutants, BAT is to select appropriate scrap qualities and other raw materials<sup>1</sup>. Regarding scrap, BAT is to undertake an appropriate inspection for visible contaminants which might contain heavy metals, in particular mercury, or might lead to the formation of polychlorinated dibenzodioxins/furans (PCDD/F) and polychlorinated biphenyls (PCB). (Note: The selection of scrap might not be entirely within the control of the operator.)

To improve the use of scrap, the following techniques can be used individually or in combination:

• specification of acceptance criteria suited to the production profile in purchase orders of

<sup>&</sup>lt;sup>1</sup> From the experience of the Spanish implementation of IPPC and BATs for this sector, this BAT is very important to achieve the emission levels stated within this chapter.





#### scrap

• having a good knowledge of scrap composition by closely monitoring the origin of the scrap; in exceptional cases, a melt test might help characterise the composition of the scrap

- having adequate reception facilities and check deliveries
- having procedures to exclude scrap that is not suitable for use in the installation

• storing the scrap according to different criteria (e.g. size, alloys, degree of cleanliness); storing of scrap with potential release of contaminants to the soil on impermeable surfaces with drainage and collection system; using a roof which can reduce the need for such a system

• putting together the scrap load for the different melts taking into account the knowledge of composition in order to use the most suitable scrap for the steel grade to be produced (this is essential in some cases to avoid the presence of undesired elements and in other cases to take advantage of alloy elements which are present in the scrap and needed for the steel grade to be produced)

- prompt return of all internally-generated scrap to the scrapyard for recycling
- having an operation and management plan

• scrap sorting to minimise the risk of including hazardous or non-ferrous contaminants, particularly polychlorinated biphenyls (PCB) and oil or grease. This is normally done by the scrap supplier but the operator inspects all scrap loads in sealed containers for safety reasons. Therefore, at the same time, it is possible to check, as far as practicable, for contaminants. Evaluation of the small quantities of plastic (e.g. as plastic coated components) may be required

• radioactivity control according to the United Nations Economic Commission for Europe (UNECE) Expert Group framework of recommendations

• The implementation of the mandatory removal of components which contain mercury from End-of-Life Vehicles and Waste Electrical and Electronic Equipment (WEEE) by the scrap processors can be improved by:

o fixing the absence of mercury in scrap purchase contracts

o refusal of scrap which contains visible electronic components and assemblies.

\* BAT is to reduce energy consumption by using continuous near net shape strip casting, if the quality and the product mix of the produced steel grades justify it.

#### Description

Near net shape strip casting means the continuous casting of steel to strips with thicknesses of less than 15 mm. The casting process is combined with the direct hot rolling, cooling and coiling of the strips without an intermediate reheating furnace used for conventional casting





techniques, e.g. continuous casting of slabs or thin slabs.

Therefore, strip casting represents a technique for producing flat steel strips of different widths and thicknesses of less than 2 mm.

Applicability

The applicability depends on the produced steel grades (e.g. heavy plates cannot be produced with this process) and on the product portfolio (product mix) of the individual steel plant.

Retrofitting existing plants with strip caster requires approximately 100 m in length.

## 4.7 BATS ON NOISE AND VIBRATIONS

## 4.7.1 Techniques to prevent noise emissions

#### Description

Some constructional and operational techniques applied to prevent noise emissions include the following:

- to restrict some noisy activities at night (e.g. scrap yard, scrap transport to the installations)

- to organise special noise reducing information and training for the crane operators

- to continuously monitor the noise in the scrap yard

- to construct the EAF building in such a way as to absorb noise from mechanical shocks resulting from the operation of the furnace

- to construct and install cranes destined to transport the charging baskets to prevent mechanical shocks

- to create special acoustical insulation of the inside walls and roofs to prevent the airborne noise of the EAF building

- to separate the furnace and the outside wall to reduce the structure-borne noise from the EAF building

- to construct physical barriers

- to reduce the free fall height of the scrap in order to reduce noise and dust emissions at the discharge of scrap metal

- to enclose the scrap stock piles

- to continuously scrap feed and melt.

Noise reduction measures at the dedusting system:





The new dedusting system had to fulfil high noise reduction requirements. Examples of this technique include the following:

- installation of fans with noise-insulation
- additional capture of fans in reinforced concrete chambers
- installation of noise absorbing sandwich elements at the new filter house
- exchange of the profiled sheeting of the existing filter house by sandwich elements
- definition of maximum noise levels for the individual plant units.
- noise-reducing measures at the existing dust filter.

#### Achieved environmental benefits

With the techniques described above, values between 37 and 50 dB(A) Leq(1h) can be achieved.

Measurements at 150 m from the EAF building are below 34 dB(A) Leq<sub>(1h)</sub>.

With continuous scrap feeding and melting systems such as CONSTEEL, the noise level can be reduced.

#### **Operational data**

Some examples of insulation parameters used in the EAF building are materials with an  $R'_w$  of 56 dB for the walls and 55 dB for the roof (values according to DIN 55210 Part 3).

#### Applicability

These techniques are applicable to all EAF type plants.

#### Driving force for implementation

The driving force for implementation is the prevention of noise emissions in the neighbouring area of the plant. Plants located close to residential areas tend to have implemented techniques to prevent noise.

#### Example plants

Arbed Esch-Belval, Luxembourg

Feralpi, Riesa, Germany.

#### **Reference literature**

[ 83, Ehrlich, C. et al 2007 ] [ 260, Germany 2007 ] [ 280, Aguado-Monsonet 2007 ] [ 355, Plickert 2007 ] [ 364, Fuchs, G. 2008 ] [ 366, Dornseiffer et al. 2007 ]

## 4.7.2 Adopted BAT conclusions

The following conclusions have been adopted :

\* BAT is to reduce noise emissions from relevant sources in the iron and steel manufacturing





processes by using one or more of the following techniques depending on and according to local conditions:

- implementation of a noise-reduction strategy
- enclosure of the noisy operations/units
- vibration insulation of operations/units
- internal and external lining made of impact-absorbent material
- soundproofing buildings to shelter any noisy operations involving material transformation equipment

• building noise protection walls, e.g. the construction of buildings or natural barriers, such as growing trees and bushes between the protected area and the noisy activity

- outlet silencers to exhaust stacks
- lagging ducts and final blowers which are situated in soundproof buildings
- closing doors and windows of covered areas.

\* BAT is to reduce noise emissions from electric arc furnace (EAF) installations and processes generating high sound energies by using a combination of the following constructional and operational techniques depending on and according to local conditions:

I. construct the electric arc furnace (EAF) building in such a way as to absorb noise from mechanical shocks resulting from the operation of the furnace

II. construct and install cranes destined to transport the charging baskets to prevent mechanical shocks

III. special use of acoustical insulation of the inside walls and roofs to prevent the airborne noise of the electric arc furnace (EAF) building

IV. separation of the furnace and the outside wall to reduce the structure-borne noise from the electric arc furnace (EAF) building

V. housing of processes generating high sound energies (i.e. electric arc furnace (EAF) and decarburisation units) within the main building.





## 4.8 BATS ON SOIL AND GROUNDWATER POLLUTION PREVENTION

The requirements established in the By-Law 27533 on landfilling of wastes and Directive 2008/98/EC of the European Parliament and of the Council (on waste), currently being transposed through a new By-Law, will also be considered BAT conclusions on waste storage and landfilling conditions.

# 4.9 BAT CONCLUSIONS ON ENVIRONMENTAL MANAGEMENT AND MONITORING

The following conclusions have been adopted :

\* BAT is to implement and adhere to an environmental management system (EMS) that incorporates the following features:

I. commitment of top management ;

II. definition of an environmental policy that includes continuous improvement for the installation by top management;

III. planning and establishing the necessary procedures, objectives and targets, in conjunction with financial planning and investment;

IV. implementation of the procedures paying particular attention to:

i. structure and responsibility

ii. training, awareness and competence

iii. communication

iv. employee involvement

v. documentation

vi. efficient process control

vii. maintenance programme

viii. emergency preparedness and response

ix. safeguarding compliance with environmental legislation;

V. checking performance and taking corrective action, paying particular attention to:

i. monitoring and measurement (see also the Reference Document on the General

Principles of Monitoring)





ii. corrective and preventive action

iii. maintenance of records

iv. independent (where practicable) internal and external auditing in order to determine whether or not the EMS conforms to planned arrangements and has been properly implemented and maintained;

VI. review of the EMS and its continuing suitability, adequacy and effectiveness by top management;

VII. following the development of cleaner technologies;

VIII. consideration for the environmental impacts from the eventual decommissioning of the installation at the stage of designing a new plant, and throughout its operating life;

IX. application of sectoral benchmarking on a regular basis.

\* BAT is to measure or assess all relevant parameters necessary to steer the processes from control rooms by means of modern computer-based systems in order to adjust continuously and to optimise the processes online, to ensure stable and smooth processing, thus increasing energy efficiency and maximising the yield and improving maintenance practices.

\* BAT is to measure the stack emissions of pollutants from the main emission sources from all processes whenever BATAELs are given and in process gas-fired power plants in iron and steel works.

BAT is to use continuous measurements at least for:

- primary emissions of dust, nitrogen oxides (NOX) and sulphur oxides (SOX) from sinter strands

- nitrogen oxides (NOX) and sulphur oxides (SOX) emissions from induration strands of pelletisation plants

- dust emissions from blast furnace cast houses
- secondary emissions of dust from basic oxygen furnaces
- emissions of nitrogen oxides (NOX) from power plants
- dust emissions from large electric arc furnaces.

For other emissions, BAT is to consider using continuous emission monitoring depending on the mass flow and emission characteristics.

\* For relevant emission sources not mentioned in the previous conclusion, BAT is to measure





the emissions of pollutants from electric arc furnace process and from process gas-fired power plants within iron and steel works as well as all relevant process gas components/pollutants periodically and discontinuously. This includes the monitoring of process gases, stack emissions, polychlorinated dibenzodioxins/furans (PCDD/F) and monitoring the discharge of waste water.

#### Description

The monitoring of process gases provides information about the composition of process gases and about indirect emissions from the combustion of process gases, such as emissions of dust, heavy metals and SO2.

Stack emissions can be measured by regular, periodic discontinuous measurements at relevant channelled emission sources over a sufficiently long period allowing to obtain representative emission values.

For monitoring the discharge of waste water a great variety of standardised procedures exist for sampling and analyzing water and waste water, including:

- a random sample which refers to a single sample taken from a waste water flow

- a composite sample, which refers to a sample taken continuously over a given period, or a sample consisting of several samples taken either continuously or discontinuously over a given period and blended

- a qualified random sample shall refer to a composite sample of at least five random samples taken over a maximum period of two hours at intervals of no less than two minutes, and blended.

Monitoring should be done according to the relevant EN or ISO standards. If EN or ISO standards are not available, national or other international standards should be used that ensure the provision of data of an equivalent scientific quality.

\* BAT is to determine the order of magnitude of diffuse emissions from relevant sources by the methods mentioned below. Whenever possible, direct measurement methods are preferred over indirect methods or evaluations based on calculations with emission factors.

- Direct measurement methods where the emissions are measured at the source itself.

In this case, concentrations and mass streams can be measured or determined.

Indirect measurement methods where the emission determination takes place at a certain distance from the source; a direct measurement of concentrations and mass stream is not





#### possible.

- Calculation with emission factors.

#### Description

Direct or quasi-direct measurement

Examples for direct measurements are measurements in wind tunnels, with hoods or other methods like quasi-emissions measurements on the roof of an industrial installation. For the latter case, the wind velocity and the area of the roofline vent are measured and a flow rate is calculated. The cross-section of the measurement plane of the roofline vent is subdivided into sectors of identical surface area (grid measurement).

Examples for sampling and determination of the size distribution and concentration of dust (PM0.1, PM1, PM2.5, and PM10) are:

- cascade impactors, based on internal classification
- electrical impactors, based on electric and internal classification
- spectrometers, based on diffuse and internal classification
- laser diffractometers, based on optical classification.

Indirect measurements

Examples of indirect measurements include the use of tracer gases, reverse dispersion modelling (RDM) methods and the mass balance method applying light detection and ranging (LIDAR).

Calculation of emissions with emission factors

Guidelines using emission factors for the estimation of diffuse dust emissions from storage and handling of bulk materials and for the suspension of dust from roadways due to traffic movements are:

- VDI 3790 Part 3

- US EPA AP 42

## 4.10 BAT CONCLUSIONS ON DECOMISSIONING

The following conclusions have been adopted :

\* BAT is to prevent pollution upon decommissioning by using necessary techniques as listed





#### below.

Design considerations for end-of-life plant decommissioning:

I. giving consideration to the environmental impact from the eventual decommissioning of the installation at the stage of designing a new plant, as forethought makes decommissioning easier, cleaner and cheaper

II. decommissioning poses environmental risks for the contamination of land (and groundwater) and generates large quantities of solid waste; preventive techniques are process-specific but general considerations may include:

i. avoiding underground structures

ii. incorporating features that facilitate dismantling

iii. choosing surface finishes that are easily decontaminated

iv. using an equipment configuration that minimises trapped chemicals and facilitates draindown or cleaning

v. designing flexible, self-contained units that enable phased closure

vi. using biodegradable and recyclable materials where possible.

# 4.11 BATS ON PROCESSES ASOCIATED TO EAF: HOT ROLLING, COLD ROLLING, WIRE DRAWING PLANTS AND GALVANIZING OF SHEET

#### 4.11.1 Hot Rolling Mill

For **storing and handling of raw materials and auxiliaries** the following techniques are considered to be BAT:

- Collection of spillages and leakages by suitable measures, e.g. safety pits and drainage.
- Separation of oil from the contaminated drainage water and reuse of recovered oil.
- Treatment of separated water in the water treatment plant.

In general, the best way to reduce the environmental impact from **surface rectification and conditioning of input** is to avoid the need for rectification. The improvement of surface quality of cast products to reduce the need for surface rectification is therefore considered BAT.

Furthermore, the following measures were identified as BAT for surface rectification and conditioning of input:





#### For machine scarfing (BREF Ferrous Metals Processing Industry A.4.1.2.1):

- Enclosures for machine scarfing and dust abatement with fabric filters. There was agreement that this technique constitutes BAT, but there were different opinions on the associated emission level and the TWG recorded a split view. One plant reported achieved dust emission levels of 5 - 10 mg/m<sup>3</sup>. Some EU Member States argued (without supporting data for this type of installation) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this is the level that should be associated with BAT. Others pointed out that < 20 mg/Nm<sup>3</sup> is the appropriate level.

- The use of an electrostatic precipitator, where fabric filters cannot be operated because of very wet fume. There were no dust emission data available for individual plants, but reported current emission levels ranged from < 20 mg/Nm<sup>3</sup> to 20 - 115 mg/m<sup>3</sup>. Based on information submitted by TWG members on generally achievable dust levels for electrostatic precipitators (Reduction efficiency 95 – 99 %, grain size > 0.1  $\mu$ m and input dust content up to 100 mg/m<sup>3</sup>, dust output levels for EP 15 – 20 mg/Nm<sup>3</sup> reference) in the application of oxide and dust removal in the FMP sector, an associated dust level of 15 – 20 mg/Nm<sup>3</sup> was proposed by the EIPPCB. The TWG was unable to reach agreement on the BAT-associated level and a split view was recorded.

- Separate collection of scale/swarf from scarfing. The oil-free scale should be kept apart from oily millscale for easier reuse in metallurgical processes.

#### For grinding (BREF Ferrous Metals Processing Industry A.4.1.2.2):

- Enclosures for machine grinding and dedicated booths, equipped with collection hoods for manual grinding and dust abatement for the extracted air by fabric filters. There was consensus among TWG members that these techniques constitute BAT, but no agreement was reached as to what the associated emission level is. Emission data taken from various sources lead to a reported current dust emission range for grinding of  $1 - 100 \text{ mg/m}^3$ . Industry reported data for the application of fabric filters with resulting dust levels of < 30 mg/Nm<sup>3</sup> and 20 - 100 mg/Nm<sup>3</sup> (for different filter types). Taking into account the better range of the reported emisson levels and the information submitted by TWG members on generally achievable dust levels for fabric filters (Reduction efficiency 95 – 99 %, grain size (> 0.1 µm) > 0.5 µm and input dust content up to 500 mg/Nm<sup>3</sup>; dust output levels for FF 1 – 20 mg/Nm<sup>3</sup>) in the application of oxide and dust removal in the FMP sector, a BAT-associated level of < 20 mg/Nm<sup>3</sup> was proposed.

Some EU Member States opposed, saying (based on very limited data) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this should be the BAT-associated level.

Aditionally, for all surface rectification processes:

- Treatment and reuse of water from all surface rectification processes (separation of solids).

- Internal recycling or sale for recycling of scale, swarf and dust.





Air emissions from **reheating and heat treatment furnaces** basically comprise NOx, SO<sub>2</sub> and dust. For dust, no specific abatement measures are applied. Generally, dust emissions are in the range of  $4 - 20 \text{ mg/m}^3$ , but figures as low as 2.2 mg/Nm<sup>3</sup> have been reported.

For reducing air emissions, especially NOx, from reheating and heat treatment furnaces and to reduce the energy consumption, the general measures **(BREF Ferrous Metals Processing Industry A.4.1.3.1)** should be taken into account at the design stage. Special attention should be paid to energy efficiency and waste heat recovery, e.g by adequate furnace insulation, insulation of skids, adequate stock recuperation zone etc, and to air emission reduction, e.g. by choice of burners and placement of burners.

Additionally, the following measures, which can also be applied to existing furnaces, are considered BAT for reheating and heat treatment furnaces:

- Avoiding excess air and heat loss during charging by operational measures (minimum door opening necessary for charging) or structural means (installation of multi-segmented doors for tighter closure).
- Careful choice of fuel (in some cases, e.g. coke oven gas, desulphurisation maybe necessary) and implementation of furnace automation and control to optimise the firing conditions in the furnace. Depending on the fuel used, the following SO<sub>2</sub> levels are associated with BAT:
  - for natural gas < 100 mg/Nm<sub>3</sub>
  - for all other gases and gas mixtures < 400 mg/Nm<sub>3</sub>
  - for fuel oil (< 1 % S) up to 1700 mg/Nm<sup>3</sup>

There was a split view in the TWG on whether the limitation of < 1 % sulphur content in fuel oil can be considered as BAT. Some experts considered this limit enough to be BAT, whilst others expressed the view that the resulting emissions of up to 1700 mg  $SO_2/Nm^3$  cannot be regarded as such. They considered a lower S content or the application of additional  $SO_2$  reduction measures to be BAT.

- Recovery of heat in the waste gas
  - by feedstock preheating
  - by regenerative or recuperative burner systems

- by waste heat boiler or evaporative skid cooling (where there is a need for steam)

Energy savings of 40 - 50 % can be achieved by regenerative burners, with reported NOx reductions potentials of up to 50 %. Energy savings associated with recuperators or recuperative burners are about 25 %, with reported achievable NOx reductions of about 30 % (50 % in combination with low-NOx burners). (BREF Ferrous Metals **Processing Industry A.4.1.3.4/5**)

Second generation low-NOx burners with associated NOx emission levels of 250 - 400 mg/Nm<sup>3</sup> (3 % O<sub>2</sub>) without air preheating and reported NOx reduction potential of





about 65 % compared to conventional burners. It should be noted that in evaluating the efficiency of NOx reduction measures it is important to also pay attention to specific emission levels, not only to the achieved concentration. In some cases, NOx concentrations may be higher, but the NOx mass emitted may be equal or even lower. **(BREF Ferrous Metals Processing Industry A.4.1.3.7)** Reheating furnaces do not operate in stable conditions during start-up and shut-down;

during these phases the emission levels may increase.

• Limiting the air preheating temperature.

Higher NOx concentrations may arise in the case of reheating furnaces operating with combustion air preheating. Only very limited data were submitted on NOx concentrations in connection with air preheating. The following data, taken from available UK reports, give an indication of the NOx emission levels that may be expected with increasing air preheating temperature:

Air preheating Temperature [ºC ]	NOx [mg/Nm <sup>3</sup> ]
100 - 200	< 400
300	up to 450
400	up to 600
500	up to 800
700	up to 1500
800	up to 2300
900	up to 3500
1000	up to 5300

(Rough estimate as taken from diagram; 3 % oxygen, dry gas, standard conditions)

With increasing air preheating temperature, a significant rise in NOx concentrations is inevitable. Thus, limiting the preheating temperature may be seen as a NOx reduction measure. However, the advantages of reduced energy consumption and reductions in SO<sub>2</sub>, CO<sub>2</sub> and CO have to be weighed against the disadvantage of potentially increased emissions of NOx. (BREF Ferrous Metals Processing Industry D.2.2)

Furthermore, the following measures to minimize the energy requirements are considered to be BAT:

• Reduction of heat loss in intermediate products; by minimizing the storage time and by insulating the slabs/blooms (heat conservation box or thermal covers) depending on production layout.





• Change of logistic and intermediate storage to allow for a maximum rate of hot charging, direct charging or direct rolling (the maximum rate depends on production schemes and product quality).

In reducing water and energy consumption, material tracking is considered BAT for **descaling**.

Large amounts of heat contained in continuous cast products or in intermediate products are lost during handling and storage. To reduce unwanted energy loss during **transport of rolled stock** from roughing mill to finishing train, coil boxes or coil recovery furnaces and heat shields for transfer bars are considered to be the best available techniques, although a potentially higher risk of surface defects (rolled-in scale) and potential damages caused by curled transfer bars was reported for heat retention shields. Coil boxes may also result in increased surface defects. (**BREF Ferrous Metals Processing Industry A.4.1.7**)

During rolling in the **finishing train** fugitive emissions of dust occur. Two techniques have been identified as BAT **(BREF Ferrous Metals Processing Industry A.4.1.8.8)** for the reduction of these emissions:

- water sprays followed by waste water treatment in which the solids (iron oxides) are separated and collected for reuse of iron content.
- Exhaust systems with treatment of extracted air by fabric filters and recycling of collected dust. The reported current dust emission level ranged from 2 50 mg/Nm<sub>3</sub>. Taking into account the better range of the reported emisson levels and the information submitted by TWG members on generally achievable dust levels for fabric filters in the application of oxide and dust removal in the FMP sector, a BAT associated level of < 20 mg/Nm<sup>3</sup> was proposed. Some EU Member States opposed, saying (not supported by data) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this should be the BAT-associated level. The TWG was unable to reach agreement on the BAT associated level and a split view was recorded.

For tube mills, collection hoods and fabric filters for fugitive emissions from rolling stands are not considered BAT, due to low rolling speeds and resulting lower emissions.

For reducing fugitive dust emissions from **levelling and welding,** suction hoods and subsequent abatement by fabric filters was identified as BAT. There were no emission data available for levelling and welding, but following the general approach on what is achievable by fabric filters (see above) a BAT-associated dust level of < 20 mg/Nm<sup>3</sup> was proposed. Some EU Member States expressed the view (without supporting data) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this should be the BAT-associated level. The TWG was unable to reach agreement on the BAT associated level and a split view was recorded.

Best available operational and maintenance techniques for **roll shops** are:

- Use of water-based degreasing as far as technically acceptable for the degree of cleanliness required.
- If organic solvents have to be used, preference is to be given to non-chlorinated solvents.





- Collection of grease removed from roll trunnions and proper disposal, such as by incineration.
- Treatment of grinding sludge by magnetic separation for recovery of metal particles and recirculation into the steelmaking process.
- Disposal by incineration of oil- and grease-containing residues from grinding wheels
- Deposition of mineral residues from grinding wheels and worn grinding wheels in landfills.
- Treatment of cooling liquids and cutting emulsions for oil/water separation. Proper disposal of oily residues, e.g. by incineration.
- Treatment of waste water effluents from cooling and degreasing as well as from emulsion separation in the hot rolling mill water treatment plant.
- Recycling of steel and iron turnings into the steelmaking process.
- Recycling of worn rolls which are unsuitable for further reconditioning, into the steelmaking process or returned to the manufacturer.

For **cooling** (machines etc.) separate cooling water systems operating in closed loops are considered BAT.

Hot rolling leads to a large amount of **scale- and oil-containing process water**. The minimization of consumption and discharge by operating closed loops with recirculating rates of > 95 % is considered BAT.

Treatment of this process water and pollution reduction in the effluent from these systems are considered BAT (**BREF Ferrous Metals Processing Industry A.4.1.12.2**). The following release levels from the waste water treatment are associated with BAT:

SS: < 20 mg/l

Oil: < 5 mg/l (oil based on random measurements)

Fe: < 10 mg/l

Crtot: < 0.2 mg/l (for stainless steel < 0.5 mg/l)

Ni: < 0.2 mg/l (for stainless steel < 0.5 mg/l)

Zn: < 2 mg/l

As the volume and contamination of waste water from tube mills are quite similar to other hot rolling operations, it was noted that the same techniques and the same associated BAT levels apply for tube mills.

Recirculation to the metallurgical process of mill scale collected in water treatment is BAT. **(BREF Ferrous Metals Processing Industry A.4.1.13.2)** Depending on oil content, additional treatment may be required. All oily waste/sludge collected should be de-watered to allow for thermal utilisation or safe disposal.

Throughout the plant the following techniques for **prevention of hydrocarbon contamination** of water have beeb identified and are considered to be BAT (**BREF Ferrous Metals Processing Industry A.4.1.8.9**):





- Preventive periodic checks and preventive maintenance of seals, gaskets, pumps and pipelines.
- Use of bearings and bearing seals of modern design for work- and back-up rolls as well as the installation of leakage indicators in the lubricant lines (e.g. at hydrostatic bearings). This reduces the oil consumption by 50 70 %.
- Collection and treatment of contaminated drainage water at the various consumers (hydraulic aggregates), separation and use of oil fraction, e.g. thermally utilized by blast furnace injection. Further processing of the separated water either in the water treatment plant or in dressing plants with ultra filtration or vacuum evaporator

## 4.11.2 Cold rolling mill

At the entry side of pickling lines, **decoiling** of the hot rolled strip leads to fugitive dust emissions. For the reduction of these emissions two techniques have been identified as BAT:

- Water curtains followed by waste water treatment in which the solids are separated and collected for reuse of iron content.
- Exhaust systems with treatment of extracted air by fabric filters and recycling of collected dust.

There were no emission data available for decoiling, but following the general approach on what is achievable by fabric filters, a BAT-associated dust level of < 20 mg/Nm<sup>3</sup> was proposed. Some EU Member States expressed the view (without supporting data) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this should be the BAT-associated level. The TWG was unable to reach agreement on the BAT associated level and a split view was recorded.

To reduce the environmental impact from pickling, general measures to reduce acid consumption and waste acid generation should be applied as far as possible and be considered preferably already at design stage, especially the following techniques that are considered BAT:

- Prevention of steel corrosion by appropriate storage and handling, cooling etc.
- Mechanical pre-descaling to reduce the load on the pickling step. If mechanical descaling is applied, BAT is a closed unit, equipped with an extraction system and fabric filters.
   For shot blasting, dust emission lougle of < 1 mg/Nm<sup>3</sup>, 2.6 mg/Nm<sup>3</sup> and 4.5 mg/Nm<sup>3</sup>

For shot blasting, dust emission levels of < 1 mg/Nm<sup>3</sup>, 2.6 mg/Nm<sup>3</sup> and 4.5 mg/Nm<sup>3</sup> have been achieved

- Use of electrolytic pre-pickling.
- Use of modern, optimised pickling facilities (spray or turbulence pickling instead of dip pickling).
- Mechanical filtration and recirculation for lifetime extension of pickling baths.
- Side-stream ion-exchange or electro-dialysis (for mixed acid) or other method for free acid reclamation for bath regeneration.

For **HCl pickling**, BAT is considered to be:





• The reuse of spent HCl

Or

• The regeneration of the acid by spray roasting or fluidised bed (or equivalent process) with recirculation of the regenerate to the pickling process is considered BAT. (BREF Ferrous Metals Processing Industry A.4.2.2.7/8) Depending on site circumstances, the high acid consumption and amounts of waste acid generated and the savings generally obtained from regeneration may justify the investment in a regeneration plant. The acid regeneration plant needs to be equipped with an air scrubbing system to reduce emissions, especially acid emissions. Achievable reduction efficiencies of > 98 % were reported. Some sources report achieved HCl concentrations by applying caustic scrubbing of < 2 mg/Nm<sup>3</sup>. The following emission levels are associated with acid regeneration (waste gas treatment by scrubbers or adsorption towers):

Dust 20 -50 mg/Nm<sup>3</sup>

- HCl 2 30 mg/Nm<sup>3</sup>
- SO2 50 100 mg/Nm<sup>3</sup>
- CO 150 mg/Nm<sup>3</sup>
- CO2 180000 mg/Nm<sup>3</sup>
- NO2 300 370 mg/Nm<sup>3</sup>

The recovered solid by-product Fe2O3 is a saleable product and is externally reused.

For **H2SO4 pickling** processes, recovery of the free acid by crystallisation is considered BAT. **(BREF Ferrous Metals Processing Industry A.4.2.2.10).** The recovery plant needs to be equipped with air scrubbing devices; emission levels associated with this process are:

H2SO4 5 - 10 mg/Nm<sup>3</sup>

SO2 8 - 20 mg/Nm<sup>3</sup>.

For **mixed acid pickling**, free acid reclamation (e.g. by side-stream ion exchange or dialysis) or acid regeneration (e.g. by spray roasting or evaporation process) is considered BAT. (**BREF** Ferrous Metals Processing Industry A.4.2.2.11/12/13/14)

While free acid reclamation is applicable to virtually all plants, the applicability of regeneration processes may be limited for site-specific reasons. The emissions associated with BAT are:

	Spray Roasting	<b>Evaporation Process</b>	Free Acid Reclamation
Dust	< 10 mg/Nm <sup>3</sup>	none	
HF	<2 mg/Nm³	<2 mg/Nm <sup>3</sup>	none





NO2	< 200 mg/Nm <sup>3</sup>	< 100 mg/Nm <sup>3</sup>	
Waste water	0.003 - 0.01	not available	0.05 – 0.02 m3/t (metal-
	m3/t		containing weak acid solution)
Other output	mixed oxide	metal sulphate	filter cake

All three processes are equally considered BAT. Despite the disadvantage of higher air emissions and energy consumption, spray roasting was selected because of its high acid recovery rate and associated low fresh acid consumption. Furthermore the waste water is only a fraction of that produced by reclamation processes. Metals are basically bound in a solid byproduct. This mixed iron-chromium- nickel oxide can be reused in metal production.

The evaporation process also provides a very high acid recovery rate and thus low fresh acid consumption, but with much lower energy consumption than spray roasting. The metal sulphate filter cake, however, needs to be disposed of.

For the reduction of **air emissions from the pickling tanks**, totally enclosed equipment or equipment fitted with hoods and scrubbing of extracted air are considered BAT (**BREF Ferrous Metals Processing Industry A.4.2.2.18/D.5.2/D.5.3**) with associated emission levels:

HCl pickling: Dust 10 - 20 mg/Nm<sup>3</sup>

HCl 2 – 30 mg/Nm<sup>3</sup> (reduction efficiency > 98 %)

H2SO4 pickling: H2SO4 1- 2 mg/Nm<sup>3</sup> SO2 8 - 20 mg/Nm<sup>3</sup> (reduction efficiency > 95 %)

For mixed acid pickling of stainless steel, in addition to enclosed equipment/hoods and scrubbing, further NOx reduction measures are required. The following techniques are considered to be BAT (**BREF Ferrous Metals Processing Industry A.4.2.2.19/20**):

- Scrubbing with H2O2, urea etc.;
- or

• NOx suppression by adding H2O2 or urea to the pickling bath;

or

• SCR.

Emission levels of 200 - 650 mg/Nm<sup>3</sup> for NOx (reduction 75 - 85 %) and 2 – 7 mg/Nm<sup>3</sup> for HF (reduction 70 - 80 %) are associated with these techniques. Some sources reported achievable emission levels for HF of < 2 mg/Nm<sup>3</sup>, but as there was some recognition of difficulties in





measuring HF, especially at low levels, it was concluded that the BAT-associated level is the range given above.

As an alternative, implementation of nitric acid-free pickling (e.g. H2O2 based) with enclosed equipment or equipment fitted with hoods and scrubbing is considered BAT. However, this technique is not applicable to all applications.

The following measures have been identified as BAT for the minimization of acidic waste water:

- Cascade rinsing systems with internal re-use of overflow (e.g. in pickling baths or scrubbing).
- Careful tuning and managing of the 'pickling-acid regeneration-rinsing' system. Some sources report a possible waste water-free operation.
- in any case where acidic water blow-down from the system cannot be avoided, waste water treatment is required (neutralisation, flocculation, etc.). Associated release levels of the waste water treatment are:(BREF Ferrous Metals Processing Industry A.4.2.2.28)

SS: < 20 mg/l

Oil: < 5 mg/l (oil based on random measurements)

Fe: < 10 mg/l

Crtot:< 0.2 mg/l (for stainless steel < 0.5 mg/l)

Ni: < 0.2 mg/l (for stainless steel < 0.5 mg/l)

Zn: < 2 mg/l

For **emulsion systems** the following techniques are considered to be BAT:

- Prevention of contamination by regular checking of seals, pipework etc. and leakage control.
- Continuous monitoring of emulsion quality.
- Operation of emulsion circuits with cleaning and reuse of emulsion to extend lifetime.
- Treatment of spent emulsion to reduce oil content, e.g. by ultrafiltration or electrolytic splitting. (BREF Ferrous Metals Processing Industry A.4.2.3.8)

During **rolling and tempering**, fugitive emissions of emulsion fumes occur. To capture and reduce these emissions the best technique available is **(BREF Ferrous Metals Processing Industry A.4.2.3.9)** the installation of an exhaust system with treatment of extracted air by mist eliminators (droplet separator). Reduction efficiencies achieved are > 90 % and associated emission levels of hydrocarbons 5 - 15 mg/Nm<sup>3</sup>.

For installations operating with a **degreasing** step, the following techniques are considered BAT:





- Implementation of a degreasing circuit with cleaning and reuse of the degreaser solution. Appropriate measures for cleaning are mechanical methods and membrane filtration (BREF Ferrous Metals Processing Industry A.4.2.4.3)
- Treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content. The separated oil fraction should be reused, e.g. thermally; the separated water fraction requires treatment (neutralisation etc.) prior to discharge. (BREF Ferrous Metals Processing Industry A.4.2.4.4)
- Extraction system to capture degreaser fume and scrubbing of extracted air. (BREF Ferrous Metals Processing Industry A.4.2.4.5)
- The main environmental issues for annealing furnaces are air emissions from combustion processes and efficient energy use. The best available techniques to reduce emissions at continuous annealing furnaces are low-NOx burners (BREF Ferrous Metals Processing Industry A.4.2.4.10) with reduction rates of 60 % for NOx (and 87 % for CO) and with an associated emission level of 250 400 mg/Nm<sup>3</sup> (without air preheating, 3 % O2). The NOx emission level for batch annealing furnaces without the application of low-NOx burners and without air preheating is in the range of 150 380 mg/Nm<sup>3</sup> (without air preheating, 3 % O2). Generally the emissions levels to expect from annealing furnaces are:

	Batch Furnaces	Continuous Furnaces
Dust	5 - 10	10 - 20 mg/Nm³.
SO2	60 - 100	50 - 100 mg/Nm <sup>3</sup> .
NOx	150 - 380	250 - 400 mg/Nm <sup>3</sup> .
со	40 - 100	50 - 120 mg/Nm³.
CO2	200000 - 220000	180000 - 250000 mg/Nm <sup>3</sup> .
-		

Oxygen reference level 3 %

The best available measures to increase the energy efficiency are:

• Combustion air preheating by regenerative or recuperative burners. Higher NOx concentrations may arise in the case of annealing furnaces operating with combustion air preheating. No data was submitted on NOx concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication. Limiting the preheating temperature may be seen as a NOx reduction measure. However, the advantages of reduced energy consumption and reductions in SO2, CO2 and CO have to be weighed against the disadvantage of possible increased emissions of NOx. (BREF Ferrous Metals Processing Industry A.4.2.4.9)

or

• Preheating of stock by waste gas. (BREF Ferrous Metals Processing Industry A.4.2.4.11)

For **finishing**, the steel strip may be oiled for protection; this can lead to oil mist emissions. The best techniques to reduce these emissions are:





 Extraction hoods followed by mist eliminators and/or electrostatic precipitators. Data submitted for one plant showed an achieved average oil droplet concentration of 3.0 mg/Nm3 applying mist eliminator and electrostatic precipitator. (BREF Ferrous Metals Processing Industry A.4.2.6.1)

or

• Electrostatic oiling.

Further finishing operations, **levelling and welding**, generate fugitive dust emissions. BAT to reduce these emissions are extraction hoods with dust abatement by fabric filters (**BREF Ferrous Metals Processing Industry A.4.2.6.4.**) Emission data available from one plant range from 7 – 39 mg/Nm<sup>3</sup>; data from another plant (part time operation) from 5 – 30 mg/Nm<sup>3</sup>. Taking into account the better range of the reported emission levels and the information submitted by TWG members on generally achievable dust levels for fabric filters8 in the application of oxide and dust removal in the FMP sector, a BAT-associated level of < 20 mg/Nm<sup>3</sup> was proposed. Some EU Member States opposed, saying (not supported by data) that fabric filters in general can achieve below 5 mg/Nm<sup>3</sup> and that this should be the BATassociated level. The TWG was unable to reach agreement on the BAT associated level and a split view was recorded.

For **cooling** (machines etc.), separate cooling water systems operating in closed loops are considered BAT.

**Metallic by-products**, scrap from cutting, heads and tails are collected at different stages in the rolling mill. Collection and recirculation into the metallurgical process is BAT.

## 4.11.3 Wire drawing plants

**Pickling** operations, especially when concentrated or heated acid is used, lead to emissions of acidic vapors. Techniques to reduce the emissions depend on the acid used and on the way pickling is done (batch or continuously). Batch (discontinuous) pickling, used for preparation of wire rod, is described below. Continuous pickling of wire is typically used in combination with other operations such as hot dip coating of wire.

For batch pickling, the following techniques are considered to be BAT:

- HCl pickling: close monitoring of bath parameters: temperature and concentration and operating. (BREF Ferrous Metals Processing Industry A.4.3.3.1)
- In the case of pickling baths with high vapour emission, e.g. heated or concentrated HCl bath:installation of lateral extraction and possibly treating of the extraction air for both new and existing installations. The BAT-associated level for HCl emission is 2 – 30 mg/Nm<sup>3</sup>. (BREF Ferrous Metals Processing Industry A.4.3.3.2/3)





To reduce acid consumption, amounts of acidic wastes and waste water, the following techniques are considered to be BAT:

 Cascade Pickling (for installations above a capacity of 15 000 tonne wire rod per year. For small scale applications, the investment in a second tank, piping and process control equipment is not justified.) (BREF Ferrous Metals Processing Industry A.4.3.3.4)

or

- Reclamation of free acid fraction and reuse in pickling plant.
- External regeneration of spent acid. (On-site regeneration of spent acid, which is described as BAT for hot/cold rolling, is not feasible for wire pickling plants. These regeneration plants require a certain waste acid throughput for economic operation. The volumes of waste acid available in a wire plant are far below this threshold for economic operation).
- \_ Recycling of spent acid as secondary raw material.
- Non-acid descaling, e.g shot blasting, if quality requirements allow.
- Countercurrent cascade rinsing [CET-BAT]

To reduce fugitive soap dust emissions from **dry drawing**, enclosing the drawing machine (and connecting to a filter or similar device when necessary), is considered to be BAT for all new machines with drawing speed  $\geq 4$  m/s. (BREF Ferrous Metals Processing Industry A.4.3.5.1)

In some categories of wire drawing machines where the drawing speed is limited (< 4 m/s), the spread of lubricant-dust is limited, even without a cover. In these cases, the added environmental value of a hood or cover is very limited. Examples of such drawing machines are mono-blocs (machines with only 1 die) and multi-wire drawing machines that are coupled to another operation.

Equipping existing drawing machines with a cover with acceptable dust capture efficiency that would still allow efficient operation and maintenance of the machine is technically impossible for design reasons.

For **wet drawing** lubricants, the following measures are considered to be BAT:

- Cleaning and reuse of drawing lubricant. (BREF Ferrous Metals Processing Industry A.4.3.6.2)
- Treatment of spent lubricant to reduce oil content in the discharge and/or to reduce waste volume, e.g. by chemical breaking, electrolytic emulsion splitting or ultrafiltration. (BREF Ferrous Metals Processing Industry A.4.3.6.3)
- Treatment of discharge water fraction.

Not to use once-through cooling water systems is considered BAT. The best available techniques to reduce cooling water consumption are closed cooling-water loops for dry and wet drawing.





Burning of the protective gas purge is considered to be BAT for all batch **annealing furnaces**, continuous **annealing furnaces for stainless steel** and **furnaces used in oil hardening and tempering**.

For **continuous annealing of low carbon wire** and **patenting**, the following measures are considered to be BAT (BREF Ferrous Metals Processing Industry A.4.3.8 /10):

- Good housekeeping measures, for the lead bath with associated emission levels of Pb < 5 mg/Nm<sup>3</sup>, CO < 100 mg/Nm<sup>3</sup> and TOC < 50 mg/Nm<sup>3</sup>
- Separate storage of Pb-containing wastes, protected from rain and wind
- Recycling of Pb-containing wastes in non-ferrous metals industry
- Closed loop operation of quench bath.

## 4.11.4 Galvanizing of Sheet

For the best available techniques in pickling, refer to the section 4.11.2 of Cold Rolling Mills.

For **degreasing** operations in continuous galvanising plants, the following techniques are considered to be BAT:

• Cascade degreasing. (BREF Ferrous Metals Processing Industry B.4.1.3.1)

• Cleaning and recirculation of degreasing solution; appropriate measures for cleaning are mechanical methods and membrane filtration. (BREF Ferrous Metals Processing Industry B.4.1.3.2)

• Treatment of spent degreasing solution by electrolytic emulsion splitting or ultrafiltration to reduce the oil content; separated oil fraction should be reutilized, e.g. thermally; the separated water fraction requires treatment (neutralisation etc.). (BREF Ferrous Metals Processing Industry B.4.1.3.4)

• Covered tanks with extraction and cleaning of extracted air by scrubber or demister (BREF Ferrous Metals Processing Industry B.4.1.3.6).

• Use of squeeze rolls to minimize drag-out. (BREF Ferrous Metals Processing Industry B.4.1.3.7)

The best available techniques for the reduction of emissions and energy consumption of **heat treatment furnaces** are considered to be **( see 4.9.1/ 4.9.2**):

• Low-NOx burners with associated emission levels of 250 - 400 mg/Nm<sup>3</sup> for NOx (3 % O<sub>2</sub>) without air preheating and 100 - 200 mg/Nm<sup>3</sup> for CO.

• Combustion air preheating by regenerative or recuperative burners.

No data were submitted on NOx concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication. Limiting the preheating





temperature may be seen as a NOx reduction measure. However, the advantages of reduced energy consumption and reductions in SO<sub>2</sub>, CO<sub>2</sub> and CO have to be weighed against the disadvantage of possible increased emissions of NOx.

or

- Preheating of strip.
- Steam production to recover heat from waste gas.

The **hot dipping** zinc bath is a source of zinc-containing residues, dross or hard zinc. BAT for these residues is separate collection and external recycling in the non-ferrous metals industry.

In installations where **galvannealing** is done, BAT to reduce emissions and energy consumption are:

• Low-NOx burners with associated emission levels of 250 - 400 mg/Nm<sup>3</sup> for NOx (3 % O<sub>2</sub>) without air preheating.

• Regenerative or recuperative burner systems.

• No data were submitted on NOx concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication. Limiting the preheating temperature may be seen as a NOx reduction measure. However, the advantages of reduced energy consumption and reductions in SO<sub>2</sub>, CO<sub>2</sub> and CO have to be weighed against the disadvantage of possible increased emissions of NOx.

Post-treatments of steel, such as oiling, phosphating and chromating, are done for protection. In **oiling**, oil fumes are generated, which are best reduced by:

• Covering the strip oiling machine.

or

• Electrostatic oiling.

The environmental impact from **phosphating** and **passivation/chromating** can be reduced by the following BAT (**BREF Ferrous Metals Processing Industry B.4.1.7.3/4/5/6**):

- Covered process baths.
- Cleaning and reuse of phosphating solution.
- Cleaning and reuse of passivation solution.
- Use of squeeze rolls.
- Collection of skinpass/temper solution and treatment in waste water treatment plant.





For **cooling** (machines etc.), separate cooling water systems operating in closed loops are considered BAT.

**Waste water** arises in sheet galvanising from the chemical treatment sections and from rinsing operations. Waste water also arises from strip cooling, contaminated by abrasion dust, and from the water sprays which are used to keep working rolls in the skin pass mill clean and which is contaminated by Zn-containing abrasion dust and lubricating oil. These waste water streams require treatment by a combination of sedimentation, filtration and/or flotation/precipitation/flocculation.The techniques described in **(BREF Ferrous Metals Processing Industry B.4.1.9)** or equally efficient combinations of individual treatment measures are considered BAT.

The associated pollutant concentrations in the effluent are:

SS: < 20 mg/l Fe: < 10 mg/l Zn: < 2 mg/l Ni: < 0.2 mg/l Crtot: < 0.2 mg/l Pb: < 0.5 mg/l Sn: < 2 mg/l

With some of the existing continuous water treatment plants, a zinc level of < 4 mg/l is all that can be achieved.





## **5 EMISSIONS CONTROL AND MONITORING.**

The basic information and documents to prepare this chapter on control and monitoring of emissions have been the following:

BAT conclusions for iron and steel production

BREF on the production of iron and steel

Reference Document (General Principles of Monitoring).

Turkish environmental legislation on monitoring

Experience of implementation of IPPC Directive in the steel sector in the Basque Country

Other European IPPC guidances on steelmaking (UK EA IPPC guidance for the production of coke, iron and steel, Final Draft BAT Guidance Note on Best Available Techniques for the Initial Melting and Production of Iron & Steel Sector EPA Ireland)

Taking into account this information and the one in previous sections of this document, this chapter describes the monitoring and reporting criteria for emissions to air, water and soil in the following aspects:

Parameters to be monitored

Methodologies,

Frequency

Compliance-assessment.

The administrative process set by the IED for the control of the potential environmental effects by the IPPC sites has three important parts:

Permit writing, where conditions are set;

Assuring compliance with the permit and law during the operation. This part is becoming more and more relevant nowadays in the protection of the environment. The main tool to it is compliance assessment done mainly through monitoring. In a simple way, when monitoring is done by the operator it can be considered a control and when done by the administration an inspection.

Review of the permit according to changes in legislation or the site.

When setting the permit conditions on monitoring it is critical to have in mind the objectives of it. The first principle must be that the data should be generated by and for the operator in first place. The monitoring data should be integrated in the operation management system as any other data. Therefore the responsible for the data and first user should be the operators themselves. On top of that, monitoring should be useful to prove to administration and public that conditions that, if breached, pose a high risk to the environment are in compliance. This has to be done in an effective and efficient way.





Another aim for monitoring is environmental reporting of industrial emissions. This information is useful to establish the contribution of a particular installation to environmental pollution in general, e.g. periodic environmental reporting to the competent authorities, and in cases where there are specific problems.

From the practical and operative point of view, for an effective and efficient monitoring:

- The permit should set the ELVs in such a way that monitoring results can be compared clearly with them to assess compliance.
- The permit should set clearly the parameters to monitor in a emission point, the method and the frequency.
- Compliance assessment procedures must be specified, to avoid any doubt about the way uncertainty is treated.

Regarding reporting, clear instructions should be set for communicating incidents and deviations from compliance, on one side, and for general reporting on the other. In any case, reporting in an previously agreed format and, if possible, electronically are considered good practices .

## 5.1 General principles of emissions monitoring.

The main general good practices of the Reference Document on the General Principles of Monitoring are summarized in the following table.

Refere	ence good practice in General principles of monitoring
1	"Why" monitor
	To document the objectives of the monitoring at the start and to keep them under systematic review is a good practice. This information may include consideration of the aims, obligations, uses and users of the data collected during a monitoring programme.
	<ul> <li>The two main reasons are:</li> <li>Compliance assessments, checking that emissions are within ELVs</li> <li>To establish the contribution of a particular installation to environmental pollution in general</li> <li>Other can be: reporting for emission inventories, assessing BATs, assessing environmental impacts, optimising processes,</li> </ul>
2	Which phase should be monitored
	Monitoring should generally be undertaken during all phases of operation (i.e. commissioning, start-up, normal operation and shutting-down) unless the Regulator agrees that it is inappropriate.


г



3	"Who" carries out the monitoring
	It is highly important that monitoring responsibilities are clearly assigned to relevant parties (operators, authorities, contractors) so that they are all aware of how the work is divided and what their own duties and responsibilities are. Details of such assignments and of the methods to be used may be specified in monitoring programmes, schemes, permits, legislation or other relevant documents, such as applicable standards.
	<ul> <li>Such specifications would include details of:</li> <li>the monitoring for which the operator is responsible, including any monitoring that external contractors do when acting on his/her behalf,</li> <li>the monitoring for which the competent authority is responsible, including any monitoring that external contractors do when acting on its behalf,</li> <li>the strategy and the role of each participant,</li> <li>the methods and safeguards that are required in each case, and</li> <li>the reporting requirements.</li> </ul>
4	<ul> <li>What and when (frequency) to monitor</li> <li>In principle, there are various approaches that can be taken to monitor a parameter, although some of them may not be appropriate for particular applications: <ul> <li>direct measurements</li> <li>surrogate parameters</li> <li>mass balances</li> <li>other calculations</li> <li>emission factors.</li> </ul> </li> <li>When choosing one of these approaches for monitoring there must be a balance between the availability of the method, reliability, level of confidence, costs and the environmental benefits.</li> <li>The monitoring regime or frequency should be fixed on a risk of environmental damage based approach. The main criteria influencing the risk of having an emission higher than ELV are: <ul> <li>the likelihood of exceeding the ELV</li> <li>The consequences of exceeding the ELV.</li> </ul> </li> </ul>
5	How to express ELVs and monitoring results
	The most habitual types of units used are the following ones, either singly or in combination: concentration units, units of loads over time, specific units and emissions factors, thermal effect units, other emission value units, normalised units.
	In all cases, the units to be used for compliance monitoring purposes should be clearly stated, preferably be internationally recognised (e.g. based on the Système Internationale) and match the relevant parameter, application and context.
6	Monitoring time considerations
	The main ones are:





	<ul> <li>Moment when samples and/or measurements are taken</li> <li>Averaging time as the time over which a monitoring result is considered representative of the average load or concentration of the emissions.</li> <li>Frequency of monitoring should be based on a risk approach.</li> </ul>
7	How to deal with uncertainties To avoid ambiguity the arrangements foreseen for dealing with uncertainties need to be clearly stated in the permit e.g. "the results minus the uncertainty should be below the ELV". Even the maximum admitted uncertainty is established in some cases.
8	<ul> <li>Monitoring requirements to be included with the ELVs in the permit <ul> <li>Make it clear monitoring is legally enforceable</li> <li>Specify clearly and unambiguously the pollutant or parameter being limited</li> <li>State clearly the location where samples and measurement are to be taken</li> <li>Specify the monitoring timing requirements</li> <li>Consider the feasibility of limits with regard to available measurement methods.</li> <li>Specify the technical details of particular measurement methods.</li> <li>In case of self-monitoring, state clearly the procedure for periodically checking the traceability of the self-monitoring.</li> <li>State the operational conditions (e.g. production load) under which the monitoring is to be performed.</li> <li>Clearly state the compliance assessment procedures e.g. how uncertainty is to be considered.</li> <li>Specify the reporting requirements.</li> <li>Include appropriate Quality Assurance Control requirements, to make sure that results are reliable, comparable, consistent and auditable.</li> <li>Make arrangements for the assessment and reporting of exceptional emissions.</li> </ul> </li> </ul>
9	<ul> <li>Continuous monitoring</li> <li>Continuous monitoring and recording (or at least sampling in the case of water) are likely to be required under the following circumstances: <ul> <li>Where the potential environmental impact is significant or the concentration of substance varies widely.</li> <li>Where a substance is abated, continuous monitoring of the substance is required to show the performance of the abatement plant. For example continuous monitoring of dust is needed after a fabric filter to show the effectiveness of the filter and indicate when maintenance is needed, or sampling BOD from an effluent treatment plant.</li> <li>Where on top of the abatement controls, other measures are required to comply with the ELVs (e.g. selection of the material to be introduced in the oven in the way that reduces emissions).</li> <li>When the legislation states so, for example when the emission loads of contaminant are abaye certain threshold.</li> </ul> </li> </ul>



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10	Monitoring of fugitive and diffuse emissions.			
	Present emissions control techniques have been effective in reducing <u>channelled</u> emissions (through any kind of pipe). In this situation, <u>diffuse</u> (those arising from volatile or light dusty substances, like dust during furnace charging not captured by extraction system) and <u>fugitive</u> (those resulting from a loss in tightness of a piece of equipment like joints) emissions are becoming increasingly important.			
	Some examples of techniques for quantifying diffuse and fugitive emissions are listed below:			
	<ul> <li>Analogy with channelled emissions. This could be the case of a surface, like a window or a lantern, where a flux of matter is measured.</li> </ul>			
	<ul> <li>Assessment of equipment leaks. US EPA has a document on it, "The Protocol for Equipment Leak Emission Estimates". The principle is the screening of the leaks to assist in a Leak Detection And Repair (LDAR) programme.</li> </ul>			
	<ul> <li>Emissions from storage tanks, loading and unloading and utilities. They are normally calculated based on general emission factors.</li> </ul>			
	<ul> <li>Long path optical monitors. The basis is that downwind concentrations of pollutants are measured by using electromagnetic radiation. Two of the most known equipments are DIAL (Differential Infrared Absorption Laser) used in some countries to monitor VOC emissions and DOAS (Differential Optical Absorption Spectrometry).</li> </ul>			
	<ul> <li>Mass balances. Normally is a small difference between inputs and outputs, therefore is only applicable when accurate input, output and uncertainties can be determined.</li> </ul>			
	<ul> <li>Tracers. By using tracers and their measurement downwind, the emission rates can be estimated from simple flux assumptions with near stationary conditions and assuming that there is not reaction or deposition of gases.</li> </ul>			
	<ul> <li>Similitude assessment. "Reverse" atmospheric dispersion models can help to estimate the emissions from downwind measured air quality and meteorological data.</li> </ul>			
	<ul> <li>Assessment of wet and dry depositions downwind of the plant. Quantitative monitoring may allow a quantitative source assignment. In the case of stable compounds (metals, dioxins,) bio-monitoring can be an option.</li> </ul>			
11	Exceptional emissions			
	They are the emissions arising from an event that deviates from regular operation. They can be differentiated into foreseeable (starts-up, shutdown, maintenance works, discontinuous processes or materials quality,) and unforeseeable (equipment malfunction, process upsets, human errors,).			
12	Reliability and comparability of the monitoring data			





	Reliability can be considered as the closeness of the measurements to the true value. It is also knows as accuracy. All quality aspects have to be considered in the data production chain. The uncertainty of all steps has to be gathered. Sampling is considered to be the most contributing step to uncertainty; therefore special attention should be paid to it.
	The steps in the data production chain includes: flow/amount measurement; sampling; sample storage, transport and preservation; sample treatment; sample analysis, data processing; and reporting.
	<ul> <li>Comparability is a measure of the confidence with which one data set can be compared to another. In order to ensure it, the following measures can be taken:</li> <li>Use of published standards for sampling and analysis procedures, preferably European CEN standards, when available.</li> <li>Use of standard handling and shipping procedures for all collected samples.</li> <li>Use of skilled personnel throughout the programme.</li> <li>Use of consistent units when reporting the results.</li> </ul>
	To allow fair comparison of the data, the following information, when relevant, should go with the data: method of analysis, uncertainty, traceability, averaging time, frequency, calculation of the average, units, source that has been measured, prevailing process conditions during sampling and auxiliary measures.
13	Compliance assessment
	<ul> <li>The compliance assessment involves a comparison, that could be statistical, between the following items:</li> <li>The measurements, or a statistical summary estimated from them</li> <li>The uncertainty of the measurements</li> <li>The relevant ELV or equivalent parameter.</li> </ul>
	<ul> <li>When comparing, three categories can be found:</li> <li>Compliant. When the measured value is below the ELV, even when the uncertainty is added to the first.</li> <li>Borderline. The measured value is between (ELV-uncertainty) and (ELV+ uncertainty)</li> <li>Non-compliant. The measured value is higher than the ELV even when the first is decreased by the uncertainty.</li> </ul>

## 5.2 Monitoring of emissions to the air.

Emissions to the air are one of the most relevant aspects in electric furnace steelmaking. Therefore its monitoring is very important. The European law and BREFs do not state exactly the parameters and frequency. Therefore the information contained in this subchapter should be considered as a reference when writing the permits and/or planning the monitoring by the operators.





Operators in Turkey already perform control and monitoring according to the Turkish law. These monitoring requirements are collected in the following sections taking into account also the information of several EU Member States of the European Union in the implementation of the IPPC Directive in the steel sector, the IED and the BREF and BAT conclusions on steel.

## 5.2.1 Emissions to air.

The following table summarizes the main criteria to set the monitoring of the emissions to the air. Obviously it will depend on the site and has to be adapted to the particularities of the site and location.

Process	Parameter	Frequency	Method
Raw materials and	Particles	Daily	Continuous
waste handling (slag			observation & annual
and dust) handling			estimate of release
EAF/Secondary	Particles	Continuous	CEMS <sup>2</sup>
metallurgy	Particles	Once per year	Periodic monitoring
	CO		
	NOx		
	SO2		
	HF, HCl, Cl		
	PCDD/F		
	Metals (Zn, Pb, Ni,		
	Hg, Cu, Cr, As, Cd)		
	NMCOV		
	РАН, РСВ	Once first year and	Periodic monitoring
		then as appropriate	
Vacuum degasser	Metals	Once per year	Periodic monitoring
stack			
EAF buildings	Diffuse particle		Continuous
	emissions.		observation & annual
			estimate of release
All fume abatement	Particles	Once per year	
plants and vents			
Casting			
Rolling, scarting,	Particles	Once every 3-5 years	Periodic monitoring
coiling, welding,	Oil mist		
shot blasting,			
finishing			
Heating furnaces	NOx	Once every 1 or 3	
	SO <sub>2</sub>	years depending on	
		the power and	
		capacity	

 $<sup>^{\</sup>rm 2}$  The BAT conclusions on steel establishes a daily average ELV therefore the monitoring to check compliance must be CEMS





Pickling	Coal and low alloyed steel Particles/HCI	Once in three years	Periodic monitoring
	Stainless steel NOx SOx HF	Once per year	Periodic monitoring
Acid recla plants	iming HCl	Continuous	CEMS
	HCl Cl <sub>2</sub> Particles NOx SO2 CO HF Metals	Once per year	Periodic monitoring

In the case of continuous monitoring, equipment, methods and procedures should comply with the quality assurance standards described in the Communiqué 28082 on continuous emission monitoring systems.

Regarding periodic monitoring or spot test, laboratories authorised by the Ministry of Environment and Urbanism should perform the test and do the reporting. The methods used should be, if possible, under CEN standards and, if no, national approved methods or those under ISO standards can be accepted.

## 5.2.2 Ambient air monitoring

Setting provisions in the permit on ambient air monitoring in the surroundings of the site should be considered when there is a relevant potential impact on the air quality and in the cases when the emissions are above the thresholds established in the corresponding relevant legislation.

This monitoring may be done with the following **aims**:

- To monitor the air emissions mainly from diffuse and fugitive emissions, and
- To evaluate the impact of the emissions in the air quality because:
  - there are vulnerable receptors that can be affected by the pollutants released to the air,
  - the emissions from the site are a significant contributor to the levels in ambient air and the Environmental Quality Standards may be at risk or





- the operator is looking for higher flexibility on the emission standards based on lack of effect on the environment.
- To validate modelling work

The following two **approaches to monitor ambient air quality** can be used according to the impact of the emissions on air quality, the location and the characteristics of the affected zone and the results of the air dispersion modelling studies:

- Continuous monitoring: In these cases, automatic equipments that are ready to measure particles (total, PM10, PM2.5, PM1) can be used. A previous analysis for the location of the equipment is needed. Several criteria have to be taken into account to propose the location, including emission source, local meteorological conditions and receptors.
- Campaign monitoring: Ambient dust samplers can be used and then the dust is weighted in the laboratory. We can use high or low volume samplers to characterize the PM10, PM2.5 or PM1 fraction or the settable particles. Normally this approach can be used to gain information of the potential impact and decide if further continuous monitoring is needed and where. It is also helpful to characterize the chemical composition of the particles, so compliance with the metal levels in ambient air can be assessed. In the case of source assignments, the use of this approach is necessary.

Operators should present, within the permit application, an Air Quality Management Plan comprising the following elements:

 information about the establishment of continuous monitoring systems in the process units relevant to fugitive and point source emissions from the site as a whole, comprising:

- CEM and/or workers' observations at process units.

- closed circuit television system (CCTV) across the site.
- use of markers and similar methods to facilitate the investigation of the origin of substances releases and their management.
- a protocol for assessing the risks to local sensitive receptors at the time significant changes in releases are observed.
- a protocol for managing those releases quoted in the previous point.
- procedures for promptly investigating complaints about air quality (including odour) or deposition.
- permanent or intermittent monitoring at off-site locations close to sensitive receptors (such as residential areas with schools, hospitals,...), providing data for the Management Plan, of ambient concentrations of any prescribed substances which the installation emits which may challenge an Environmental Quality Standard.

## 5.2.3 Air dispersion modelling studies.





In the case of steelmaking EAF, operators must provide air dispersion modelling studies (see Annex II of the By-Law on the Control of Air Pollution Caused by Industries), which are of interest to assess the potential impact of the particle matter in the event of failure of the abatement systems or of the fabric filters and of the diffuse emissions during the processes of charging and unloading of the furnace.

It is important that the studies are carried out taking into account basic criteria on the selection of the models to be used for each location, the input data to be used and the settings while running the models. Regarding selection of the models, no model is prescribed but it should be taken into account that the model is appropriate for the topographical conditions of the location. The output of the model is as good as the input data, therefore special attention should be put in the input data (meteorological data, topography, soil use, emission data and surrounding buildings).

When reporting results, all relevant information of the input data and model settings should be present in the report, so that conclusions can be checked.

## 5.3 Monitoring of emissions to water.

Monitoring of the emissions to water should consider the ELVs set in the permit for the emissions to water and some other parameters that could help to characterise the emissions. The following table summarises the parameters and frequencies of monitoring that should be considered. Obviously in the case of an incidence, appropriate additional short term monitoring should be introduced.

Process	Parameter	Frequency
EAF	Flow rate	Continuous
	рН	Continuous
	Conductivity	Continuous
	Temperature	Continuous
	Turbidity	Continuous
	Oil and grease	Flow weighted sample or composite samples,
		weekly analysis, reported as flow weighted
		monthly averages
	Suspended solids	Flow weighted monthly averages
	COD	Flow weighted sample or composite samples,
		weekly analysis, reported as flow weighted
		monthly averages
	Total sulphides	Flow weighted sample or composite samples
		,quarterly analysis, reported as flow weighted
		quarterly averages
	Fe, Ni, Hg, Cr, Zn, Pb,	Flow weighted sample or composite samples
	As, Cu, Cd	,quarterly analysis, reported as flow weighted
		quarterly averages
Hot rolling	Flow rate	Continuous





Temperature	Continuous
Conductivity	Continuous
рН	Continuous
Suspended solids	Continuous
Turbidity	Continuous
COD/BOD	Flow weighted sample or composite samples,
	weekly analysis, reported as flow weighted
	monthly averages.
Oil	Weekly

The parameters and frequency have been chosen for an average EAF steelmaking site. Nevertheless the characteristics of the site have to be taken into account and further characterisation of the wastewater may be needed to elaborate the monitoring plan. Any substances found to be of concern, or any other individual substances to which the local environment may be susceptible and upon which the operations may impact, should also be monitored more regularly. This would particularly apply to the heavy metals. Composite sampling is the technique most likely to be appropriate where the concentration does not vary excessively.

The need of monitoring of surface water beyond the limits of the site should be considered. In this case, information will be needed for sampling, analysis and reporting for upstream and downstream quality of the controlled water. The discharging points should be controlled daily for any change in the visible characteristics (solids, oil, discoloration ...). On top of that, ecology surveys can be performed in some cases to establish the longer term effects on the aqueous environment. These are usually ongoing exercises structured to take account of both the sensitive receptors in the local environment and the changes which occur naturally in that environment in terms of growth, reproduction, etc of populations of organisms as well as the general health of the water course in terms of eutrophication, weed growth, sewage fungus formation, etc.

## 5.4 Waste.

A full record, available for inspection at all times, must be kept on matters relating to the waste management operations and practices carried out onsite and containing minimum details of

- Type and quantities of waste.
- The names of the waste manager and transporter of the waste.
- The name of the persons responsible for the ultimate disposal/recovery of the waste. The ultimate destination of the waste.
- Written confirmation of the acceptance and disposal/recovery of any hazardous waste consignments sent off-site.
- The tonnages and EWC Code for waste materials listed in the licence, sent off-site for disposal/recovery.





- In the event of rejected consignments of waste managements, details of why they were rejected and the actions taken.
- The tonnages and EWC Code for the waste materials listed in the licence for recovery onsite.
- Leachate testing of sludges and other material as appropriate for being sent for landfilling.
- Annual waste minimisation report showing efforts made to reduce specific consumption together with material balance and fate of all waste materials.

Where sludge and other waste materials are being disposed of to landfill, leachate testing should be carried out.

In case that the landfill is within the site, a specific monitoring plan should be designed for the landfill. This should include the infrastructure of the landfill, the leachate of it, subsurface water and groundwater. The plan must also consider the control of the entrance of the materials to the landfill.

## 5.5 Soil and groundwater.

The application for the permit should include a study of the identification of the different points of the installation that may pose a risk for the pollution of soil. In each of the points, a qualitative risk assessment should be performed to classify the risk and decide if prevention measures are needed. In the monitoring plan, the points with higher risk should be reviewed every year and if needed, soil should be sampled and analysed to check if there is any evidence of pollution of the soil. In the review of the points, the preventive measures should be monitored in order to check that they are implemented in the way that, if needed, will be effective.

Monitoring surveys will need to be established where sensitive soil systems or terrestrial ecosystems are at risk from indirect emission via the air. Operators of steel plants should provide a survey of PCDD/F levels in soil around the site and proposals for future monitoring.

There should not be any emission to groundwater, including during the extraction and treatment of water. Nevertheless, taking into account the location and the process of the site, mainly if there is groundwater in the area and the process includes activities that could lead to soil pollution like uncertainty about drainage systems (specially in old sites), the landfills or storage of materials on soil, the setting of a monitoring network should be considered. It should be designed to characterise both quality and flow and take into account short- and long-term variations in both. Monitoring will need to take place both upstream and downstream of the site.

## 5.6 Noise.





Noise surveys, measurements, investigations (e.g. on sound power levels of individual items of plant) or modelling may be necessary for either new or for existing installations, depending upon the potential for noise problems. Where appropriate, the operator should have a noise management plan as part of its management system.

An annual noise survey should be conducted following the prescriptions stated in the By-Law 26809 on the assessment and management of environmental noise, published in the Official Journal on the 07/03/2008.

## 5.7 Monitoring standards

1. As far as possible, Operators should ensure their monitoring arrangements comply with the requirements of the Turkish Accreditation Institute where available, for example using certified instruments and equipment, and using a stack testing organisation accredited to European standards. Where the monitoring arrangements are not in accordance with these requirements, the operator should provide justification and describe the monitoring provisions in detail.

## Sampling and analysis standards

- 2. As mentioned in the beginning of this chapter, for a given installation the integrated environmental permit should set clearly the parameters to monitor in an emission point, the method (specifying the standard used) and the frequency. Standards should be selected in the order of priority as given in the IPPC Bureau's Reference Document on the General Principles of Monitoring. This order is:
  - Committee European de Normalisation (CEN)
  - International Standardisation Organisation (ISO)

If the substance cannot be monitored using CEN or ISO standards then a method can be selected from any one of the following

- American Society for Testing and Materials (ASTM)
- Association Francaise de Normalisation (AFNOR)
- British Standards Institution (BSI)
- Deutsches Institute fur Normung (DIN
- United States Environmental Protection Agency (US EPA)
- Verein Deustcher Ingenieure (VDI)

If the substance cannot be monitored using any of the standards above then other methods may be adapted for use, following the requirements for validation in ISO 17025. For stack emission monitoring the following occupational methods may be adapted to the air emissions conditions:

• Methods for the Determination of Hazardous Substances (MHDS)





- National Institute for Occupational Safety and Health (NIOSH)
- Occupational Safety and Health Administration (OSHA)

The intended application of the standard method must always be taken into account. For example, a CEN method may be less suitable than another less-rigorously validated standard method if the application is not one for which the CEN method was developed.

Operators should be expected to be able to demonstrate compliance with the above hierarchy and validate the use of non-standard methods, in-house designed/developed methods, standard methods used outside their intended scope and modifications of standard methods to confirm that these methods are fit for purpose.

- 3. Further guidance on standards for monitoring gaseous releases relevant to IPPC is provided in the By-Law 27277 on the control of air pollution caused by industry, published in the Official Journal on the 03/07/2009. This guidance specifies manual methods of sampling and analysis that will also be suitable for calibration of continuous emission monitoring instruments. Further instructions relevant to water and waste sampling and analysis is available in the By-Law on water pollution control, , in the By-Law on the control of pollution caused by hazardous substances in the aquatic environment and its surroundings, in the By-Law on the control of soil pollution, and in the By-Law on the control of hazardous waste control.
- 4. In case of doubt the operator should consult the Regulator

## 5.8 Reporting on environmental monitoring and control

## 5.8.1 Monitoring of process variables and environmental performance indicators

Some process variables will have potential environmental impact and these should be identified and monitored as appropriate. Examples might be:

- Raw materials monitoring for contaminants which are likely to be present and if there is inadequate supplier information;
- Oxygen, carbon monoxide, pressure or temperature in the furnace atmosphere or offgases;
- Plant efficiency where it has an environmental relevance;
- Energy consumption across the plant and at individual points of use in accordance with the energy plan. Frequency – normally continuous and recorded;
- Fresh water use across the activities and at individual points of use should be monitored as part of the water efficiency plan. Frequency – continuous and recorded;
- The quantity of each class of waste generated.





The use of natural resources, energy and water in this sector will vary according to the production level and the characteristics of the site. There is also variability in the emission of the pollutants. Some of them, like heavy metals, do not degrade in the environment. Therefore it is important to benchmark the environmental performance of the sites with the available references and with the data of similar sites across the sector. It is important to agree the reporting and methodology to be able to compare the data.

Balance	Parameter	Units
Input	Lime	t/t LS
	Dolomite	t/t LS
	Carbon	t/t LS
	Scrap	t/t LS
	Energy by source	t/t LS
	Water by source	t/t LS
Output	Liquid Steel	t
	Finished steel by type	Т
To air	Particle	t/ t LS
	SO <sub>2</sub>	t/ t LS
	NOx	t/ t LS
To water	Volume (by release point)	m³/t LS
	COD	t/ t LS
	Suspended solids	t/ t LS
	Oil and grease	t/ t LS
	Metals	t/ t LS
To land	Filters dust	t/ t LS
	Slag by type	t/ t LS
	Scale	t/ t LS
	Refractory	t/ t LS
	Others	t/ t LS

## 5.8.2 E-PRTR

The European Pollutant Release and Transfer Register (E-PRTR) is the new Europe-wide register that provides easily accessible key environmental data from industrial facilities in EU Member States and in Iceland, Liechtenstein, Norway, Serbia and Switzerland. It replaces and improves upon the previous European Pollutant Emission Register (EPER).

The E-PRTR is established by Regulation No 166/2006 of the European Parliament and of the Council of 18 January 2006 concerning the establishment of a European Pollutant Release and Transfer Register and amending Council Directives 91/689/EEC and 96/61/EC.

According to the Regulation, a facility has to report data under E-PRTR if it fulfils the following criteria:





- The facility falls under at least one of the E-PRTR economic activities listed in Annex I of the E-PRTR Regulation and exceeds at least one of the E-PRTR capacity thresholds
- The facility transfers waste off-site which exceeds specific thresholds set out in Article 5 of the E-PRTR Regulation.
- The facility releases pollutants which exceed specific thresholds specified for each media air, water and land - in Annex II of the E-PRTR Regulation.

Steelmaking and hot rolling are included in Annex I, epigraph 2 (b) and 2 (c)

The data to be reported annually by each facility for which the applicable thresholds are exceeded are the following:

- Releases to air, water and land of any of the E-PRTR pollutants (91 listed in 2012);
- Off-site transfers of any of the E-PRTR pollutants (91 listed in 2012) in waste water destined for waste-water treatment outside the facility;
- Off-site transfers of waste (reported as tonnes per year) for recovery or disposal. For transboundary movements of hazardous waste outside the reporting country, details of the waste receivers have to be provided.

The reported releases include any introduction of any of the listed pollutants into the environment as a result of any human activity, whether deliberate, accidental, routine or non-routine, at the site of the facility. E-PRTR also contains information on releases from diffuse sources into water which will be upgraded and extended gradually.

In article 14 of the E-PRTR, Regulation provides that the European Commission shall draw up a guidance document supporting the implementation of the E-PRTR. Such a document was developed in 2006 (<u>http://prtr.ec.europa.eu/pgDownloadGuidance.aspx</u>).

Operators of facilities have to report all required information to the competent authorities in the EU Member States. Before submitting the data to the relevant competent authority, the operator should ensure an appropriate quality of the data by ensuring that the information is complete, consistent and credible.

The E-PRTR Regulation does not stipulate deadlines for the reporting from facilities to the competent authorities in the EU Member States. In accordance with the principle of subsidiarity, it is the responsibility of EU Member States to adopt such timelines at national level. These timelines must enable timely reporting to the Commission. Operators are obliged to keep records of the data from which the reported information was derived and a description of the methodology used for data gathering for a period of five years.

The guidance provides practical information on the following aspects:

 Identification of the facility. There is a table which gives an overview of information that is obligatory for the identification of the facility. It also gives additional information on what to report by means of explanations and examples.





- Coding of activities and identification of the main Annex I activity. It has to be carried out according to the coding system given in Annex I and IPPC code. Often the main Annex I activity is similar to the main economic activity of the facility.
- Release to water, air and land. Operators shall report any release above the threshold set in Annex II. All data has to be expressed in kg/year and with 3 significant digits. The reported data must include a reference to the determination methodology (measured M, calculated C o estimated E). Appendix 3 of the guidance contains a list of internationally approved measuring methods for air and water pollutants.
- Off-site transfer of pollutants in waste water. It means the movement beyond the boundaries of a facility of pollutants in waste water destined for waste-water treatment including industrial waste water treatment. The off-site transfer may be carried out via a sewer or any other means such as containers or (road) tankers.
- Off-site transfer of waste. It means the movement beyond the boundaries of a facility of waste destined for disposal or recovery.
- Measurement/calculation/estimation of releases and off-site transfers. The indication of M (measured) is given when the release or transfer is obtained from continuous or spot monitoring and, if necessary, flow. Calcutated C is indicated for those obtained through calculations using activity data. Finally, the indication of E (estimated) is use for determinations by assumptions or expert best guesses.

The annual quantities should be determined with a frequency and duration of data collection sufficient over the year to give reasonably representative and comparable data. When determining the frequency, it is important to balance the requirements with emission characteristics, risk to the environment, practicalities of sampling and the costs. Good practice also suggests matching the monitoring frequency to the timeframes over which harmful effects or potentially harmful trends occur. For more information see the BREF document on General Principles for Monitoring.

Reporting shall be based on the best available information which enables appropriate quality assurance and which is in accordance with internationally approved methodologies where such methodologies are available. Other methodologies can be used if they meet some criteria considered in the Guidance. The method used must be reported together with data.

 Quality assurance. Operators are obliged to use the "best available data" when preparing their reports. In accordance with article 9(2) of the E-PRTR Regulation, data reported by operators should be of high quality in particular as regards its completeness, consistency and credibility as defined below:

<u>Completeness</u> means that the reported data should cover all releases and off-site transfers of all pollutants and wastes exceeding thresholds for all facilities with Annex I activities above the capacity thresholds. The purpose of the reporting threshold values is to minimise the reporting burden, although reporting of releases lower than the thresholds is





also allowed. Completeness means also that all additionally required information on the identification of the facility and Annex I activities is fully reported.

<u>Consistency</u> means that data shall be reported on the basis of unambiguous and uniform definitions, source identification and reliable methodologies for the determination of releases over several years.

<u>Credibility</u> refers to the authenticity, reliability, comparability and transparency of the data.

The competent authorities have the duty to assess the quality of information provided by operators.

## 5.8.3 Reporting monitoring

Reporting of monitoring results involves summarising and presenting monitoring results, related information and compliance findings in an effective way. Good practice is based on consideration of the following items, which are explained in detail below:

- requirements and audience for the report
- responsibilities for producing the report
- scope of the report
- type of report
- good reporting practices
- Quality considerations.

Regarding <u>requirements and audience for the report</u>, it is considered good practice to know how and by whom the information will be used, so they can design their reports to be useable for the applications and users. Monitoring reports can be used mainly by the operators themselves, administration, general public and prosecutors. The main uses of the reports are:

- To check compliances with the permit and environmental law and give evidence of it in case of non-compliances.
- To take action in the event of non-compliance and document it.
- To show the environmental performance of the site through the indicators.
- To provide data for the inventories of the administration.
- To inform residents of the surrounding neighbourhoods and public groups.
- In some cases, to charge or provide data on pollutant emission for negotiating and trading of permitted emission quotas.

Regarding <u>responsibilities for producing the report</u>, it is good practice to assign reporting responsibilities to the appropriate level and organisation. There is a general trend in EU EU Member States towards putting more responsibility onto the operator. The European Law





requires that the operator's duty to report results from their own processes is stated unambiguously in the relevant permit or legislation, including specifying the scope and timing of the reports.

Normally the reports for groups or installations and the one at regional or national level are produced by the competent authority or a relevant government department.

Regarding the *scope of the report,* there are three main aspects to consider:

- Type of situation: good practice involves defining and addressing the situation(s) which led to the requirement for monitoring (programmed monitoring set by the permit, modifications in process, complaints, incidents, accidents, deviations from normal conditions of operation,...)
- Timing requirements: good practice involves defining and addressing the timing requirements specified in the permit or relevant legislation and those needed to assess compliance and/or environmental impacts.
- Location: Good practice includes reporting details of:
  - monitoring locations, i.e. description and explanation of why/how they were chosen
  - point and area sources, i.e. type, height and/or area of the emission
  - grid reference, i.e. definition of the position of each emission
  - receiving environments, i.e. details of local receiving environments
  - groups, i.e. say how groups of locations are defined.

Regarding <u>type of the report</u>, these can be classified in local or basic reports, national or strategic reports and specialised reports. Operators normally only produce local or basic ones that serve to generate the other ones. These local reports can be divided between the programmed ones, that are those that are foreseen in the permit, and non programmed ones, that are mainly those related to the deviations from the normal conditions of operation, like when emissions are above the ELVs, incidents, accidents, complaints,...

### 5.8.3.1.- Good reporting practices

There are three stages in the reporting of information on monitoring:

- a) Data collection
- b) Data management
- c) Presentation of results

(a) Data collection - this involves the acquisition of basic measurements and facts.

Considerations of the following items are good practice in data collection:





 <u>Schedules</u> – permits should contain schedules which state how, when, by whom and to whom the data are to be reported, and what types of data are acceptable (e.g. calculated, measured, estimated).

The schedule may cover the time-scales and locations of interest, and the format of the data. It can also give details of relevant limits, the units to be used and any normalisation required (e.g. to standard conditions of temperature and pressure).

- <u>Forms</u> standard forms should be used for collecting data so that it is easy to compare values and to identify gaps and anomalies. These forms may be paper based or electronic files
- <u>Data qualification details</u> standard forms should be used to record whether data values are based on measurements, calculations or estimations, and may also identify the methods used for monitoring, sampling and analysis. The forms may also include other relevant information concerning the data production chain such as timing considerations
- <u>Uncertainties and limitations data</u> these details must be collected and reported alongside the monitoring data (e.g. details of detection limits, numbers of samples available)
- <u>Operational context details</u> collected data must include details of the prevailing process operations and/or environmental conditions (e.g. fuel type, feedstock, utilisation, process temperature, production load, abatement equipment, weather conditions, river level).

**(b) Data management** - this involves the organisation of data and its conversion into information. Considerations of the following items are good practice in data management:

- <u>Transfers and databases</u> permits should specify how and when data are to be transferred. It is not necessarily desirable for all data to be sent from the operators to the authority, or for all necessary data to be sent immediately, as this could create handling and storage problems for the authority. Instead, data may be sent in line with agreed criteria and schedules, or in response to requests
- <u>Data processing</u> the permit should specify a plan for the collation, analysis and condensation of data. Processing would normally be carried out in stages, so that recent data are available in a detailed form and earlier data in a more summarised form. Each operator is principally responsible for condensing the data for his installation
- <u>Results below the detection limit</u> the approach for estimating these values should be explained when reporting the data.
- <u>Software and statistics</u> details of any software packages and statistical methods used to analyse or summarise the data can be provided in the report
- <u>Archiving</u> data can be systematically archived in a secure store, so that records of past performance are readily available. It is usually more practical for the operator to maintain this archive than the authority.





(c) Presentation of results - this involves the delivery of information to users in a clear and usable form. Considerations of the following items are good practice in the presentation of monitoring results, depending on the type of report:

- <u>Scope of the report</u> a clear reminder on the objectives of the monitoring covered by the report is useful to appreciate the impact of the results
- <u>Programme</u> permits can identify the users of reports and define a programme of presentations using different events and media as appropriate (e.g. public registers, publications, meetings, Internet). Each presentation usually includes opportunities for feedback
- <u>Trends and comparisons</u> presentations can set results in context by showing trends over time and comparisons with other sites and standards. Graphs and other forms of pictorial representation can be useful tools for supporting the presentation of the results
- <u>Statistical significance</u> reports should indicate if exceedences or changes are significant when compared with the uncertainties in measurements and process parameters
- <u>Interim performance</u> interim reports can provide performance statistics for the year to date
- <u>Strategic results</u> national and strategic reports can detail levels of compliance for different policies, activities, technologies, environmental receptors and geographical areas
- <u>Non-technical summaries</u> reports can be prepared for the public using non-technical language which can be readily understood by non-specialists
- <u>Distribution</u> permits or other relevant documents can state who is responsible for distributing reports, who should receive them and when, and the number of copies required.

EU legislation in general and the Aarhus convention<sup>3</sup> in particular, promote public access to environmental information. The IPPC and IE Directive require information for compliance assessment procedures, as established also in the By-Law on Integrated Environmental Permits In cases where confidentiality is allowed, it is good practice for the compliance assessment and the operator to make it clear why the information is not made available to the public.

## 5.8.3.2.- Quality considerations.

In order for reports to be used in decision making processes, they need to be readily available and accurate (to within stated uncertainties).

Data providers and report authors can achieve good practice in accessibility and quality of their reports by considering the following items:

<sup>&</sup>lt;sup>3</sup> The access of the public to the environmental information was promoted by the Aarhus Convention, signed in 1998, and included in the European legislation through Regulation 1367/2006 of application of the provisions of the Convention.





- <u>Quality objectives and checks</u> quality objectives for the technical standard and availability of reports should be set. Checks should be carried out to test how well these are being met. These may involve checks by both internal and external experts, and even certification under a formal quality management system
- <u>Competence</u> reports should be prepared by competent and experienced teams who may maintain their skills by participating in relevant technical groups and quality initiatives, e.g. in workshops and certification schemes
- <u>Contingency arrangements</u> special contingency arrangements should be in place for rapid reporting of abnormal and upset events, including off-scale conditions and breakdowns of monitoring equipment
- <u>Sign-off systems</u> it is desirable that a nominated person is responsible for the authenticity and quality of the information in each report using a "sign-off" system, which may be manual or electronic
- <u>Retention of data</u> the operator should retain basic monitoring data and reports for periods to be agreed with the authority and make them available to the authority on request
- <u>Falsification of data</u> regulators should define procedures for dealing with any falsification of reported monitoring results. These can include unannounced audits and effective legal sanctions.





## 6 EMERGING TECHNIQUES

The term 'emerging technique' is understood in this document as an innovative technique that has not yet been applied in any industrial sector on a commercial basis. This chapter contains those techniques that may appear in the near future and that may be applicable to the iron and steel production sector, i.e. steel production and casting. No further information is provided on the emerging techniques on other associated processes considered in chapters 2 and 4 of this guide, in order to limit the length of this guide and focus it in the most practical and relevant information (for the readers interested in emerging techniques of associated processes, please read sections A.6, B.6 and C.6, of the BREF Reference Document for the Ferrous Metals Processing Industry). For example, this chapter:

- identifies any novel pollution prevention and control techniques that are reported to be under development and may provide future economic or environmental benefits
- includes techniques to address environmental issues that have only recently gained interest in relation to the sector at hand
- does not include established techniques in other sectors that may be emerging in practice within this sector.

The structure to describe each of the emerging techniques is the same as the one explained in Table 4.1 of chapter 4.

Applied to this particular sector, the European Union has had (for more than 50 years) and continues to have a strong R&D programme to develop the steel sector. Some of the projects in this chapter have been financed by these programmes. As an example, one of the projects is the ULCOS (Ultra-Low Carbon dioxide Steelmaking) project. It is a consortium of 48 European companies and organisations from 15 European countries. The aim of the project is to reduce de CO2 emissions by at least 50%.

## 6.1 General emerging techniques

## 6.1.1 CO<sub>2</sub> capture and storage

## Description

One option to reduce CO2 emissions is Carbon Capture and Storage (CCS), which is regarded as a bridging technology with a certain potential to mitigate climate change for some decades. It is currently being developed for application in power production and in CO2 intensive industrial plants such as e.g. iron and steel production.

CCS is a process chain consisting of three consecutive steps:

a) capture: CO2 separation from a flue gas or industrial gas stream





- b) transport: the separated CO2 is compressed to the liquid or supercritical state and transported to a storage site
- c) storage (sequestration) in geological formations.

Regarding step a) capture: several capture processes are still in the phase of research and development. Other processes have been applied for some decades, but currently there is no large scale reference plant that gives proof of their applicability. Up to now, chemical and physical absorption processes have been applied predominantly for CO2 removal in natural gas production. Different to that, there are other species present in flue gases derived from oxidation processes, such as NOx, SOx, O2, etc., which lead to technological problems such as high solvent consumption due to oxidative degradation. There is still a need to further develop capture processes, especially to reduce the significant energy demand of capture processes.

Regarding step b) transport: CO2 transport takes place in the compressed (liquid or supercritical) state, e.g. in pipelines or, in single applications by ship. Lorry transport shall not be applied due to its high specific energy demand as well as because of safety considerations.

Regarding step c) storage (sequestration): supercritical CO2 is stored in on-shore or off-shore geological formations, e.g. oil and gas fields, depleted coal mines or saline aquifers. Storage in the marine water column or on the seabed is prohibited by the OSPAR Convention. Directive 2009/31/EC also enables injection in still producing natural gas or oil fields (EHR, Enhanced Hydrocarbon Recovery), but in this case a significant amount of the injected CO2 is being transported out of the geological storage site in the course of ongoing hydrocarbon production.

### Achieved environmental benefits

The emissions of CO2 decrease to a large extent when the separated CO2 can be stored in onshore or off-shore geological formations.

### Cross-media effects

CO2 capture and storage significantly increases energy demands (especially for capture and compression), which normally increases CO2 and air pollutants (e.g. NOx) emissions. The amount of avoided or net captured CO2 represents the difference between emissions with and emissions without implementing the technique.

CO2 storage has been carried out for several decades predominantly in course of enhanced oil recovery (EOR) in the United States and on-shore and off-shore storage, e.g. in the Sleipner gasfield in Norway. In these projects CO2 and other species derived from natural gas/oil cleanup are reinjected in a gas/oil field, so that chemical interaction with the cap-rock is not expected.

CO2 derived from other processes could contain a wider range of species which have not been in contact with the cap-rock before. Possible interaction of these contaminants of the CO2 stream with the cap rock should be subject to further investigation.





CO2 storage in saline aquifers is a new and unknown application, and its long-term influence on ground water quality, etc. still should be investigated.

Quality requirements with regard to CO2 pureness and tolerable amounts of other species present in the CO2 stream have been specified, e.g. by the DYNAMIS project [ 181, Vangkilde-Pedersen et al. 2007 ], their applicability in practice has yet to be proved.

Monitoring techniques for surveying storage site integrity and leakage/seepage of CO2 from the storage site need to be upgraded in terms of accuracy and detection limits.

CO2 transport is a major issue in terms of safety for human health and nature.

## **Operational data**

According to international energy agency (IEA) and results from the experimental blast furnace trials, CO2 capture and storage, when applied to the core process blast furnace, could amount to a reduction up to 75 % of the total emissions.

Capturing the remaining CO2 emitted from non-core processes such as coke ovens, sinter plants, basic oxygen furnaces and rolling mills, could only be achieved at considerably higher costs.

## Applicability

Based on the first trials with the experimental blast furnace CO2 from blast furnaces could be removed by redesigning the blast furnace to use oxygen and removing the CO2 with physical absorbents. Further trials for proving this technology and the applicability of this process for an upscaling to an operational blast furnace are necessary.

### Economics

The IPCC gives a range of capture costs between USD 25 and 115 (2002)/t CO2 net captured for the industrial sector. This wide range reflects on the one hand the variety of technologies used and on the other hand it reflects the missing experience with that technology. These published figures should therefore only be considered as a rough estimate and presenting one scenario among many other possible ones. Because of R&D efforts, those current costs could be reduced by at least 20 - 30 % over the next ten years. However many uncertainties remain for costs in an industrial sector such as iron and steel due to its lack of capture experience. Additional costs for capture are transportation costs (USD 1 - 8 (2002)/t CO2 transported over 250 km) and geological storage costs (USD 0.5 - 29 (2002)/t CO2).

## **Reference literature**

[ 179, Metz et al. 2005 ] [ 180, N.N. 2008 ] [ 181, Vangkilde-Pedersen et al. 2007 ]

# 6.1.2 Ceramic filters for the abatement of both particles and nitrogen oxides from gas streams

Description





This dry flue-gas cleaning uses ceramic filters. They are designed to combine filtration and SCR reaction in one unit using a catalytic filter. These filters allow for the use of the high energy content of the gas as well as preventing the plugging of the catalyst (oxides of Ti, V and W).

Furthermore, the combination of two units into one unit reduces processing costs as well as investment and maintenance costs.

Ceramic hot gas filter elements with a fine filtering outer membrane and a catalyst integrated into the support structure of the filter elements can be used to achieve an efficient particle removal as well as an efficient NOX removal. The use of these filter elements enables the combination of a filter and an SCR reactor into one unit. Moreover, the function of the integrated catalytic layer can be tailored in such a way as to allow not only catalytic NOX removal but also the catalytic oxidation of volatile organic compounds (VOC).

The pollutants SO2 and HCl are removed by using, for example, sodium bicarbonate (NaHCO3)or calcium hydroxide (Ca(OH)2) as sorbents, whereas NOX is catalytically converted with NH3 and O2 to N2 and H2O by passing through the catalytic filter elements.

## Achieved environmental benefits

Preliminary results reduced NO content by 83 - 98 % (NO inlet at levels of 500 - 1720 ppmv and temperatures between 140 - 360 °C). By injecting sodium bicarbonate, the removal of SOX can be up to 99 %. Filtration efficiencies are typically higher than 99.99 %.

## Cross-media effects

N2O formation was not detected.

## **Operational data**

This system has a simpler plant set-up compared to a wet cleaning process and tends to be smaller. This system can work at high temperatures (up to 500  $^{\circ}$ C).

### Applicability

Especially applicable for small and medium scale plants.

### Economics

The capital investment, maintenance and running costs are lower than for a conventional multistep wet flue-gas cleaning system. Moreover, the dry cleaning system prevents waste water generation in the gas cleaning process.

### **Example plants**

The technique has been tested in Spain at a biomass power plant of 3.5 MWth.

### **Reference literature**

[ 377, Heidenreich et al. 2007 ] [ 381, Pall 2006 ]

## 6.2 Emerging techniques for EAF





## 6.1.3 Contiarc furnace

## Description

The Contiarc furnace is a direct current arc furnace with an annular shaft formed by an outer and inner vessel. The furnace operates continuously with raw material being charged into the top of the annular shaft. The submerged, continuous nature of the furnace makes it more energy efficient than the cupola. In addition, it is now possible to both melt and smelt iron in the same furnace system producing 80 tonnes/hr while melting and smelting. The furnace can take lowgrade scrap (automobile shreddings), direct reduced iron (DRI) and/or hot briquetted iron (HBI) and combine it with coal and silica rock to produce quality ductile base iron with 3.5 % carbon (C) and 2.5 % silicon (Si).

The furnace is charged automatically through a hopper system that feeds a conveyor to the top of the furnace. Once the charge reaches the top of the furnace, it is deposited into one of eight hoppers that are positioned in a rotating carousel around the top of the furnace. The computerised charging system works in unison with the computerised furnace control system to determine where within the annular shaft a charge is required.

By maintaining a full stack of charge material, the heat content of the furnace gases acts as a preheater for the charge material. Due to the volume of gas, stack permeability is not an issue; however, the charge material must be sized properly to prevent bridging in the stack.

The continuous arc melting concept is driven by the central cathode (graphite electrode) inside the inner vessel and the corresponding conductive bottom anode. In a traditional arc furnace, when a charge is added, the electrode rises to the top of the charge. In the continuous arc furnace, the inner vessel keeps the electrode submerged. The central graphite electrode is protected against damage from falling scrap by the inner vessel. Its tip operates at a distance below the bottom of this vessel so that the long direct current arc burns between the electrode and the molten metal bath. The shell is shielded from the radiation of the direct current arc by charge materials.

The completely encapsulated melter ensures a reducing atmosphere in the lower part of the furnace and a slightly oxidising condition in the shaft to achieve the desired process metallurgy and a utilisation of gases. In addition, this design results in low losses of oxidised iron or silicon. A bag house system captures emissions.

### Main achievements

The Contiarc furnace is designed to perform both melting and smelting operations. This provides the following advantages:

- the ability to melt low-cost and abundant shredded scrap, borings, HBI and/or DRI (thus maintaining tramp element control)
- quartz (SiO), through gravel used in the construction industry, can be substituted for highcost ferrosilicon as a means of developing the necessary silicon level in the melt





- coal can be used instead of coke during melting to carburise the base metal and reduce the quartz because the carbon product is not required for heat generation
- without the use of coke, the sulphur level of the molten metal is reduced
- there is less slag with the Contiarc than that associated with the cupola since it is a reduction furnace which means that many oxides that normally act as slag are reduced back into the metal
- during melting, the temperature control in the Contiarc furnace is flexible meaning it can be adjusted by a simple variation of the current/voltage ratio. This allows the iron to be superheated before tapping.

### Example plants

In July 2001, the first continuous submerged direct current electric arc (Contiarc) furnace went into operation at ACIPCO, Birmingham, US.

## 6.1.4 Intermetallic bag filter to minimise emissions of dust, PCDD/F and heavy metals

## Description

An intermetallic bag filter with high-temperature resistance combines filtering and catalytic operations and allows for a drastic decrease in dust and associated pollutant emissions.

### Achieved environmental benefits

In pilot tests at LME Trith-Saint-Léger, France, a dust reduction efficiency of 99.9 %, a PCDD/F reduction efficiency of more than 95 % and a heavy metal reduction efficiency of 95 – 100 % (except for heavy metals present in the gas phase like mercury) were achieved. Moreover, energy can be saved as a consequence of moderate waste gas cooling. This technique should be operated at 350 – 550 °C, whereas traditional cleaning is operated at 150 – 200 °C.

### Reference literature

[ 252, France 2007 ]

## 6.1.5 Recovery of old tyres in EAF

### Description

As has been applied in cement plants, old tyres (which represented 2.2 Mt/yr in Europe in 1999) can be recovered and can replace coal (anthracite) in electric steelmaking. An optimised recovery process in EAF requires an adapted addition of tyres, charged at the right place, neither on top nor at the bath bottom, and oxygen lances should be operated in such a way as to prevent post-combustion anywhere else than in the arc furnace.





## Achieved environmental benefits

This technique allows for both the recovery of old tyres and a decrease in the demand of coal mining.

## **Cross-media effects**

Recovery of old tyres does not give extra emissions in terms of PCDD/F, heavy metals, PAH, SO2, and VOC and does not demand extra energy.

## **Example plants**

In pilot tests at Ascometal Hagondange, SAM Neuves-Maisons and LME Trith-Saint-Léger, all three in France, a substitution rate of 1.7 kg old tyres for 1 kg anthracite was achieved. An addition of 5 – 12 kg old tyres/t LS is achievable if tyres are cut into small pieces at a length of no more than 10 - 15 cm. In 2006, LME Trith-Saint-Léger, France had a treatment capacity of 7000 tonnes old tyres/yr.

Also ArcelorMittal, Belval and Differdange, both in Luxembourg have carried out some trials.

## **Reference literature**

[ 252, France 2007 ]

# 6.1.6 Recycling of (BOF and EAF) slags as a flux agent in electric steelmaking

### Description

Several techniques have been tested to recycle BOF and EAF ladle slags:

a) recycling of liquid ladle slag into the EAF. A recycling rate of 80 % has been achieved

b) recycling of solid ladle slag into the EAF. Around 15 % of lime has been substituted by ladle slag in with ratio of 1:2. About 50 % of the generated ladle slag can be recycled

c) recycling of spent refractory materials from EAF, BOF and secondary metallurgy. Careful processing and quality controls are a prerequisite in recycling.

### Achieved environmental benefits

For technique a) no processing of the slag is necessary.

For technique b) no processing of the slag is necessary.

For technique c) spent magnesite is a suitable substitute for olivine and of soft-burnt dolomite.

## Cross-media effects

For technique a) some increases in the total energy consumption can be seen due to the additional opening of the furnace.

### **Operational data**





For technique a) no detrimental impact has been observed on the quality of steel in the EAF.

For technique b) the handling of solid materials has the advantage that a selection of favoured slag composition is possible. Some minor effects with respect to metallurgy and steel quality are induced.

## Applicability

For technique c) a recycling test has been carried out at a sinter plant, a blast furnace burden and a BOF converter.

### Economics

For technique b) the operational costs are counterbalanced by savings in lime. Economic benefits are due to the reduced amount of dumped ladle slag.

## Driving force for implementation

A step towards steelmaking without residues is the driving force for implementation.

### **Example plants**

RIVA Acciaio, Verona Works, Italy; Krupp Edelstahlprofile (KEP), Siegen, Germany; EKO Stahl, Eisenhüttenstadt, Germany.

#### **Reference literature**

[ 386, Cores et al. 2005 ]





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# ANNEX 1. CHECK-LISTS TO BE USED IN THE ASSESSMENT OF THE PERMIT APPLICATION

CONTENTS OF THE PERMIT APPLICATION FILE						
	DESCRIPTION			CHECK		
	Name of the company					
		Full address	2			
	Owner of the company	VAT number	3			
		Main activity	4	Γ		
		Name of the company	5			
		Data of the contact person (in each work centre)	6			
	Operator (If is different from	Full address	7	Γ		
	the owner)	VAT number	8			
		Main activity	9			
		Number of work centres	10			
		Register number of industrial establishments	11			
		National Classification of Economic Activities (NACE)	12			
		Total number of workers	13	Γ		
		Investments targeted to environmental improvements.	14			
		Organization chart	15			
	Description of the installation	UTM coordinates	16			
	and technical characteristics	Activity of Annex I of the By Law	17			
		Main activity and others	18	Γ		
		Nominal production/treatment capacity and size	19			
		Planned date for commencing and completion of building	20	Г		
		activities (for new installations)	20	L		
RT		Planned date for starting operation (for new installations)	21			
0d		Operational time of the installation	22			
L RE		Production process description, with a schematic flow	22	Г		
G		chart divided into phases.	25	L		
ſQ		Description of the phases	24			
4	Description of the production	Operational hours in each phase	25			
	process	The methods of operation (continuous or discontinuous)	26			
		Description of the equipment and the techniques used,		_	_	
		specifying which of them are considered as Best Available	27	L		
		Techniques (BAT)				
		Energy consumption: use of fuel for heat and steam				
		generation and for transport inside the enterprise not				
		including use of fuel for production of electricity or	20		-	
		combined power and neat, use of neat and steam from	28			
		external suppliers, use of electricity, use of fuel for				
		production of electricity and heat -power plants and boiler bouses. Measures to increase energy officiency				
		Water: quantity of water used in the process, intake of				
		surface ground and marine water -detailed description of				
	petaled description of the	intake, and indication of the cases of supply of water from	29			
	auviliary materials and products	outside or re-circulated				
	auxiliary materials and products	Raw materials: list and quantities of raw materials	+		_	
		indicating hazardous or non-hazardous character	30	L		
		Auxiliary materials: list and quantities of auxiliary	ry us 31			
		materials, indicating hazardous or non-hazardous			ר	
		character		-	-	
		Products and by-products: list of output products and by-				
		products, types and quantity generated of each of them,	32	Γ	ן ר	
		per hour, day or year.				





CONTENTS OF THE PERMIT APPLICATION FILE						
	DESCRIPTION			CHECK		_
		Modelization requirements		33		<u> </u>
		Air quality	Plan for monitoring of immisions	34	Ļ	<u> </u>
			Description of the emission points	35		
			Requirements and technical conditions of the focus	36	Г	٦
			(including operational hours)	37		
		Air:	Gaseous effluents generated (air flow, temperature and			٦
		Channelled	pollutants emitted and their amounts)			
		emissions:	Abatement equipment, specifying which ones are BAT	38		╡
			Plan for Monitoring and Control	39		╡
		A	Description of the emission points	40 [		╡
		Alf: Non	Pollutants emitted	41		╡
		channelled	Abatement equipment, specifying which ones are BAT	42		_
		emissions	Plan for Monitoring and Control	43		
			Description of sources (location and characterization)	44		
			Acoustic study	45		
			Abatement measures, specifying which ones are BAT	46		
		Noise	Plan for Monitoring and Control	47		
RT			Description of the flow (including discharging points) and		_	_
DO			the associated process (industrial, sanitary, rainwater or	48		
r re			other discharges)			
ECI			Requirements and technical conditions of discharging	49	Г	٦
SOJ			points			
Ы		Waste water	Description of pollutants and emitted amounts	50		4
			WWIP (specifying BAT)	51		╡
			Monitoring and control (sampling points)	52		
		Hazardous waste	Production (amounts) and characterization (classification	53	Ľ	
			Storage conditions	Γ4		-
			Storage conditions Provention on pollution measures (specifying PAT)	54		╡─
	Environmental		Waste management (incide/offcide treatment)	55		╡—
	emissions and controls		Plan for minimization of waste	50		╡
		ols Non hazardous waste	Characterization (classification amounts and labelling)	58		╡—
			Prevention on pollution measures (specifying BAT)	59		╡─
			Waste management (inside /offside treatment)	60		╡
		Packaging waste	Characterization	61		╡
			Plan for minimization of waste	62		╡
			Safety measures for storage, specifying BAT	63	Ē	1
		Soil and	Systems of drainage or collection of potentially polluted	-		
		groundwater	waters.	64		
		protection	Plan for monitoring and control	65	E	J
			Situations when not normal operation will take place.	66		 ר
		Net a surrest	Characterization	00		
		Not normal	Measures which will be taken to minimize environmental	67		٦
		operation	impact in these not normal conditions	07		
		conditions	Description of operation under emergency situations	68	Ē	]
			Measures to be taken upon definite cessation of activities	69		]
ADDITIONAL NFORMATION	Non-technical summary of the details specified in the foregoing paragraphs			70		
	Environmental Impact Assessment (EIA) Report (for new installations, article 11 By Law			71		
	26939)					
	Development plans and landscape planning report			72		<u> </u>
	SEVESU report (classification of the installation according to applicable legislation on control			73		]
	Identification of the information which the applicant deems to be confidential under the					
=	provisions in force		74			
	Any other documentation evidencing compliance with the requirements under the applicable		75	Г	]	





CONTENTS OF THE PERMIT APPLICATION FILE				
	DESCRIPTION		CHECK	
	environmental legislation including, where applicable, the legislation on obligatory security or insurance required under the applicable environmental legislation			
	The baseline report, that shall contain the information necessary to determine the state of soil and groundwater contamination so as to make a quantified comparison with the state upon definitive cessation of activities	76		
	Receipt of the fees paid by the operator	77		

## BREF SECTIONS TO BE TAKEN INTO ACCOUNT TO ESTABLISH THE PERMIT'S CONDITIONS

The sections indicated below correspond by default to the BREF Document for Iron & Steel Industry. Where there is reference to other relevant BREF Documents, their name is explicitly indicated.

	SUBJECT	BREF SECTION				
1	EAF process optimisation	8.3.1				
BATs	on air emissions					
2	Advanced emission collection systems	8.3.4, 9.7				
	Abatement techniques for primary and secondary	8.3.5, 9.7				
3	emissions to air from electric arc furnaces					
4	Reducing of dust emissions from slag processing	8.3.3, 9.7				
Adopt	Adopted BAT Conclusions					
	Diffuse dust emissions from materials storage,	9.1.5, 9.7				
	handling and transport of raw materials and					
5	(intermediate) products					
6	Prevention of mercury emissions	9.7				
7	Primary and secondary dedusting	9.7				
8	Dust emissions from slag processing	9.7				
BATs on emissions to water and wastewater						
9	Treatment of waste water from continuous casting	8.3.6				
10	Closed loop water cooling system	8.3.7				
11	Adopted BAT conclusions	9.1.6, 9.7				
BATs on solid waste and by-products						
12	EAF dust processing for the recovery of heavy metals	8.3.8				
13	EAF slag processing	8.3.9				
	Treatment of high alloyed and stainless steel EAF	8.3.10				
14	slags					
15	Adopted BAT conclusions	9.1.4, 9.7				
BATs on raw materials and fuel and energy consumption						
16	Scrap preheating	8.3.2				
17	Near net shape strip casting	8.3.11				
18	Adopted BAT Conclusions	9.1.2, 9.1.3, 9.7				
BATs on noise and vibrations						
19	Techniques to prevent noise emissions	8.3.12				
20	Adopted BAT conclusions	9.1.9, 9.7				
21	BATs on soil and groundwater pollution prevention					





	SUBJECT	BREF SECTION	
	BAT conclusions on Environmental management	9.1.1, 9.1.7	
22	and Monitoring		
23	BAT conclusions on Decommissioning	9.1.8	
BATs	on processes associated to EAF: Hot rolling , cold rol	ling, wire drawing plants and	
galvar	nizing of sheet		
24	Hot rolling mill	<b>BREF Ferrous Metals Processing</b>	
		Industry:	
		o A.4.1.2.1-2	
		o A.4.1.3.1	
		o A.4.1.3.4-5	
		o A.4.1.3.7	
		o A.4.1.7	
		o A.4.1.8.8-9	
		o A.4.1.12.2	
		o A.4.1.13.2	
		o D.2.2	
25	Cold rolling mill	<b>BREF Ferrous Metals Processing</b>	
		Industry:	
		o A.4.2.2.7-8	
		o A.4.2.2.10	
		o A.4.2.2.11-14	
		o A.4.2.2.18	
		o A.4.2.2.19-20	
		o A.4.2.2.28	
		o A.4.2.3.8-9	
		o A.4.2.4.3-5	
		o A.4.2.4.9-11	
		o A.4.2.6.1	
		o A.4.2.6.4	
		o A.4.3.3.1-4	
		o A.4.3.5.1	
		o A.4.3.6.2-3	
		o A.4.3.8/10	
		o D.5.2-3	
26	Galvinizing of sheet	BREF Ferrous Metals Processing	
		Industry:	
		o B.4.1.3.1-2	
		o B.4.1.3.4	
		o B.4.1.3.6-7	
		0 B.4.1./.3-6	
		o B.4.1.9	
HORIZ	ONTAL ISSUES		
27	Emission monitoring and reporting	BREF on General Principles of	
		Monitoring	




## ANNEX 2. BEST AVAILABLE TECHNIQUES (BATS) ASSOCIATED EMISSION LEVELS

#### ELECTRIC ARC FURNACE STEELMAKING AND CASTING

BAT Conclusions for Electric Arc Furnace Steelmaking and Casting.

- mass of emitted substances per volume of waste gas under standard conditions (273,15 K, 101,3 kPa), after deduction of water vapour content, expressed in the units g/Nm 3 , mg/Nm 3 , µg/Nm 3 or ng/Nm 3
- Mass of emitted substances per volume of waste water, expressed in the units g/l, mg/l or  $\mu$ g/l.

Best Available Techniques / Split views on BAT	BAT associated emission levels
Primary and secondary dedust	ing
Efficient extraction of all emission sources by using one of the	The overall average collection
techniques listed below and to use subsequent dedusting by	efficiency associated with BAT is
means of a bag filter:	>98 %.
	Dust level:
I. A combination of direct off-gas extraction (4th or 2nd hole)	<5 mg/Nm3, determined as a
and hood systems	daily mean value.
II. direct gas extraction and doghouse systems	
III. direct gas extraction and total building evacuation (low-	Mercury level:
capacity electric arc furnaces (EAF) may not require direct gas	<0.05 mg/Nm3. determined as
extraction to achieve the same extraction efficiency).	the average over the sampling
	period (discontinuous
	measurement, spot samples for
	at least four hours)
	,





Prevent and reduce polychlorinated dibenzodioxins/furans	Polychlorinated
<ul> <li>(PCDD/F) and polychlorinated biphenyls (PCB) emissions by avoiding, as much as possible, raw materials which contain PCDD/F and PCB or their precursors using one or a combination of the following techniques, in conjunction with an appropriate dust removal system:</li> <li>I. appropriate post-combustion</li> <li>II. appropriate rapid quenching</li> <li>III. injection of adequate adsorption agents into the duct</li> </ul>	dibenzodioxins/furans (PCDD/F) level: <0.1 ng I-TEQ/Nm <sub>3</sub> , based on a 6 – 8 hour random sample during steady-state conditions. In some cases, the emission level can be achieved with primary measures only
before dedusting	
Slag processing	
Reduce dust emissions by using a:	dust level:
I. efficient extraction of the slag crusher and screening devices with subsequent offgas cleaning, if relevant	< 10-20 mg/Nm <sup>3</sup> , determined as the average over the sampling period (discontinuous measurement, spot samples for at least half an hour)
Casting	
<ul> <li>Minimise the waste water discharge from continuous casting by using the following techniques in combination:</li> <li>I. the removal of solids by flocculation, sedimentation and/or filtration</li> <li>II. the removal of oil in skimming tanks or in any other effective device</li> <li>III. the recirculation of cooling water and water from vacuum generation as much as possible.</li> </ul>	Levels for waste water based on a qualified random sample or a 24-hour composite sample, are: suspended solids <20 mg/l iron <5 mg/l zinc <2 mg/l nickel <0.5 mg/l total chromium <0.5 mg/l total hydrocarbons <5 mg/l

# HOT ROLLING MILL: Emission levels associated with the best available techniques (BAT)





consumption levels / Split views on associated levels
Split views on associated levels
Machine scarfing
• Enclosures for machine scarfing and dust abatement with split view on dust level:
fabric filters. < 5 mg/Nm <sup>3</sup>
< 20 mg/Nm³
Electrostatic precipitator, where fabric filters cannot be     split view on dust level:
operated because of very wet fume. < 10 mg/Nm <sup>3</sup>
20 - 50 mg/Nm³
Grinding
• Enclosures for machine grinding and dedicated booths, split view on dust level:
equipped with collection hoods for manual grinding and < 5 mg/Nm <sup>3</sup>
< 20 mg/Nm <sup>3</sup>
Re-heating and heat treatment furnaces
Careful choice of fuel and implementation of furnace
automation/control to optimise the firing conditions. SO2 levels:
<pre>- for natural gas</pre> < 100 mg/Nm3
$\sim 100 \text{ mg/Nm}^3$
- for all other gases and gas mixtures
- for fuel oil (< 1 % S)
Recovery of heat in the waste gas by feedstock pre-     Energy savings 25 - 50 % and
heating NOx reductions potentials of up
• Recovery of heat in the waste gas by regenerative or to 50 % (depending on system).
recuperative burner systems
evaporative skid cooling (where there is a need for steam)
<ul> <li>Second generation low-NOx burners</li> <li>NOx 250 - 400 mg/Nm<sup>3</sup> (3% O2)</li> </ul>
without air pre-heating
reported
NOx reduction potential o
about 65 % compared to conventional





<ul> <li>Limiting the air pre-heating temperature. Trade-off energy saving vs. NOx emission: Advantages of reduced energy consumption and reductions in SO2, CO2 and CO have to be weighed against the</li> </ul>	
disadvantage of potentially increased emissions of NOX	
Finishing train	
<ul> <li>Exhaust systems with treatment of extracted air by fabric filters and recycling of collected dust.</li> </ul>	split view on dust level: < 5 mg/Nm <sup>3</sup> < 20 mg/Nm <sup>3</sup>
Levelling and welding	
Suction hoods and subsequent abatement by fabric filters	split view on dust level: < 5 mg/Nm <sup>3</sup> < 20 mg/Nm <sup>3</sup>
Waste water treatment/ scale- and oil-contair	ing process water
• Operating closed loops with recirculating rates of > 95 %	
Reduction of emissions by using a suitable combination of	SS: < 20 mg/l
treatment techniques	Oil: < 5 mg/l
	Fe: < 10 mg/l
	Cr <sub>tot</sub> : < 0.2 mg/l
	Ni: < 0.2 mg/l
	Zn: < 2 mg/l

# COLD ROLLING MILL: Emission levels associated with the best available techniques (BAT)





Best Available Techniques / Split views on BAT	BAT-associated emission and
	consumption levels /
	Split views on associated levels
Decoiling	
• Enclosures for machine scarfing and dust abatement with	split view on dust level:
fabric filters.	< 5 mg/Nm³
	< 20 mg/Nm³
• Exhaust systems with treatment of extracted air by fabric	split view on dust level:
filters and recycling of collected dust.	< 10 mg/Nm <sup>3</sup>
	20 - 50 mg/Nm <sup>3</sup>
HCl pickling	-
Regeneration of the acid by spray roasting or fluidised bed (or	Dust 20 -50 mg/Nm <sup>3</sup>
equivalent process) with recirculation of the regenerate; air scrubbing system for the regeneration plant: reuse of Fe2O3	HCl 2 – 30 mg/Nm <sup>3</sup>
by-product.	SO2 50 - 100 mg/Nm <sup>3</sup>
	CO 150 mg/Nm <sup>3</sup>
	CO2 180000 mg/Nm <sup>3</sup>
	NO2 300 – 370 mg/Nm <sup>3</sup>
Totally enclosed equipment or equipment fitted with hoods	Dust 10 - 20 mg/Nm <sup>3</sup>
and scrubbing of extracted air.	HCl 2 – 30 mg/Nm
H2SO4 Pickling	
Recovery of the free acid by crystallisation; air scrubbing	H2SO4 5 - 10 mg/Nm <sup>3</sup>
devices for recovery plant.	SO2 8 – 20 mg/Nm <sup>3</sup>
Totally enclosed equipment or equipment fitted with hoods	H2SO4 1 - 2 mg/Nm <sup>3</sup>
and scrubbing of extracted air.	SO2 8 - 20 mg/Nm <sup>3</sup>
Mixed acid pickling	
Acid regeneration .	
- by spray rosting	Dust < 10 mg/Nm <sup>3</sup>
	HF < 2 mg/Nm <sup>3</sup>
	NO <sub>2</sub> < 200 mg/Nm <sup>3</sup>
or by by avaparation process	
- or by by evaporation process	HF < 2 mg/Nm <sup>3</sup>
	NO <sub>2</sub> < 100 mg/Nm <sup>3</sup>





<ul> <li>Enclosed equipment/hoods and scrubbing, and additionally:</li> <li>Scrubbing with H2O2, urea etc.</li> <li>or NOx suppression by adding H2O2 or urea to the pickling bath</li> </ul>	for all: NOx 200 - 650 mg/Nm³ HF 2 – 7 mg/Nm³
• or SCR.	
Waste water treatment	
Treatment by neutralisation, flocculation, etc., where acidic	SS: < 20 mg/l
water blow-down from the system cannot be avoided.	Oil: < 5 mg/l
	Fe: < 10 mg/l
	Crtot:< 0.2 mg/l
	Ni: < 0.2 mg/l
	Zn: < 2 mg/l
Rolling and tempering	
• Exhaust system with treatment of extracted air by mist	Hydrocarbons:
eliminators (droplet separator).	5 – 15 mg/Nm³.
Annealing furnaces	
• For continuous furnaces, low NOx burners.	NOx 250–400 mg/Nm <sup>3</sup> without air pre-heating, 3 % O2. Reduction rates of 60 % for NOx (and 87 % for CO)
Levelling and welding	
• Extraction hoods with dust abatement by fabric filters.	split view on dust level:
	< 5 mg/Nm <sup>3</sup>
	< 20 mg/Nm²

# WIRE DRAWING PLANTS: Emission levels associated with the best available techniques (BAT)





Best Available Techniques / Split views on BAT	BAT-associated emission and consumption levels / Split views on associated levels
Pickling	
For of pickling baths with high vapour emission, e.g. heated or concentrated HCI-bath: installation of lateral extraction and possibly treating of the extraction air for both new and existing installations.	HCl 2 – 30 mg/Nm <sup>3</sup> .
Continuous annealing of low carbon wire a	nd patenting,
Good housekeeping measures, for the lead bath.	Pb < 5 mg/Nm <sup>3</sup> , CO < 100 mg/Nm <sup>3</sup> TOC < 50 mg/Nm <sup>3</sup> .

# GALVANIZING OF SHEET: Emission levels associated with the best available techniques (BAT)

Best Available Techniques / Split views on BAT	BAT-associated emission and consumption levels / Split views on associated levels
Pickling	
Refer to the chapter of Cold rolling Mills.	
Heat treatment furnaces	
Low-NOx burners.	NOx 250 - 400 mg/Nm <sup>3</sup>
	(3% O2) without air preheating
	CO 100 - 200 mg/Nm <sup>3</sup>
Galvannealing	
Low-NOx burners.	NOx 250 - 400 mg/Nm <sup>3</sup>
	(3% O2) without air preheating





Waste water	
Waste water treatment by a combination of	
sedimentation,	SS: < 20 mg/l
filtration and/or flotation/ precipitation/flocculation.	Fe: < 10 mg/l
Techniques or equally efficient combinations of individual	Zn: < 2 mg/l
treatment measures	Ni: < 0.2 mg/l
For existing continuous water treatment plants which only	Crtot: < 0.2 mg/l
achieve Zh < 4 mg/i, switch to batch treatment.	Pb: < 0.5 mg/l
	Sn: < 2 mg/l





# ANNEX 3. EU REGULATION 333/2011 AFFECTING SCRAP METAL MANAGEMENT

### Council Regulation (EU) No 333/2011

### of 31 March 2011

### establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives [1] and in particular Article 6(2) thereof,

Having regard to the proposal from the European Commission,

After submission of the proposed measures to the European Parliament,

Whereas:

(1) It results from an evaluation of several waste streams that recycling markets for scrap metal would benefit from the development of specific criteria determining when scrap metal obtained from waste ceases to be waste. Those criteria should ensure a high level of environmental protection. They should be without prejudice to the classification of scrap metal as waste by third countries.

(2) Reports of the Joint Research Centre of the European Commission have shown that a market and demand exist for iron, steel and aluminium scrap to be used as feedstock in steel works, foundries, aluminium refiners and remelters for the production of metals. Iron, steel and aluminium scrap should therefore be sufficiently pure and meet the relevant scrap standards or specifications required by the metal producing industry.

(3) The criteria determining when iron, steel and aluminium scrap cease to be waste should ensure that iron, steel and aluminium scrap resulting from a recovery operation meet the technical requirements of the metal producing industry, comply with existing legislation and standards applicable to products and do not lead to overall adverse environmental or human health impacts. Reports of the Joint Research Centre of the European Commission have shown that the proposed criteria on the waste used as input in the recovery operation, on the treatment processes and techniques, as well as on the scrap metal resulting from the recovery operation, fulfil those objectives since they should result in the production of iron, steel and aluminium scrap devoid of hazardous properties and sufficiently free of non-metallic compounds.





(4) In order to ensure compliance with the criteria, it is appropriate to provide that information on scrap metal which has ceased to be waste is issued and that a quality management system is implemented.

(5) A review of the criteria may prove necessary if, on the basis of a monitoring of the development of market conditions for iron and steel scrap and aluminium scrap, adverse effects on recycling markets for iron and steel scrap and aluminium scrap are noted, in particular with regard to the availability of, and access to, such scrap.

(6) In order to allow operators to adapt to the criteria determining when scrap metal ceases to be waste, it is appropriate to provide for a reasonable period to elapse before this Regulation applies.

(7) The Committee established by Article 39(1) of Directive 2008/98/EC has not delivered an opinion on the measures provided for in this Regulation and the Commission therefore submitted to the Council a proposal relating to the measures and forwarded it to the European Parliament.

(8) The European Parliament has not opposed the proposed measures,

#### HAS ADOPTED THIS REGULATION:

#### Article 1

Subject matter

This Regulation establishes criteria determining when iron, steel and aluminium scrap, including aluminium alloy scrap, cease to be waste.

#### Article 2

Definitions

For the purposes of this Regulation, the definitions set out in Directive 2008/98/EC shall apply.

In addition, the following definitions shall apply:

(a) "iron and steel scrap" means scrap metal which consists mainly of iron and steel;

(b) "aluminium scrap" means scrap metal which consists mainly of aluminium and aluminium alloy;

(c) "holder" means the natural or legal person who is in possession of scrap metal;

(d) "producer" means the holder who transfers scrap metal to another holder for the first time as scrap metal which has ceased to be waste;

(e) "importer" means any natural or legal person established within the Union who introduces scrap metal which has ceased to be waste into the customs territory of the Union;

(f) "qualified staff" means staff which is qualified by experience or training to monitor and assess the properties of scrap metal;





(g) "visual inspection" means inspection of scrap metal covering all parts of a consignment and using human senses or any non-specialised equipment;

(h) "consignment" means a batch of scrap metal which is intended for delivery from a producer to another holder and may be contained in either one or several transport units, such as containers.

#### Article 3

Criteria for iron and steel scrap

Iron and steel scrap shall cease to be waste where, upon transfer from the producer to another holder, all of the following conditions are fulfilled:

(a) the waste used as input for the recovery operation complies with the criteria set out in Section 2 of Annex I;

(b) the waste used as input for the recovery operation has been treated in accordance with the criteria set out in Section 3 of Annex I;

(c) the iron and steel scrap resulting from the recovery operation complies with the criteria set out in Section 1 of Annex I;

(d) the producer has satisfied the requirements set out in Articles 5 and 6.

#### Article 4

Criteria for aluminium scrap

Aluminium scrap, including aluminium alloy scrap, shall cease to be waste where, upon transfer from the producer to another holder, all of the following conditions are fulfilled:

(a) the waste used as input in the recovery operation complies with the criteria set out in Section 2 of Annex II;

(b) the waste used as input in the recovery operation has been treated in accordance with the criteria set out in Section 3 of Annex II;

(c) the aluminium scrap resulting from the recovery operation complies with the criteria set out in Section 1 of Annex II;

(d) the producer has satisfied the requirements set out in Articles 5 and 6.

#### Article 5

Statement of conformity

1. The producer or the importer shall issue, for each consignment of scrap metal, a statement of conformity in accordance with the model set out in Annex III.

2. The producer or the importer shall transmit the statement of conformity to the next holder of the scrap metal consignment. The producer or the importer shall retain a copy of the statement of conformity for at least 1 year after its date of issue and shall make it available to competent authorities upon request.





3. The statement of conformity may be in electronic form.

#### Article 6

Quality management

1. The producer shall implement a quality management system suitable to demonstrate compliance with the criteria referred to in Articles 3 and 4, respectively.

2. The quality management system shall include a set of documented procedures concerning each of the following aspects:

(a) acceptance control of waste used as input for the recovery operation as set out in Section 2 of Annexes I and II;

(b) monitoring of the treatment processes and techniques described in Section 3.3 of Annexes I and II;

(c) monitoring of the quality of scrap metal resulting from the recovery operation as set out in Section 1 of Annexes I and II (including sampling and analysis);

(d) effectiveness of the radiation monitoring as set out in Section 1.5 of Annexes I and II, respectively;

(e) feedback from customers concerning compliance with scrap metal quality;

(f) record keeping of the results of monitoring conducted under points (a) to (d);

(g) review and improvement of the quality management system;

(h) training of staff.

3. The quality management system shall also prescribe the specific monitoring requirements set out in Annexes I and II for each criterion.

4. Where any of the treatments referred to in Section 3.3 of Annex I or Section 3.3 of Annex II are carried out by a prior holder, the producer shall ensure that the supplier implement a quality management system which complies with the requirements of this Article.

5. A conformity assessment body, as defined in Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products [2], which has obtained accreditation in accordance with that Regulation, or any other environmental verifier as defined in Article 2(20)(b) of Regulation (EC) No 1221/2009 of the European Parliament and of the Council of 25 November 2009 on the voluntary participation by organisations in a Community ecomanagement and audit scheme (EMAS) [3] shall verify that the quality management system complies with the requirements of this Article. The verification should be carried out every 3 years.

6. The importer shall require his suppliers to implement a quality management system which complies with the requirements of paragraphs 1, 2 and 3 of this Article and has been verified by an independent external verifier.





7. The producer shall give competent authorities access to the quality management system upon request.

#### Article 7

Entry into force

This Regulation shall enter into force on the 20th day following its publication in the Official Journal of the European Union.

It shall apply from 9 October 2011.

This Regulation shall be binding in its entirety and directly applicable in all EU Member States.

Done at Brussels, 31 March 2011.

For the Council

The President

Völner P.

[1] OJ L 312, 22.11.2008, p. 3.

[2] OJ L 218, 13.8.2008, p. 30.

[3] OJ L 342, 22.12.2009, p. 1.



### **Eşleştirme Projesi TR 08 IB EN 03** IPPC – Entegre Kirlilik Önleme ve Kontrol T.C. Çevre ve Şehircilik Bakanlığı



#### ANNEX I

Criteria for iron and steel scrap

	Criteria	Self-monitoring requirements
1.	Quality of scrap resulting from the recovery operation	
1.1.	The scrap shall be graded according to a customer specification, an industry specification or a standard for direct use in the production of metal substances or objects by steel works or foundries.	Qualified staff shall grade each consignment.
1.2	The total amount of foreign materials (steriles) shall be $\leq$ 2 % by weight.	Qualified staff shall carry out a visual inspection of each consignment.
	<ul> <li>Foreign materials are:</li> <li>(1) non-ferrous metals (excluding alloying elements in any ferrous metal substrate) and non-metallic materials such as earth, dust, insulation and glass;</li> <li>(2) combustible non-metallic materials such as rubber, plastic, fabric, wood and other chemical or</li> </ul>	At appropriate intervals (at least every 6 months), representative samples of foreign materials shall be analysed by weighing after magnetic or manual (as appropriate) separation of iron and steel particles and objects under careful visual inspection. The appropriate frequencies of monitoring by sampling shall be established taking into account the following fortex:
	organic substances; (3) larger pieces (brick-size) which are non-conductors of electricity such as tyres, pipes filled with	<ol> <li>the expected pattern of variability (for example as shown by historical results);</li> </ol>
	<ul><li>cement, wood or concrete;</li><li>(4) residues arising from steel melting, heating, surface conditioning (including scarfing), grinding,</li></ul>	(2) the inherent risk of variability in the quality of waste used as input for the recovery operation and any subsequent processing;
	sawing, welding and torch cutting operations, such as slag, mill scale, baghouse dust, grinder dust, sludge.	<ul> <li>(3) the inherent precision of the monitoring method; and</li> <li>(4) the proximity of results to the limitation of the foreign materials' content to a maximum of 2 % per weight.</li> <li>The process of determining monitoring frequencies should be documented as part of the quality management system and should be available for auditing.</li> </ul>
1.3.	The scrap shall not contain excessive ferrous oxide in any form, except for typical amounts arising from outside storage of prepared scrap under normal atmospheric conditions.	Qualified staff shall carry out a visual inspection for the presence of oxides.
1.4	Scrap shall be free of visible oil, oily emulsions, lubricants or grease except negligible amounts that will not lead to any dripping.	Qualified staff shall carry out a visual inspection of each consignment, paying particular attention to those parts where oil is most likely to drip.
1.5.	Radioactivity: there is no need for response action according to national or international rules on monitoring and response procedures for radioactive scrap metal. This requirement is without prejudice to the basic standards on the health protection of workers and members of the public adopted in acts falling under Chapter III of the Euratom Treaty, in particular Directive $96/29$ /Euratom ( <sup>1</sup> ).	Qualified staff shall monitor the radioactivity of each consignment. Each consignment of scrap shall be accompanied by a certificate established in accordance with national or international rules on monitoring and response procedures for radioactive scrap metal. The certificate may be included in other documentation accompanying the consignment.





Criteria	Self-monitoring requirements
1.6. The scrap shall not display any of the hazardous properties listed in Annex III to Directive 2008/98/EC. The scrap shall comply with the concentration limits laid down in Decision 2000/532/EC ( <sup>2</sup> ) and shall not exceed the concentration limits laid down in Annex IV to Regulation (EC) No 850/2004 ( <sup>3</sup> ). Properties of individual elements included in iron and steel alloys are not relevant for this requirement.	Qualified staff shall carry out a visual inspection of each consignment. Where visual inspection raises any suspicion of possible hazardous properties, further appropriate monitoring measures shall be taken, such as sampling and testing where appropriate. The staff shall be trained on potential hazardous properties that may be associated with iron and steel scrap and on material components or features that allow hazardous properties to be recognised. The procedure for recognising hazardous materials shall be documented under the quality management system.
1.7. The scrap shall not contain any pressurised, closed or insufficiently open containers that could cause an explosion in a metalwork furnace.	Qualified staff shall carry out a visual inspection of each consignment.
2. Waste used as input for the recovery operation	
<ul> <li>2.1. Only waste containing recoverable iron or steel may be used as input.</li> <li>2.2. Hazardous waste shall not be used as an input except where proof is provided that the processes and techniques specified in Section 3 of this Annex to remove all hazardous properties have been applied.</li> <li>2.3. The following waste shall not be used as an input: <ul> <li>(a) filings and turnings that contain fluids such as oil or oily emulsions; and</li> <li>(b) barrels and containers, except equipment from end-of-life vehicles, which contain or have contained oil or paints.</li> </ul> </li> </ul>	Acceptance control of all waste received (by visual inspection) and of the accompanying documentation shall be carried out by qualified staff which is trained on how to recognise waste that does not meet the criteria set out in this Section.

#### 3. Treatment processes and techniques

3.1.	The iron or steel scrap shall have been segregated at source or while collecting and shall have been kept separate or the input waste shall have been treated to separate the iron and steel scrap from the non-metal and non-ferrous components.
3.2.	All mechanical treatments (like cutting, shearing, shredding or granulating; sorting, separating, cleaning, de-polluting, emptying) needed to prepare the scrap metal for direct input into final use in steel works and foundries shall have been completed.
3.3.	For waste containing hazardous components, the following specific requirements shall apply:
	(a) input materials that originate from waste electrical or electronic equipment or from end-of-life vehicles shall have undergone all treatments required by Article 6 of Directive 2002/96/EC of the European Parliament and of the Council ( <sup>4</sup> ) and by Article 6 of Directive 2000/53/EC of the European Parliament and of the Council ( <sup>5</sup> );
	(b) chlorofluorocarbons in discarded equipment shall have been captured in a process approved by the competent authorities;





Criteria	Self-monitoring requirements
(c) cables shall have been stripped or chopped. If a cable contains organic coatings (plastics), the organic coatings shall have been removed in accordance with the best available techniques;	
(d) barrels and containers shall have been emptied and cleaned, and	
(e) hazardous substances in waste that is not mentioned in point (a) shall have been efficiently removed in a process which is approved by the competent authority.	
(1) Council Directive 96/29/Euratom of 13 May 1996 laving down basic safety standards for the protection of the her	alth of workers and the general public against the dangers arising from ionizing radiation (OI L 159, 29.6.1996, p. 1).

(1) Control Directive 20/22/Eurotom of 12 may 1226 taying down basic safety standards for the protection of the nearth of workers and the general public against the dangers ansing from ionizing radiation (O) E 159, 29.6.1996, p. 1).
 (2) Commission Decision 2000/532/EC of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Directive 91/689/EEC on hazardous waste (O) L 226, 6.9.2000, p. 3).

(3) Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants (OJ L 158, 30.4.2004, p. 7).

(4) OJ L 37, 13.2.2003, p. 24.

(5) OJ L 269, 21.10.2000, p. 34.



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#### ANNEX II

Criteria for aluminium scrap		
Criteria	Self-monitoring requirements	
1. Scrap quality		
1.1. The scrap shall be graded in accordance with a customer specification, an industry specification or a standard for direct use in the production of metal substance or objects by refining or re-melting.	Qualified staff shall grade each consignment.	
<ul> <li>1.2. The total amount of foreign materials shall be ≤ 5 % by weight or the metal yield shall be ≥ 90 %; Foreign materials are:</li> <li>(1) metals other than aluminium and aluminium alloys;</li> <li>(2) non-metallic materials such as earth, dust, insulation materials and glass;</li> <li>(3) combustible non-metallic materials such as rubber, plastic, fabric, wood and other chemical or organic substances;</li> <li>(4) larger pieces (brick-size) which are non-conductors of electricity such as tyres, pipes filled with cement, wood or concrete; or</li> <li>(5) residues arising from the melting of aluminium and aluminium alloys, heating, surface conditioning (including scarfing), grinding, sawing, welding and torch cutting operations such as slag, dross, skimmings, baghouse dust, grinder dust, sludge.</li> </ul>	The producer of the aluminium scrap shall check compliance by monitoring the amount of foreign materials or by determining the metal yield. Qualified staff shall carry out visual inspection of each consignment. At appropriate intervals (at least every 6 months), representative samples of each grade of aluminium scrap shall be analysed to measure the total amount of foreign materials or the metal yield. The representative samples shall be obtained in accordance with the sampling procedures described in standard EN 13920 ( <sup>1</sup> ). The total amount of foreign materials shall be measured by weight after separating aluminium metallic particles and objects from particles and objects consisting of foreign materials by hand sorting or other means of separation (such as by magnet or by using density as a basis). Metal yield shall be measured in accordance with the following procedure: (1) determination of mass (m <sub>1</sub> ) after removal and determination of moisture (in accordance with point 7.1 of the EN 13920-1:2002 standard); (2) removal and determination of free iron (in accordance with point 7.2 of the EN 13920-1:2002 standard); (3) determination of the mass of the metal after melting and solidifying (m <sub>2</sub> ) following the procedure for the determiniation of the metal yield in accordance with point 7.3 of the EN 13920-1:2002 standard; (4) calculation of the metal yield m [%] = (m <sub>2</sub> /m <sub>1</sub> ) × 100. The appropriate frequencies of analysis of representative samples shall be established taking into account the following factors: (1) the expected pattern of variability (such as shown by historical results); (2) the inherent risk of variability in the quality of waste used as input for the recovery operation and in the performance of the treatment processes; (3) the inherent precision of the monitoring method; and (4) the proximity of results to the limit values for the total amount of foreign materials or the metal vield	
1.3. The scrap shall not contain polyvinyl chloride (PVC) in form of coatings, paints, plastics.	Qualified staff shall carry out a visual inspection of each consignment.	





Criteria	Self-monitoring requirements
1.4. The Scrap shall be free of visible oil, oily emulsions, lubricants or grease except negligible amounts that will not lead to any dripping.	Qualified staff shall carry out a visual inspection of each consignment, paying particular attention to those parts where oil is most likely to drip.
1.5. Radioactivity: there is no need for response action according to national or international rules on monitoring and response procedures for radioactive scrap metal. This requirement is without prejudice to the basic standards on the health protection of workers and members of the public adopted in acts falling under Chapter III of the Euratom Treaty, in particular Council Directive 96/29/Euratom ( <sup>2</sup> ).	Qualified staff shall monitor the radioactivity of each consignment. Each consignment of scrap shall be accompanied by a certificate established in accordance with national or international rules on moni- toring and response procedures for radioactive scrap metal. The certificate may be included in other documentation accompanying the consignment.
1.6. The scrap shall not display any of the hazardous properties listed in Annex III to Directive 2008/98/EC. The scrap shall comply with the concentration limits laid down in Commission Decision 2000/532/EC (?) and shall not exceed the concentration limits laid down in Annex IV to Regulation (EC) No 850/2004 (*). Properties of individual elements included in aluminium alloys are not relevant for this requirement.	Qualified staff shall carry out a visual inspection of each consignment. Where visual inspection raises any suspicion of possible hazardous properties, further appropriate monitoring measures shall be taken, such as sampling and testing where appropriate. Staff shall be trained on potential hazardous properties that may be associated with aluminium scrap and on material components or features that allow hazardous properties to be recognised. The procedure for recognising hazardous materials shall be documented under the quality management system.
1.7. The scrap shall not contain any pressurised, closed or insufficiently open containers that could cause an explosion in a metalwork furnace.	Qualified staff shall carry out a visual inspection of each consignment.
2. Waste used as input in the recovery operation	·

<ol> <li>Only waste that contained a</li> <li>Hazardous waste shall not be and techniques specified und been applied.</li> </ol>	recoverable aluminium or aluminium alloys may be used as input. e used as an input except where proof is provided that the processes ler Section 3 of this Annex to remove all hazardous properties have	Acceptance control of all waste received (by visual inspection) and of the accompanying documentation shall be carried out by qualified staff which is trained on how to recognise waste that does not fulfil the criteria set out in this Section.
2.3. The following waste shall no	ot be used as an input:	
(a) filings and turnings that	contain fluids such as oil or oily emulsions; and	
(b) barrels and containers, e contained oil or paints.	except equipment from end-of-life vehicles, which contain or have	

#### 3. Treatment processes and techniques

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Criteria	Self-monitoring requirements
3.2. All mechanical treatments (like cutting, shearing, shredding or granulating; sorting, separating, cleaning, de-polluting, emptying) needed to prepare the scrap metal for direct input into final use shall have been completed.	
3.3. For waste containing hazardous components the following specific requirements shall apply:	
(a) input materials that originate from waste electrical or electronic equipment and end-of-life vehicles shall have undergone all treatments required by Article 6 of Directive 2002/96/EC of the European Parliament and of the Council ( <sup>5</sup> ) and Article 6 of Directive 2000/53/EC of the European Parliament and of the Council ( <sup>6</sup> );	
<ul> <li>(b) chlorofluorocarbons in discarded equipment shall have been captured in an process approved by the competent authorities;</li> </ul>	
(c) cables shall have been stripped or chopped. If a cable contains organic coatings (plastics), the organic coatings shall have been removed in accordance with the best available techniques;	
(d) barrels and containers shall have been emptied and cleaned;	
(e) hazardous substances in waste not mentioned in point (a) shall have been efficiently removed in a process which is approved by the competent authority.	
(1) EN 13920-1:2002; Aluminium and aluminium alloys – Scrap- Part 1: General requirements, sampling and tests; (2) OI L 159, 29.6.1996, p. 1.	CEN 2002.

(\*) OJ L 159, 29.6.1996, p. 1.
(\*) OJ L 226, 6.9.2000, p. 3.
(\*) OJ L 229, 30.4.2004, p. 1.
(\*) OJ L 37, 13.2.2003, p. 24.
(\*) OJ L 269, 21.10.2000, p. 34.



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#### ANNEX III

#### Statement of Conformity with the end-of-waste criteria referred to in Article 5(1)

1.	Producer/importer of scrap metal: Name: Address: Contact person: Tel. Fax E-mail:
2.	<ul><li>(a) name or code of the scrap metal category, in accordance with an industry specification or standard:</li><li>(b) where relevant, main technical provisions of a customer specification, such as composition, size, type and properties:</li></ul>
3.	The scrap metal consignment complies with the specification or standard referred to in point 2:
4.	Quantity of the consignment in tonnes:
5.	A radioactivity test certificate has been established in accordance with national or international rules on monitoring and response procedures for radioactive scrap metal:
6.	The producer of scrap metal applies a quality management system complying with Article 6 of Regulation (EU) No 333/2011 ( <sup>1</sup> ), which has been verified by an accredited verifier or, where scrap metal which has ceased to be waste is imported into the customs territory of the Union, by an independent verifier:
7.	The scrap metal consignment meets the criteria referred to in points (a) to (c) of Articles 3 and 4 of Regulation (EU) No 333/2011 (1):
8.	Declaration of the producer/importer of scrap metal: I certify that the above information is complete and correct to my best knowledge. Name: Date: Signature:

(1) Council Regulation (EU) No 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council (OJ L 94, 8.4.2011, p. 2).