BEST AVAILABLE TECHNIQUES GUIDANCE DOCUMENT ON IRON & STEEL INDUSTRY

FOREWORD

Best Available Techniques Economically Achievable (BAT) document had been prepared as a guidance notes for the nine (9) major industries in Malaysia and to support the implementation of the new Environmental Quality (Clean Air) Regulations 20xx. These documents were prepared based on the latest state-of-the-art technologies, internationally accepted limit values but had been adjusted and tailored to local requirements.

BAT is defined as the effective methods in preventing pollution and, where generally that is not practicable, to reduce emissions from industrial activities and their impact on the environment. This definition implies that BAT not only covers the technology used but also the way in which the installation is operated, to ensure a high level of environmental protection. Implementations of BAT in any specific industrial sectors are under economically and technically viable condition.

It is hope that the technical contents of these documents will prove beneficial to the industries in their endeavour to comply with the environmental regulations and standards through more cost-efficient means. In the identification of BAT, emphasis is placed on pollution prevention techniques rather than end-of-pipe treatment. These documents will be reviewed and updated from time to time.

These documents have been prepared in consultations with the University of Malaya Consultancy Unit (UPUM), Malaysia German Technical Cooperation (GTZ) and the relevant industries/stakeholders. The Department of Environment wishes to record appreciation to representatives of the relevant industrial sectors, government agencies and individuals for their invaluable input.

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LIST OF ABBREVIATIONS

AOD	-	Argon-Oxygen-Degasser
AVGAS	-	High Octane Aviation Fuel
BAT	-	Best Available Techniques
BREF	-	Best Available Technique Reference
CAR	-	Clean Air Regulation Document
DOE	-	Department of Environment, Malaysia
DRI	-	Direct Reduce Iron
EAF	-	Electric Arc Furnace
EOS	-	Emission Optimised Sintering
ESP	-	Electrostatic Precipitator
HCB	-	Hexaclorobenzene
IPPC	-	Integrated Pollution Prevention and Control
mg/Nm^3	-	milligram per cubic meter at standard temperature (273K) and pressure (1atm)
NOx	-	Oxides of Nitrogen
PAH	-	Polycyclic Aromatic Hydrocarbon
PCB	-	Polychlorinated biphenyl
PCDD/F	-	Polychlorinated dibenzo-p-dioxin or furan
RAC	-	Regenerative Activated Carbon
SCR	-	Selective Catalytic Reduction
SOx	-	Oxides of Sulphur
VOD	-	Vacuum-Oxygen-Degasser

1.0 PREFACE

1.1 Status of This Document

This document forms a part of a series presenting the guidance notes for selected industries in Malaysia (list given at the end of this preface) to apply best available techniques economically achievable (BAT), associated monitoring and developments in them. This series is published by the Department of Environment (DOE) in accordance to the Environmental Quality (Clean Air) Regulations 2014 (CAR 2014).

1.2 Definition of BAT

In order for the user of this document to understand the legal context of this document, the interpretation on the definition of BAT is taken from Regulation 2 – Interpretation of CAR 2014 and described as below:

"Best Available Techniques Economically Achievable" means the effective methods in preventing pollution and, where that is not practicable, generally to reduce emissions in the air from the industrial activities and their impact on the environment as a whole. In this regard:

"Techniques" includes both the technology used and the way in which the facility is designed, built, maintained, operated and decommissioned;

"Available Techniques" means those techniques that are accessible to the occupier and that are developed on a scale that allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages; and

"Best" means effective in achieving a high general level of protection of the environment as a whole;

On the basis of this assessment, techniques, and as far as possible emission and consumption levels associated with the use of BAT, are presented in this document that are considered to be appropriate to the sector as a whole and in many cases reflect current performance of some installations within the sector. Where emission or consumption levels “associated with best available techniques” are presented, this is to be understood to mean those levels representing the environmental performance that could be expected as a result of the application, of the techniques described, taking into account the balance of costs and advantages inherent within the definition of BAT. However, they are neither emission nor consumption limit values and should not be understood as such.

In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross media considerations, they are not considered to be appropriate as BAT for the sector as a whole. However, such levels may be considered to be justified in more specific cases where there are special driving forces.

The emission and consumption levels associated with the use of BAT have to be seen together with any specified reference conditions (e.g. averaging periods).

The concept of “levels associated with BAT” described above is to be distinguished from the term “achievable level” used elsewhere in this document. Where a level is described as “achievable” using a particular technique or combination of techniques, this should be understood to mean that the level may be expected to be achieved over a substantial period of time in a well maintained and operated installation or process using those techniques.

The actual cost of applying a technique will depend strongly on the specific situation such as taxes, fees, and the technical characteristics of the installation concerned. It is not possible to evaluate such site-specific economic viability of techniques drawn from observations on existing installations.

The purpose of CAR 2014 is to achieve prevention and control of pollution arising from activities listed in its First Schedule and Second Schedule. More specifically, it provides for a notification system for certain categories of industrial installations to conduct an integrated and comprehensive view of the pollution and consumption potential of their installation. The overall aim is to ensure a high level of protection of the environment as a whole based on appropriate preventative measures through the application of BAT.

1.3 Objective of This Document

The 'emission minimization principle' as cited in CAR 2014 requires that the goal of emission abatement is to achieve minimum emissions as a result of applying current BAT. Hence this guideline document is meant to provide the reference information for the permitting authorities to take into account when determining permit conditions. This document should serve as valuable input to achieve better environmental performance.

1.4 Information Sources

The information is mainly based on the European IPPC BREF document where the assessment was achieved through an iterative process involving the following steps:

- identification of the key environmental issues for the sector
- examination of the techniques most relevant to address those key issues;
- identification of the best environmental performance levels, on the basis of the available data world-wide;
- examination of the conditions under which these performance levels were achieved; such as costs, cross-media effects, main driving forces involved in Implementation of these techniques;

- selection of the BAT and the associate emission and/or consumption levels for this sector

1.5 How to Use This Document

It is intended that the general BAT in this document could be used to judge the current performance of an existing installation or to judge a proposal for a new installation and thereby assist in the determination of appropriate BAT based conditions for that installation. It is foreseen that new installations could be designed to perform at or even better than the general BAT levels presented here. It is also considered that many existing installations could reasonably be expected, over time, to move towards the general "BAT" levels or perform better. This reference document does not set legally binding standards, but they are meant to give information for the guidance of industry, the relevant government bodies and the public on achievable emission and consumption levels when using specified techniques.

The structure of the guideline document is as follows:

An overview of each particular sector in the Malaysian context is firstly covered briefly followed by process description, process optimization, sources of pollution, emission control options, recommended practices and emission values and finally emission monitoring and reporting. More often than not, trade-off judgements between different types of environmental impacts and specific site condition are the influencing factors.

Another important point to note is that BAT change over time and this guidance document needs to be reviewed and updated as appropriate.

2.0 OVERVIEW OF IRON & STEEL INDUSTRY IN MALAYSIA

2.1 General Information- The Steel Industry

Steel is the essential raw material used in the manufacturing sector, machinery and engineering industries, transportation equipment (automotive, railway and shipping) as well as the major ingredient for infrastructure projects. Hence, steel-making capacities are often viewed as a national interest to add value to natural resources, it ensures ready supply for the development of manufacturing and construction sectors, substitute for import, as well as generate saving on foreign exchange

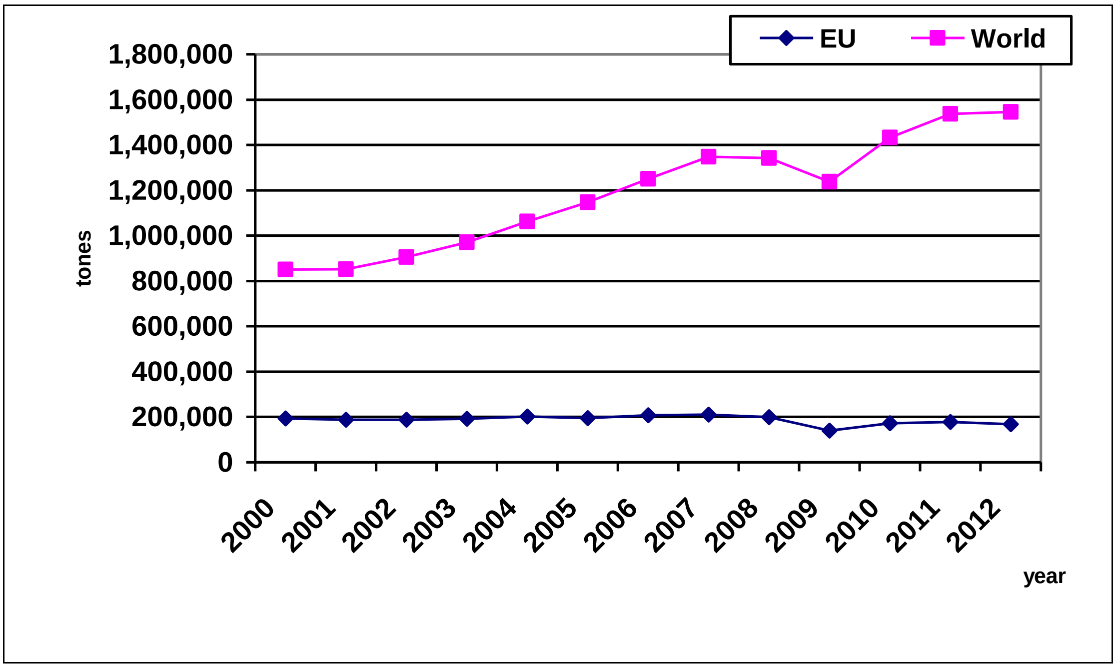
Steel production has a high multiplier effect in the economy through increased activities in other related areas. The level of per capita consumption of steel is treated as one of the important indicators of socio-economic development and living standard of the people in any country. It is a product of a large and technologically complex industry having strong linkages in terms of material flow and income generation.

The steel industry can be classified into two segments i.e. primary steel producers and secondary steel producers. Primary steel producers, also known as integrated steel producers, are involved in the entire range of iron and steel production commencing from exploration of iron ore to the production of finished steel products. The secondary producers purchase iron ore or steel scrap as raw material for production process that do not use coking coal. The secondary steel producers can be classified into three type's i.e. major secondary players, mini steel plants and steel re-rollers. Finished steel is used mainly in the form of long products, flat products, (which in turn contain hot rolled and cold rolled and galvanised products) and alloy steels. The demands for steel are mainly from sectors like automobiles, consumer durables, and infrastructure and construction industry. Being a core sectors, it tracks the overall economic growth.

The steel industry is well known for its cyclical nature. The up and down turns are not new to the steel industry. Over the past decade, the steel industry has witnessed had emerged as more resilient and more efficient industry despite of the cyclic nature.

Together with coal and cotton, iron and steel were the principal materials upon which the industrial revolution was based. Technical developments from the early eighteenth century onwards allowed dramatic increases in output, for example by replacing relatively scarce charcoal with hard coal/lignite and coke respectively and by the development of the paddling process for converting pig iron into steel.

Crude steel production has grown exponentially in the second half of the twentieth century, rising to a world total of 757 million tones in 1995 and growing further to 1.146 million tones ten years later in 2005. In 2012, crude steel production worldwide recorded 1.545 million tones. (**Figure 1**)



Source: World Steel Association

Figure 1: Crude Steel Production in Europe and Worldwide

2.2 The Structure of the Iron & Steel Industry in Malaysia

The steel industry in Malaysia is centered on the country's construction and manufacturing needs. Steel production is no longer dominated by long products such as bars and wire-rods as the importance of flats and steel sections has increased in recent years with the rapid economic development in the country.

Table 1 below shows the structure of the Malaysian steel industry in 2008, by product and number of establishments.

Table 1: Structure of the Steel Industry in Malaysia, 2008

Sub-Sector	Product Type	Number of Establishments	Rated Capacity ('000 MT)
Primary Products	Direct Reduced Iron	2	2,700
	Hot Briquetted	1	720
	Billets	6	5,250
	Bloom	1	750
	Slabs	1	2,500
Rolling/Finished Products	Light sections	5	500
	Medium to heavy sections	1	700
	Hot Rolled Coils	1	3,000
	Cold Rolled Coils	4	2,380
	Plates	2	850
Secondary Products - Longs	Wire Mesh	40	500
	Galvanized Wire	6	250
	Hard Drawn Wire	40	120
	Bolts and Nuts	15	150
	Nails	14	84
	Welding Electrodes	10	40
	High Carbon	4	154
	Shafting Bars	7	60
	Others	6	120
Secondary Products - Flats	Steel and cement-lined	31	2,300
	Pipes	4	-
	Pipe Fittings	1	250

	Tinplate	5	700
	Galvanizing	9	517
	Colour Coating	50	500
	Roll-Formers	45	5,000

Source: Malaysian Iron and Steel Industry Federation (MISIF)

1.2.1 Major Producers of Iron & Steel in Malaysia

The major producers of billets, bars and wire rods in the country are:

- Amsteel Mills Sdn Bhd,
- Ann Joo Steel Berhad (formerly known as Malayawata Steel Berhad)
- Malaysia Steel Works (KL) Berhad
- Perwaja Steel Berhad
- Southern Steel Berhad

Megasteel Sdn. Bhd remains the only producer of Hot rolled coils. **Table 2** summarises the production capacity of the major Malaysian iron & steel companies.

Table 2: Production Facility and Capacity of Major Steelmaking Companies in Malaysia

Name of Company	Location	Facility	Products	Capacity (MT)
Amsteel Mills Sdn Bhd, Lion Group	Labuan , Sabah	MIDREX DR Process (with HBI facilities)	Hot Briquetted Iron (HBI)	750,000
	Amsteel 1 Klang, Selangor	1X 85 tonne EAF with Ladle Furnace 12 Strand CCM 2 bar and 1 rod mills	Billets, Bars and Wire Rods	850,000 680,000
	Amsteel 2 (Banting, Selangor)	1X160 tonne EAF 1 bar and Rod Mill	Billets, Bars and Wire Rods	400,000 600,000
	Antara Steel, Johor	1X100 tonne EAF 1 Bar Mill 1 Section mill	Billets, Bars and light sections	330,000

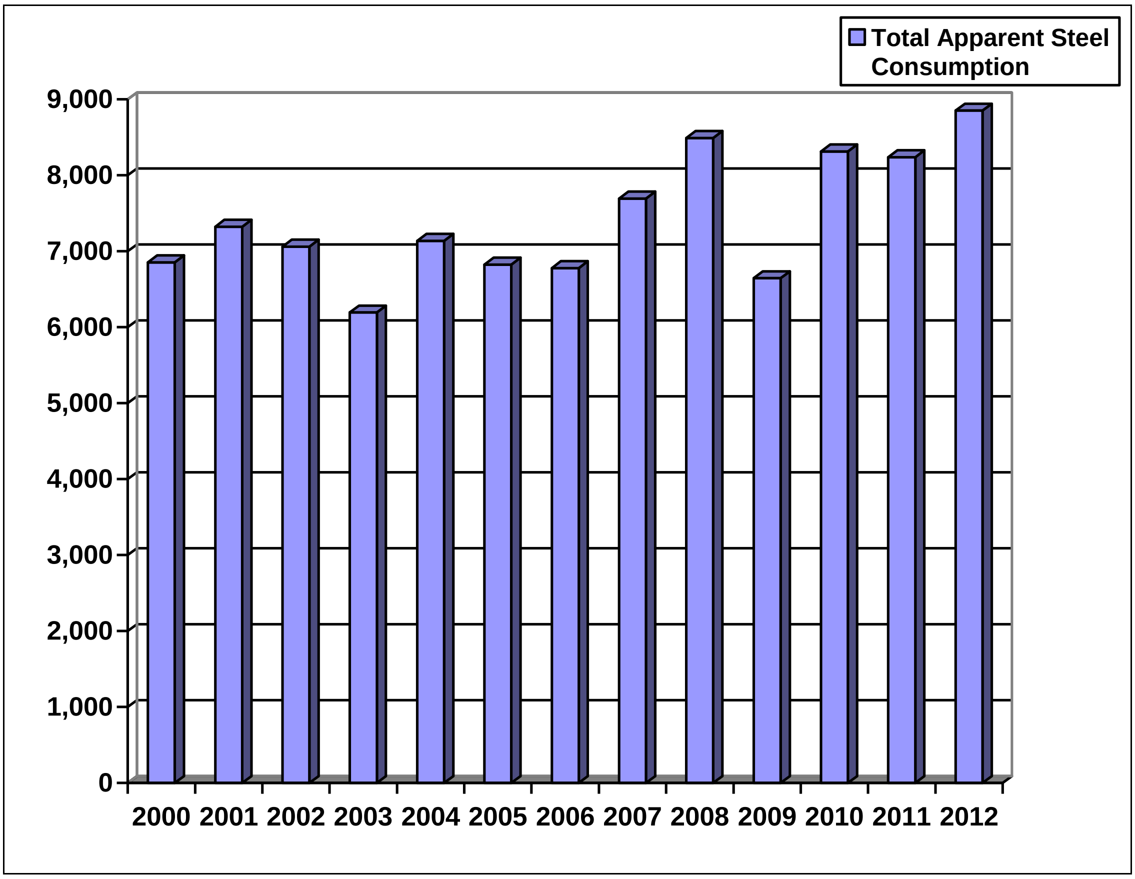
Name of Company	Location	Facility	Products	Capacity (MT)
Lion DRI Sdn Bhd	Banting, Selangor	MIDREX HDRI/HBI	Direct Reduced Iron (DRI)	1,500,000
Ann Joo Steel Berhad	Prai, Penang	1X75 tonne DC Furnace 2 Strand CCM 2 bar and rod mill	 Billets Bars & wire rod	 600,000 600,000
	Shah Alam, Selangor	1 bar mill	Bar	150,000
Malaysia Steel Works (KL) Berhad	Bukit Raja, Klang, Selangor	1 EAF 1 Caster	Billets	350,000
	Petaling Jaya, Selangor	1 Rolling Mill	Bars	250,000
Megasteel Sdn Bhd	Banting, Selangor	2X160 tonne EAF 2 Ladle Furnaces 2 VOD 2 Casters	Hot rolled coils	3,000,000
		1 tandem mill	Cold Rolled Mills	1,450,000
Perwaja Steel Berhad	Kemaman, Trengganu	HYL Process 3 X 75 tonne EAF 14 strand CCM 2 X80 tonne EAF 1 Bloom Caster	Direct Reduced Iron Billets Blooms Bars and wire rods	1,200,000 900,000 800,000
Perfect Channel Sdn Bhd	Gurun, Kedah	1 Rolling Mill (Bars and wire rods) 1 Rolling Mill (sections)		450,000 700,000
Southern Steel Berhd	Prai, Penang	1X 75 tonne EAF and 1 X 80 tonne EAF 10 strand CCM 1 bar x 2 rod mill	Billet Bar and wire rod	1,300,000 1,300,000

Source: Malaysian Iron and Steel Industry Federation (MISIF)

2.3 Outlook of the Malaysian Iron and Steel Industry

After enjoying many years of good growth, the iron and steel industry in Malaysia, like elsewhere, is going through a severe slowdown. This has been brought about by Economic Crisis which has hit the world economy since second half of 2008.

The situation had resulted in a slight decline in the Apparent Steel Consumption by just over 8.2 million MT from 2010 to 2011. (**Figure 2**)



Source: Malaysia Iron and Steel Industry Federation (MISIF)

Figure 2: Average Steel Consumption Forecast till Year 2012

2.4 Environmental Relevance of the Iron and Steel Industry

The iron and steel industry is highly intensive in both materials and energy. Important subject for action in response to environmental concerns are generally related to controlling air emissions and managing solid wastes. Air pollution remains an important issue. In integrated steelworks, sinter plants dominate the overall emissions for most atmospheric pollutants, followed by coke-oven plants.

Blast furnaces, basic oxygen steelmaking, coke ovens as well as electric arc furnaces have considerable relative percentages of dust emissions.

The first step towards air pollution control is dust collection and removal. In the eighties and nineties dust removal has become increasingly effective (especially secondary dedusting). This has reduced the directly related heavy metal emissions except in the case of those with high vapour pressure such as mercury. Efforts to minimise SO_2 and NO_x emissions have also been made. In addition the emission of organohalogen compounds such as polychlorinated dibenzo-p-dioxins and -furans (PCDD/F), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) together with polycyclic aromatic hydrocarbons (PAH) and monocyclic aromatic hydrocarbons, especially benzene, became increasingly important. The so-called diffuse emission from plants and emission from open yard storage also became subject to control.

3.0 STEEL-MAKING –AN OVERVIEW

3.1 Steel-making Process Routes

Four routes are currently used for the production of steel: the classic blast furnace/basic-oxygen furnace route, direct melting of scrap (electric arc furnace), smelting reduction and direct reduction (**Figure 3**).

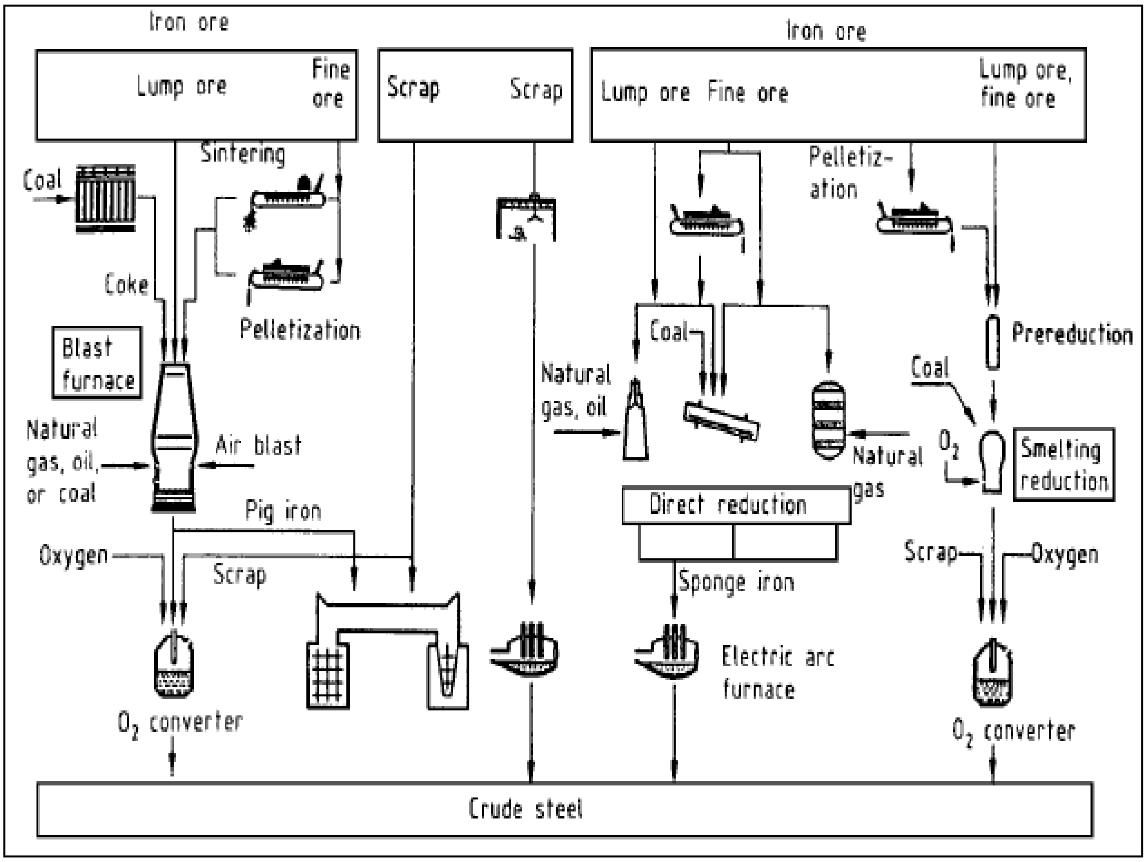


Figure 3: Crude Steel Production Methods

4.0 INTEGRATED STEELWORKS

Of the four steel-making routes described above the classic blast furnace/basic oxygen furnace route is by far the most complex, taking place in large industrial complexes known as integrated steelworks. Integrated steelworks are characterised by networks of interdependent material and energy flows between the various production units.

4.1 Process Overview

The process routes of an integrated steelworks considered in this BAT are shown in **Figure 4**. The figure gives a schematic view of the main material inputs and outputs (emission mass streams) for each stage of the process route.

In an integrated steel works the blast furnace is the main operational unit where the primary reduction of oxide ores takes place leading to liquid iron, so-called pig iron. Modern high-performance blast furnaces require physical and metallurgical preparation of the burden. The two types of iron ore preparation plants are the sinter plants and the pellet plants. Pellets are nearly always made from one well-defined iron ore or concentrate. Sinter is generally produced at the ironworks from predesigned mixtures of fine ores, residues and additives.

The main reducing agents in a blast furnace are coke and powdered coal forming carbon monoxide and hydrogen which reduce the iron oxides. Coke and coal also partly act as a fuel. Coke is produced from coal by means of dry distillation in a coke oven and has better physical and chemical characteristics than coal. In many cases, additional reducing agents/fuels are supplied by injection of oil, natural gas and (in a few cases) plastics. A hot blast provides the necessary oxygen to form the carbon monoxide (CO), which is the basic reducing agent for the iron oxides.

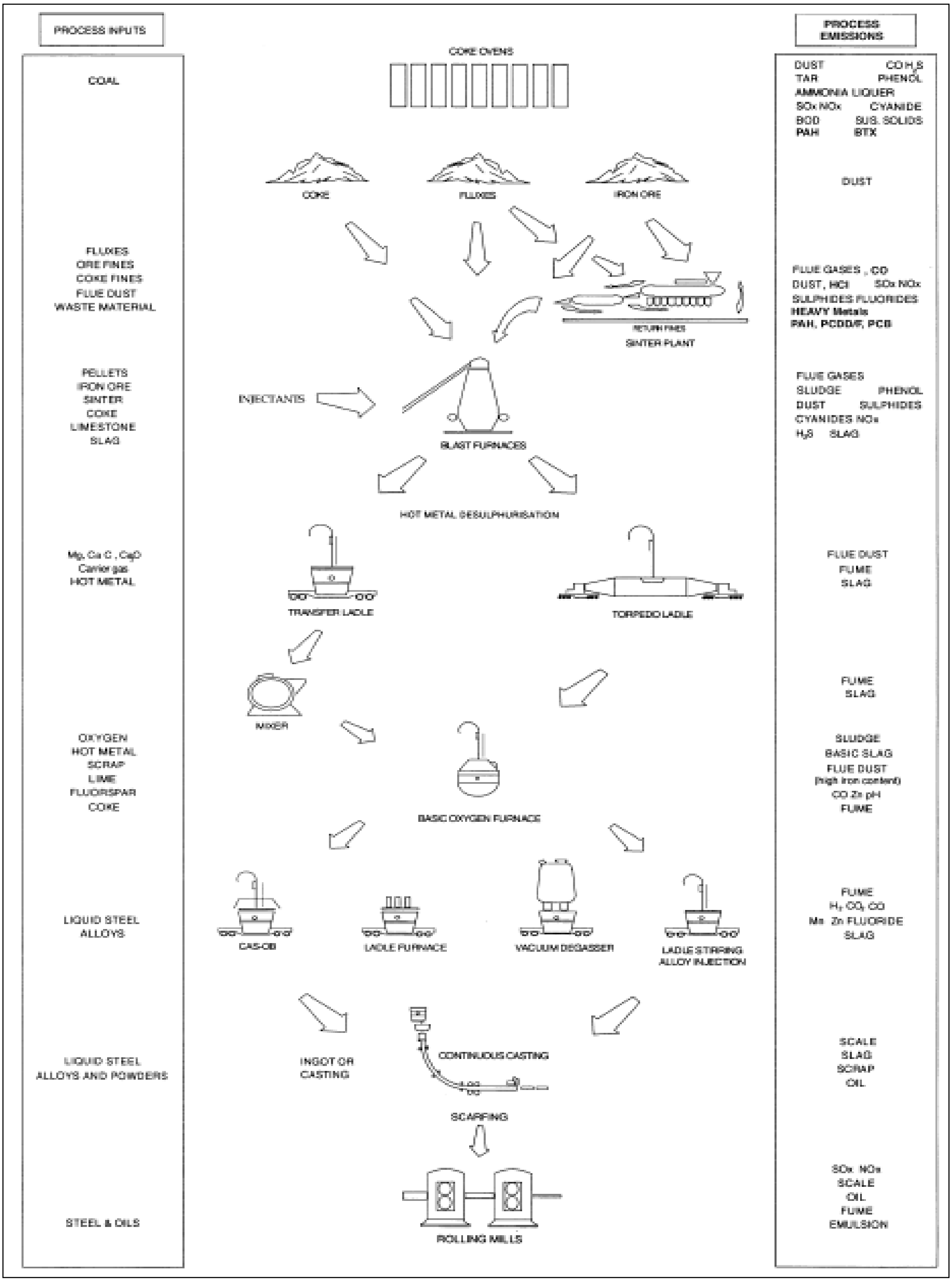


Figure 4: Overview of the Process Route of an Integrated Steel Works

The blast furnace is charged at the top with burden consists of alternate layers of coke and a mixtures of sinter and/or pellets, lump ore and fluxes. In the furnace the iron ore is increasingly reduced and liquid iron and slag are collected in the bottom of the furnace, from where they are tapped.

The slag from the blast furnace is granulated, pelletised, or tapped into slag pits. The slag granules or pellets are usually sold to cement manufacturing companies. Also, slag from pits can be used in road construction.

The liquid iron from the blast furnace (pig iron) is transported to a basic oxygen furnace, where the carbon content (approx. 4%) is lowered to less than 1%, thereby resulting in steel. Upstream ladle desulphurisation of the pig iron and downstream ladle metallurgy of the steel is generally applied in order to produce steel with of the required quality. On leaving the basic oxygen furnace the liquid steel is cast, either into ingots or by means of continuous casting. In some cases vacuum degassing is applied in order to further improve the quality of the steel.

Casting products, whether ingots, slabs, billets or blooms, are subsequently processed in rolling mills and product finishing lines in order to prepare them for market.

4.2 Sinter Plants

Modern high-performance blast furnaces achieve improved performance by prior physical and metallurgical preparation of the burden which improves permeability and reducibility. This preparation entails agglomerating the furnace charge either by sintering or pelletisation. The charge consists of a mixture of fine ores, additives, iron-bearing recycled by-product from downstream operations such as coarse dust and sludge from blast-furnace gas (BFgas) cleaning, mill scale, casting scale, etc. to which coke breeze is added enabling the ignition of it (**Figure 5**).

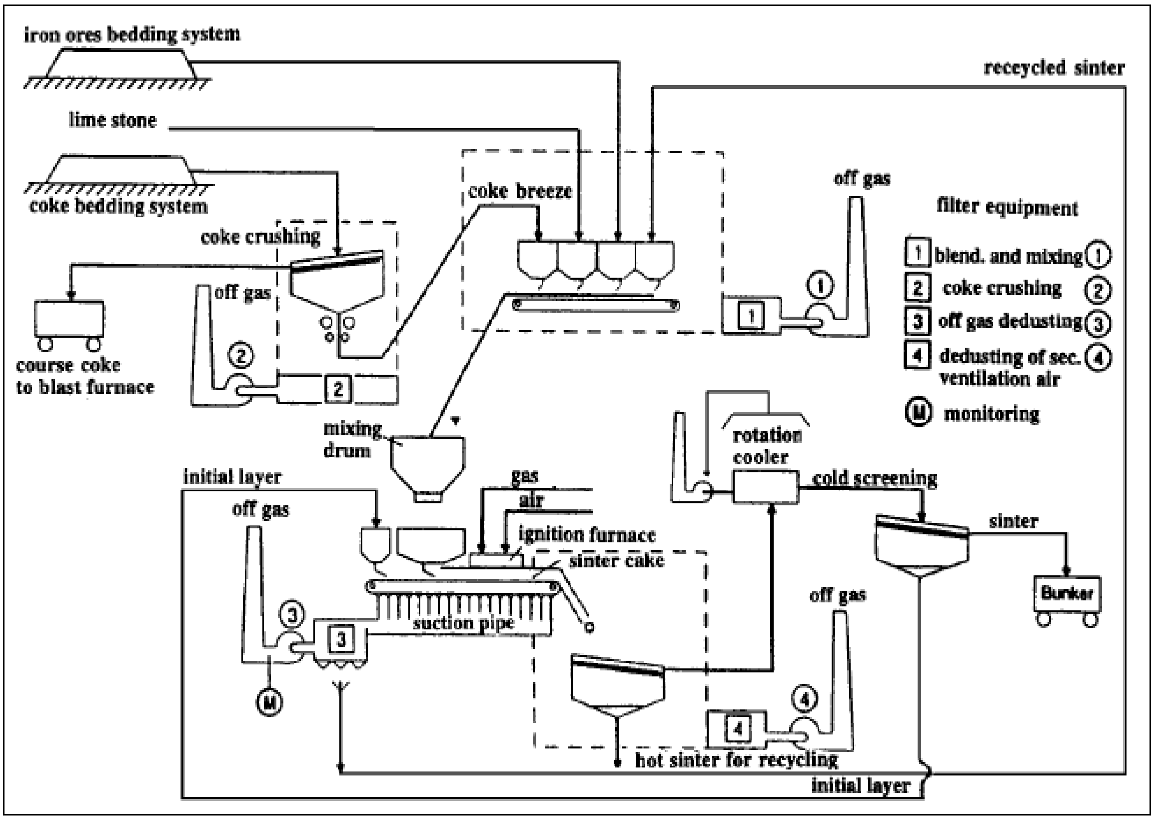


Figure 5: Schematic Diagram of a Sinter Plant Showing the Main Emission Points

A number of chemical and metallurgical reactions take place during the sintering process. These produce both the sinter itself, and also dust and gaseous emissions. The reactions overlap and influence each other, occurring as solid-state and heterogeneous reactions between the melt, solids and gaseous phases which are present in the sintering zone. The following processes and reactions take place in medium basicity sinter mixtures:

-evaporation of moisture
-pre-warming and calcination of basic compounds, ignition of the coke breeze and reactions between carbon, pyrite, chloride- and fluoride-compounds and airborne oxygen
-decomposition of hydrates and cleavage of carbonates
-reaction between calcium oxide and hematite
-reaction between the silicate phase and calcium oxide and iron oxide phases to produce a silicate melt and increase the proportion of the molten phases

-formation of calcium-sulphur compounds and fluorine containing compounds together with alkali chlorides and metal chlorides
-reduction of iron oxides to metallic iron in the high temperature zone
-cavity and channel forming effects by coke combustion and moisture evaporation
-re-oxidation and re-crystallisation processes with shrinking, gearing and hardening effects during sinter cooling
-formation of cracks due to thermal strain during sinter cooling and defects in the sinter

4.2.1 Mass Stream Overview and Input/Output Data

Figure 6 shows an overview of the input and output mass streams of a sinter plant. This overview may be used for the collection of data from sinter plants.

4.2.2 Single Emission Mass Streams

As already indicated the gaseous emissions from the sinter plant especially from the strand are of high environmental significance. When abatement techniques are applied to reduce emissions, cross-media effects can occur. Emissions to air include:

- Particulate matter emissions from handling, crushing, screening and conveying of sinter feedstock and product;
- Waste gas emissions from the sinter strand;
- Particulate matter emissions from sinter cooling

Heavy metal emissions from sinter plants can be of high significance. They include lead, mercury and zinc. Gas emissions also contain SO_x, fluorides, NO_x, hydrocarbons and PCDD/F, PCB and PAH.

4.3 Techniques to Consider In the Determination of BAT

This section lists both process-integrated and end-of-pipe techniques for environmental protection and energy saving at sinter plants.

Process-integrated techniques

The following process-integrated techniques are known to be used at sinter plants:

- Process optimisation for minimisation of PCDD/F emissions
- Recycling of iron-containing waste into the sinter plant
- Lowering the content of volatile hydrocarbons in the sinter feed
- Lowering the sulphur content of the sinter feed
- Heat recovery from sintering and sinter cooling
- Top-layer-sintering
- Waste gas recirculation e.g. Emission Optimised Sintering (EOS)
- Sectional waste gas recirculation for additional power generation

End-of-pipe techniques

The following end-of-pipe techniques are known to be in use at sinter plants:

- Electrostatic precipitator (ESP)
- Fabric filter system
- Cyclone
- Fine wet scrubber, e.g. Airfine
- Desulphurisation
- Regenerative activated carbon (RAC)
- Selective catalytic reduction (SCR)

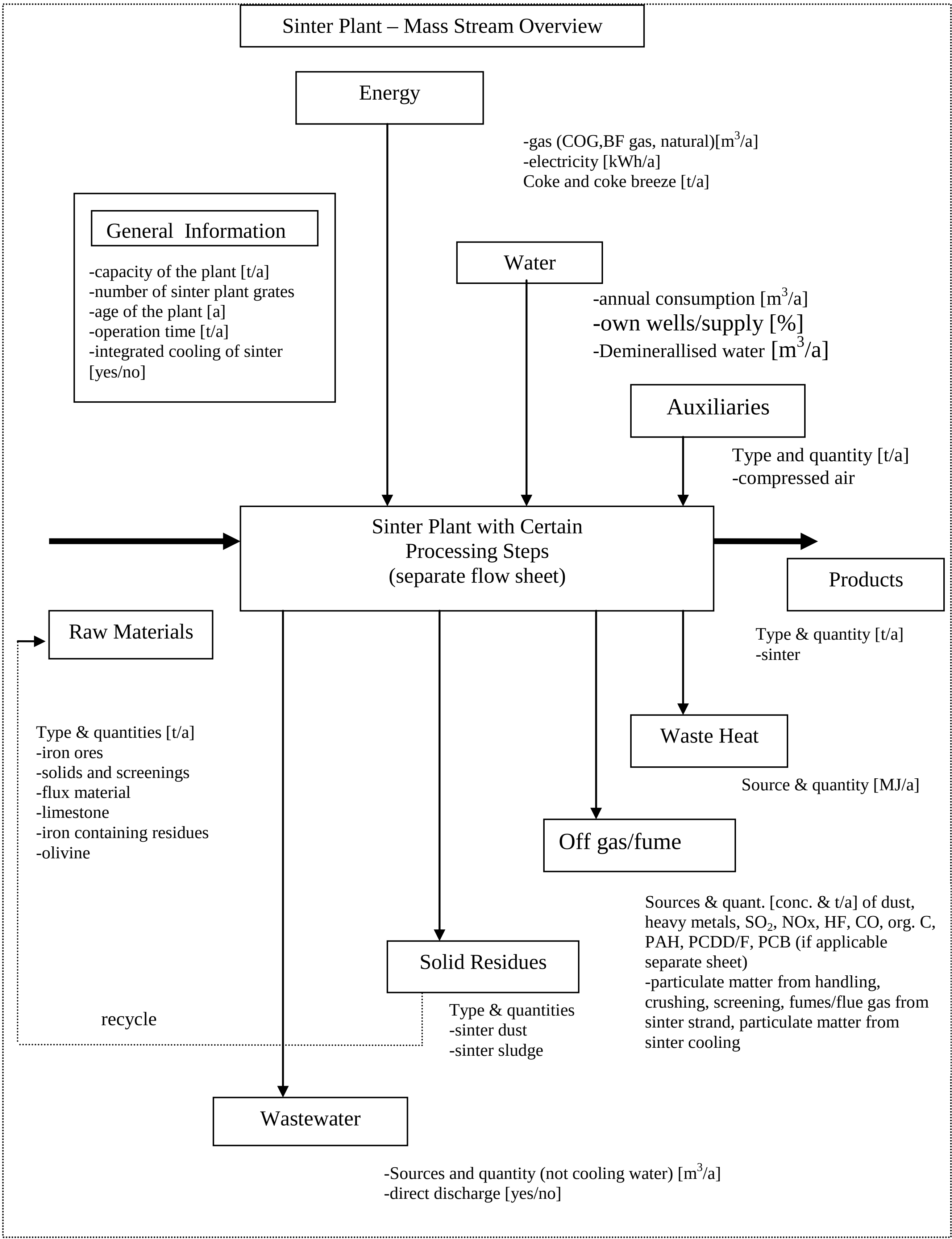


Figure 6: Mass Stream Overview of a Sinter Plant

5.0 COKE OVEN PLANTS

5.1 Process Overview

Coal pyrolysis means the heating of coal in an oxidation free atmosphere to produce gases, liquids and a solid residue (char or coke). Coal pyrolysis at high temperature is called carbonisation. In this process the temperature of the flue gases is normally 1150 – 1350 °C indirectly heating the coal up to 1000 – 1100 °C for 14 – 24 hours. This produces blast furnace and foundry cokes. Coke is the primary reducing agent in blast furnaces and can not be wholly replaced by other fuels such as coal. Coke functions both as a support material and as a matrix through which gas circulates in the stock column.

Only certain coals, for example coking or bituminous coals, with the right plastic properties, can be converted to coke and, as with ores, several types may be blended to improve blast furnace productivity, extend coke battery life, etc.

Developments in recent years have also been particularly aimed at minimising emissions from the processes and at improving working conditions for operators.The coke making process can be subdivided into:

- coal handling,
- battery operation (coal charging, heating/firing, coking, coke pushing, coke quenching),
- coke handling and preparation,
- collection and treatment of coke oven gas (COG) with recovery of by-products.

Figure 7 shows a simplified scheme of the whole sequence of operations and processes required to produce coke (showing emission sources).

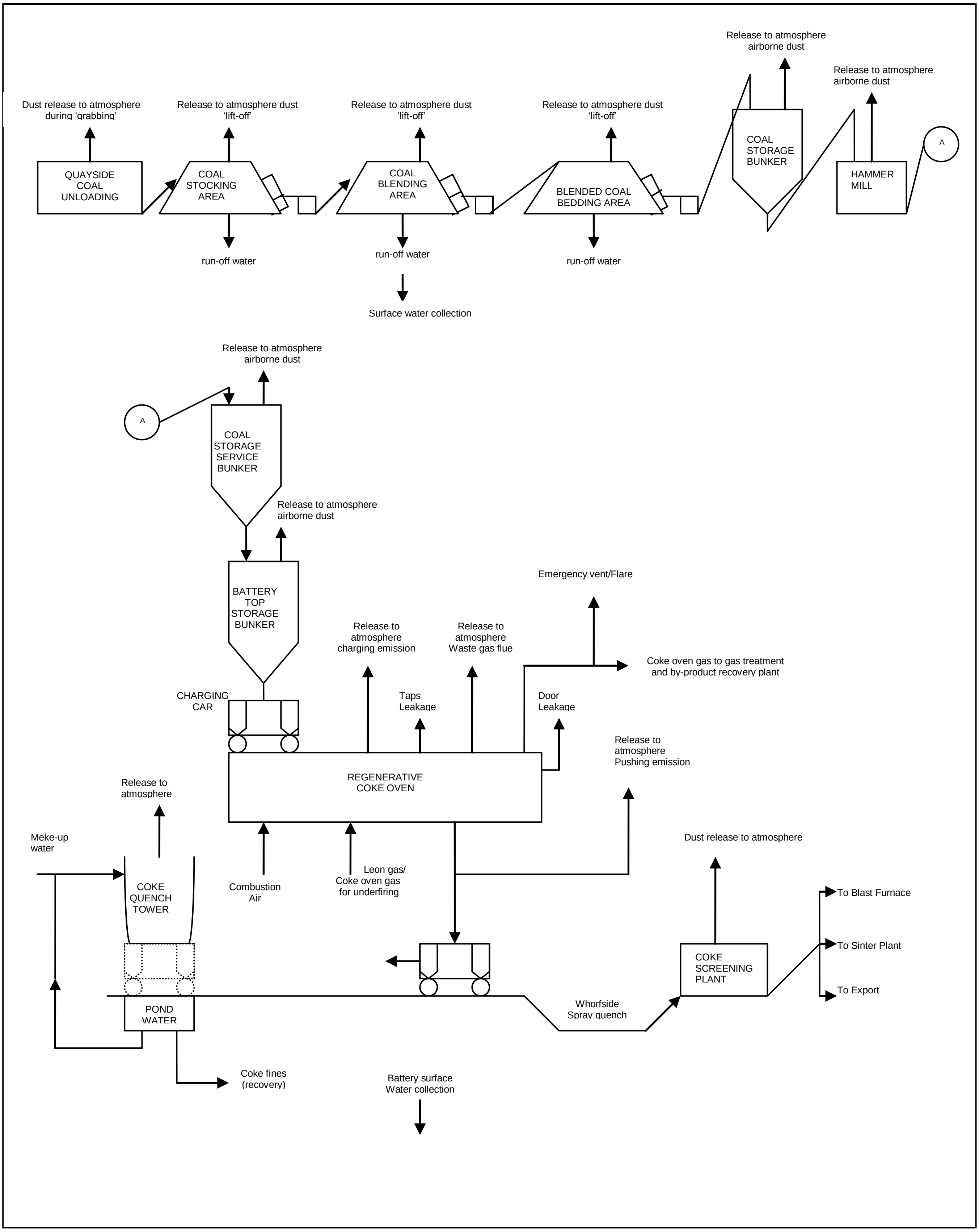


Figure 7: Typical Flow Diagram of a Coke Oven Plant

5.2 Mass Stream Overview and Input/Output Data

Figure 9 shows an overview of the input and output mass streams of a coke oven treatment plant.

5.3 Emissions to Air

It should be noted that coke oven plants have a relatively large number of emission sources (see **Figure 8**). The emissions from many of these vary considerably with time (e.g. semi-continuous emissions from doors, lids, ascension pipes and discontinuous emissions from pushing and quenching). Moreover, these emissions are difficult to quantify. Maintenance can be a determining factor. Indeed, one can well find examples of good results with traditional (knife edged) doors on well-maintained small ovens and bad results with modern flexible sealing doors on badly maintained large ovens.

5.4 Techniques to Consider In the Determination of BAT

This section lists both process-integrated and end-of-pipe techniques for environmental protection and energy saving at coke oven plants.

Process integrated measures

The following process-integrated techniques are known to be used at coke ovens:

- Smooth and undisturbed operation of the coke oven plant
- Maintenance of coke ovens
- Improvement of oven door and frame seals
- Cleaning of oven door and frame seals
- Maintaining free gas flow in the coke oven
- Emission reduction during coke oven firing
- Coke dry quenching (CDQ)

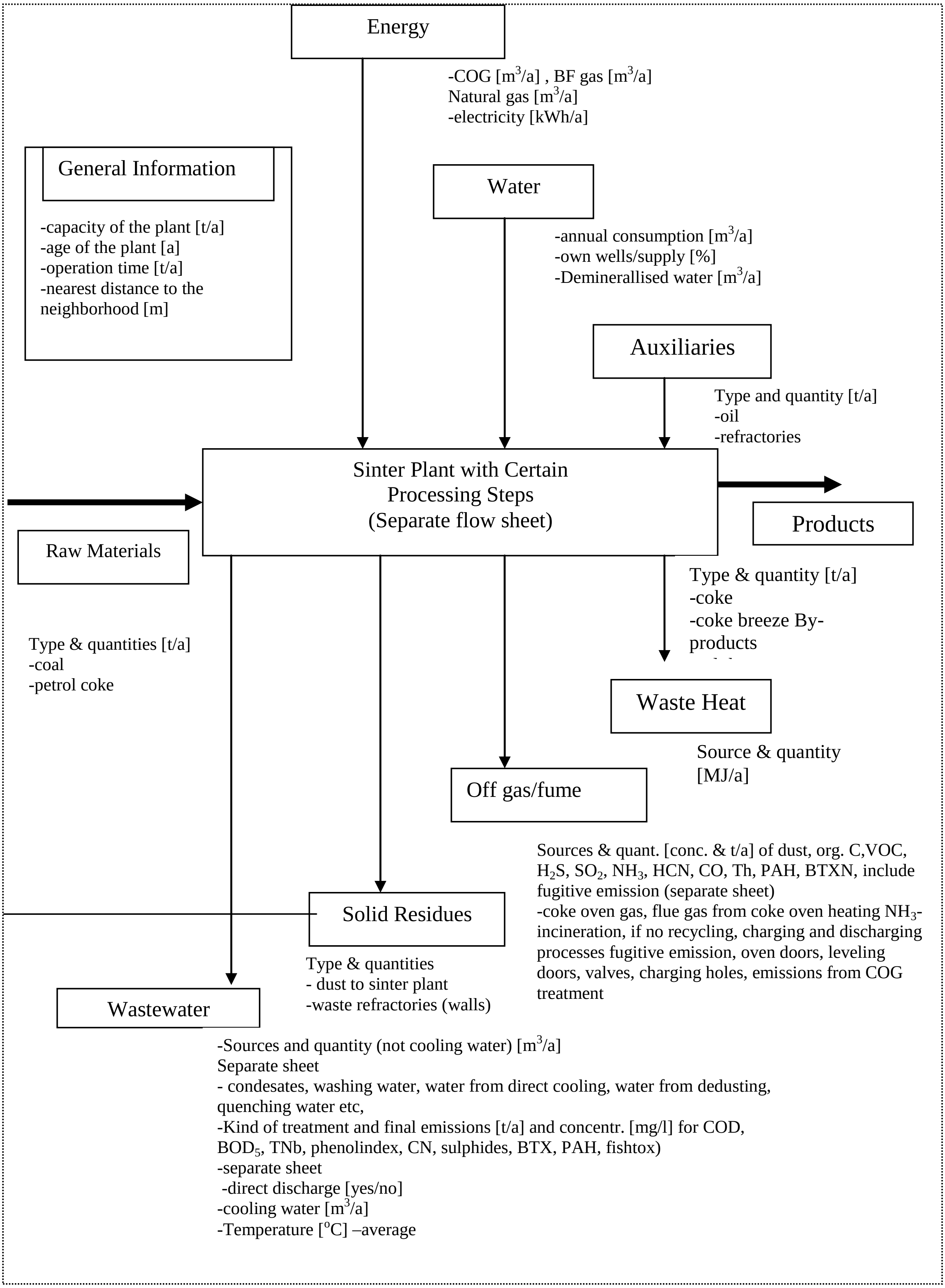


Figure 8: Mass Stream Overview of a Coke Oven Plant.

- Larger coke oven chambers
- Non-recovery coking
- Coke oven gas to hot blast stove
- Heat recovery from coke oven gas to other plants

End-of-pipe techniques

The following end-of-pipe techniques are known to be in use at coke oven plants:

- Minimising oven charging emissions
- Sealing of ascension pipes and charging holes
- Minimising leakage between coke oven chamber and heating chamber
- De-dusting of coke oven pushing
- Emissions minimised wet quenching
- De-NO_x of waste gas from coke oven firing
- Coke oven gas desulphurisation
- Removing tar (and PAH) from the coal water
- Ammonia stripper

6.0 BLAST FURNACES

6.1 Process Overview

The blast furnace remains by far as the most important process for the production of pig iron. A blast furnace is a closed system into which iron bearing materials (iron ore lump, sinter and/or pellets), additives (slag formers such as limestone) and reducing agents (coke) are continuously fed from the top of the furnace shaft through a charging system that prevents escape of blast furnace gas (BFgas). **Figure 9** shows a simplified layout of a blast furnace consisting of the furnace itself, the cast house, the hot stoves and two-stage treatment of BFgas.

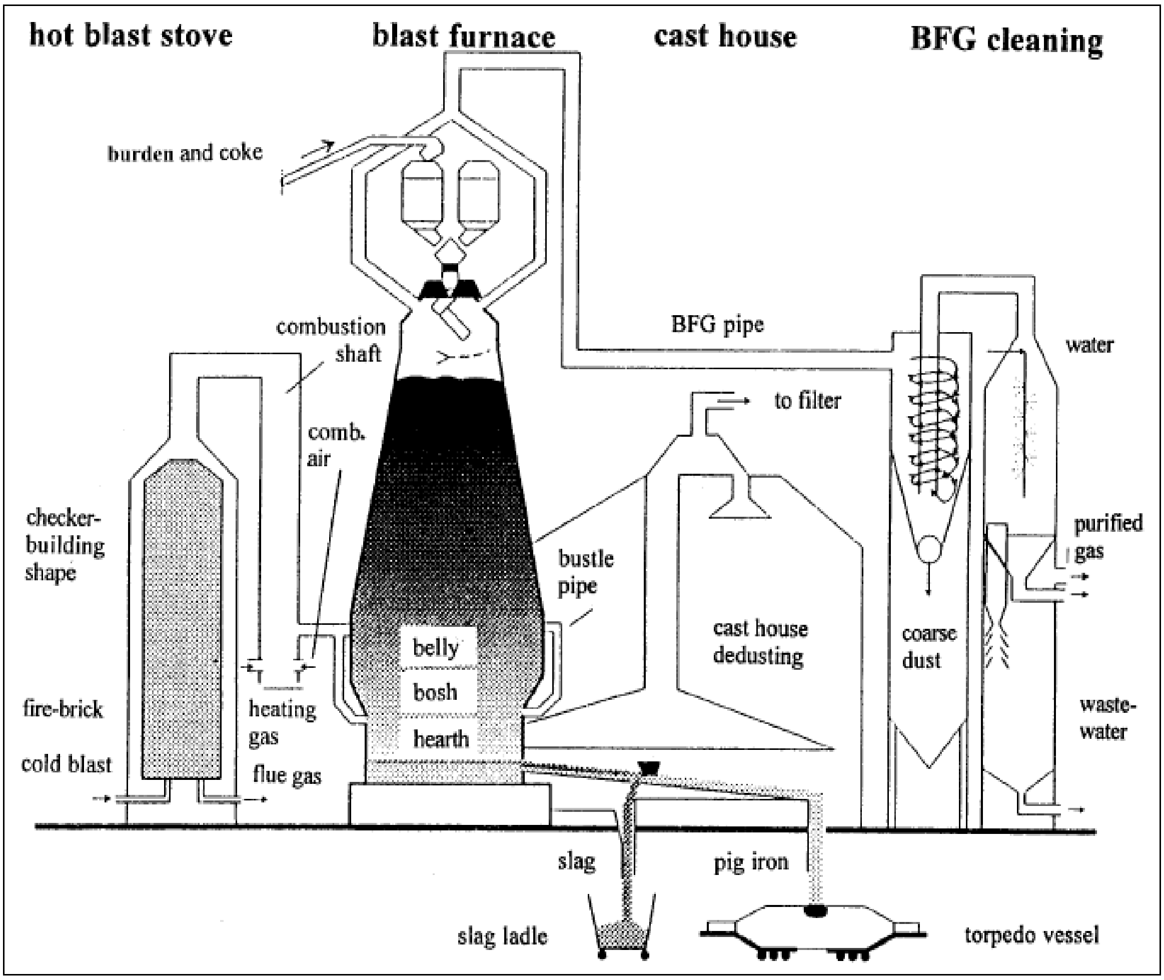


Figure 9: Simplified Scheme of a Blast Furnace

A hot air blast, enriched with oxygen and auxiliary reducing agents (coal powder, oil, natural gas and in a few cases plastics) is injected on the tuyère level providing a counter-current of reducing gases. The air blast reacts with the reducing agents to produce mainly Carbon monoxide (CO), which in turn reduces iron oxides to metal iron. The liquid iron is collected in the hearth along with the slag and both are cast on a regular basis. The liquid iron is transported in torpedo vessels to the steel plant and the slag is processed to produce aggregate, granulate or pellet for road construction and cement manufacture. The blast furnace gas (BFgas) is collected at the top of the furnace. It is treated and distributed around the works to be used as a fuel for heating or for electricity production.

Various reducing agents are available. Carbon/hydrocarbons in the form of coke, coal, oil, natural gas, or nowadays in some cases also plastics, are generally available in sufficient quantities at reasonable cost. However, the choice between several reducing agents is not determined by costs alone. Apart from being a reducing agent, coke also serves as a carrier of the bulk column in the blast furnace. Without this carrying capacity, blast furnace operation would not be possible.

Iron ore processed nowadays contains a large content of hematite (Fe_2O_3) and sometimes small amounts of magnetite (Fe_3O_4). In the blast furnace, these components become increasingly reduced, producing iron oxide (FeO) then a partially reduced and carburised form of solid iron. Finally, the iron charge melts, the reactions are completed and liquid hot metal and slag are collected in the bottom. The reducing carbons react to form CO and CO_2. Fluxes (limestone) and additives are added to lower the melting point of the gangue, improve sulphur uptake by slag, provide the required liquid pig iron quality and allow for further processing of the slag.

As the blast furnace burden moves down, its temperature increases, thus facilitating oxide reduction reactions and slag formation. The burden undergoes a series of composition changes as this happens:

- The iron oxide in the burden becomes increasingly reduced (forming sponge iron and finally molten pig iron).
- The oxygen from the iron ore reacts with the coke or the carbon monoxide, thus forming carbon monoxide or carbon dioxide, which is collected at the top.
- The gangue components combine with the fluxes (limestone) to form slag. This slag is a complex mix of silicates of a lower density than the molten iron.
- The coke primarily serves as a reducing agent, but also as a fuel. It leaves the furnace as carbon monoxide, carbon dioxide or carbon in the pig iron.
- Any hydrogen present also acts as a reducing agent by reacting with oxygen to form water.

The main operations are as follows:

- Charging of raw materials
- Generation of hot blast
- Blast furnace process
- Direct injection of reducing agents
- Casting
- Slag processing

6.2 Mass Stream Overview and Input/Output Data

Figure 10 shows an example of a general process layout of a blast furnace together with the input and output mass streams.

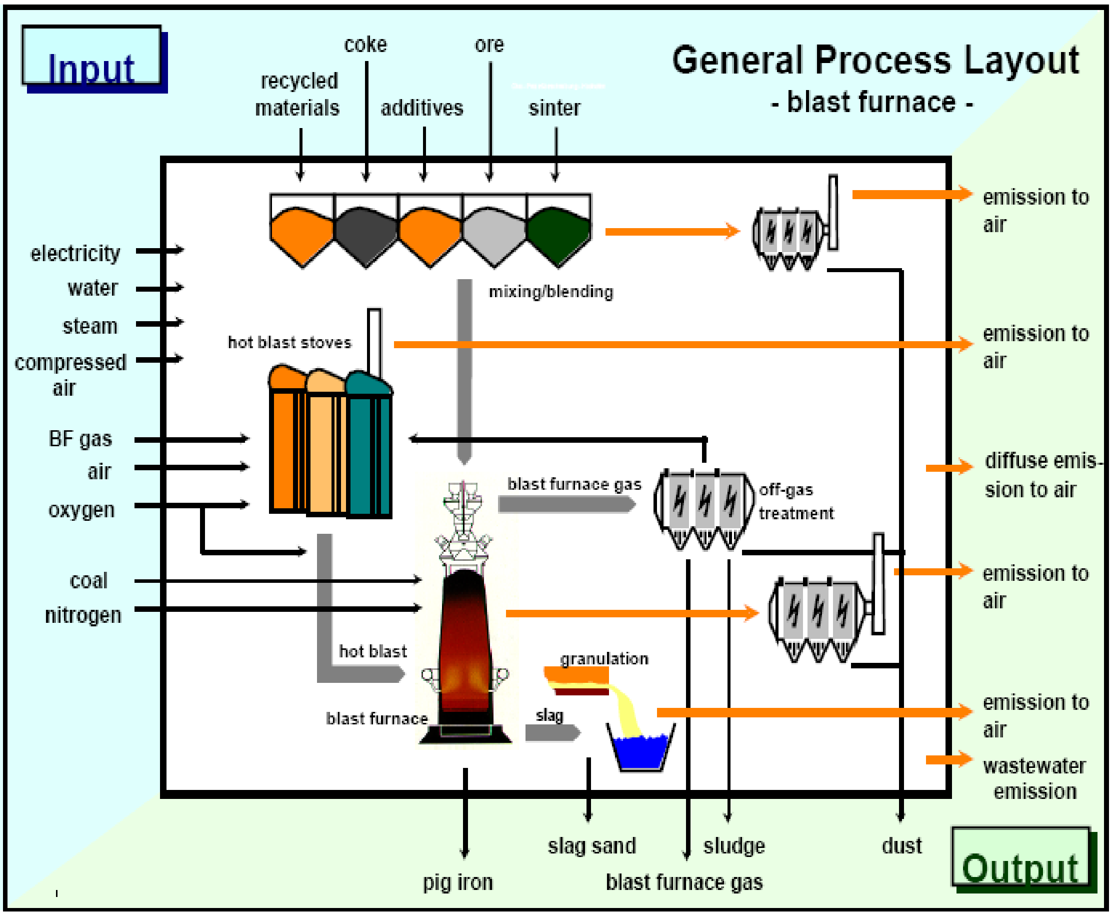


Figure 10: General Process Layout of a Blast Furnace

6.3 Emissions to the Air

The waste gas emissions consist of the following:

- Flue gas from the hot stove
- Emissions from charging
- Blast furnace gas
- Emissions from cast house
- Emissions from slag processing

The effluent gases contain particulate matter, CO, CO_2, sulphur compounds, ammonia, cyanide compounds, hydrocarbons and PAHs.

6.4 Techniques to Consider in the Determination of BAT

Process-integrated measures include:

- Direct injection of reducing agents
- Energy recovery from blast furnace gas for power generation
- Energy recovery from top gas pressure
- Energy saving at the hot stove
- Use of tar-free runner linings

End-of-pipe techniques

- Blast furnace gas treatment
- Fume suppression during casting
- Hydro-cyclonage of blast furnace sludge
- Energy recovery from hot blast stoves for power generation

7.0 BASIC OXYGEN STEELMAKING AND CASTING

7.1 Process Overview

The objective in oxygen steelmaking is to burn (i.e., oxidise) the undesirable impurities contained in the metallic feedstock. The main elements thus converted into oxides are carbon, silicon, manganese, phosphorus, and sulphur. The purpose of this oxidation process, therefore, is:

- to reduce the carbon content to a specified level (from approximately 4% to less than 1 %, but often lower)
- to adjust the contents of desirable foreign elements
- to remove undesirable impurities to the greatest possible extent

The production of steel by the BOF process is a discontinuous process which involves the following steps:

- transfer and storage of hot metal
- pre-treatment of hot metal (desulphurisation)
- oxidation in the BOF (decarburisation and oxidation of impurities)
- secondary metallurgical treatment
- casting (continuous or/and ingot)

The individual steps and their associated emissions are summarised in **Figure 11**.

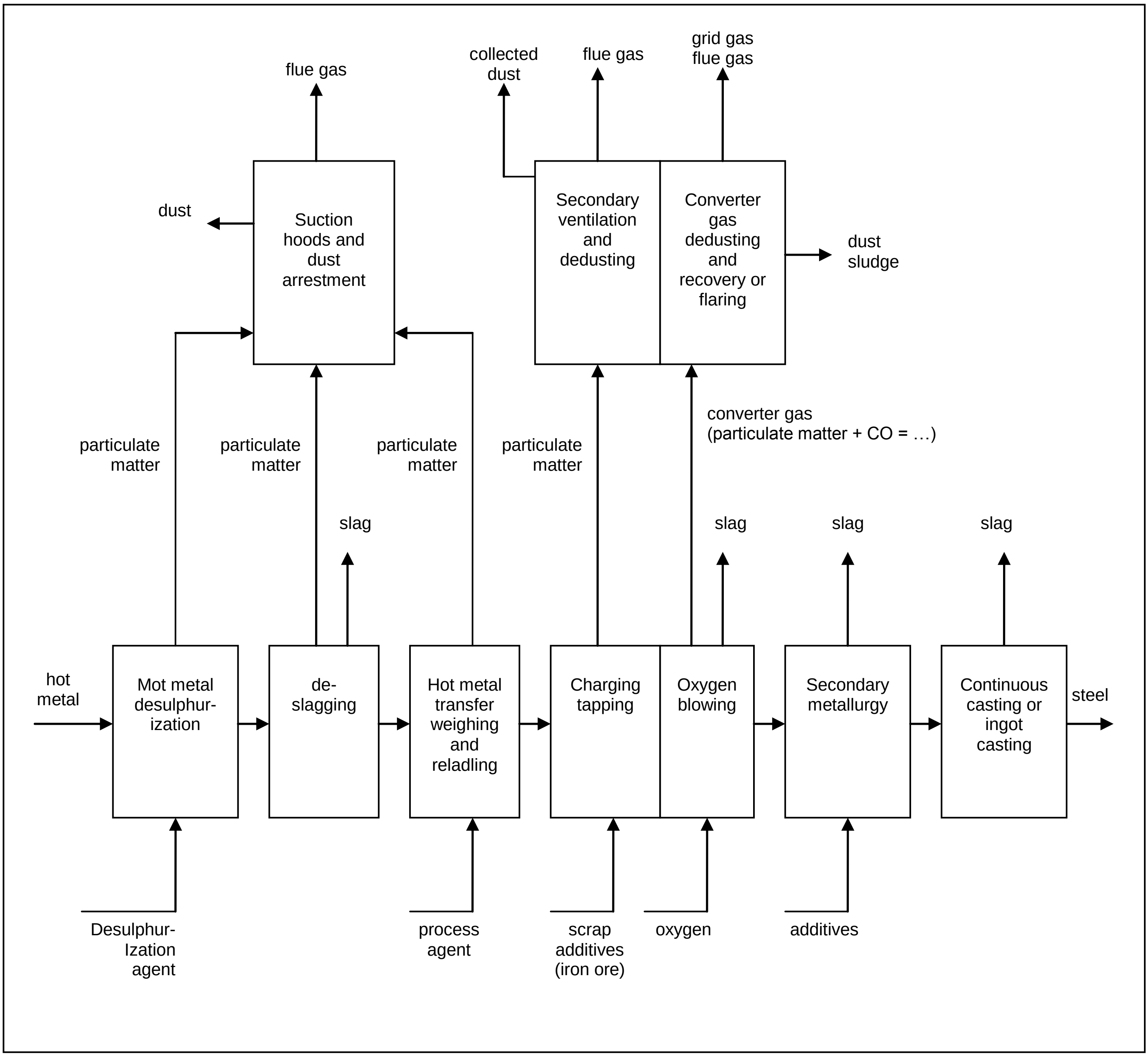


Figure 11: The Sequence of Oxygen Steelmaking Indicating the Individual Emission Sources

7.2 Mass Stream Overview and Input/Output Data

Figure 12 presents the general layout of the basic oxygen steelmaking showing its input and output streams together with the possible emissions.

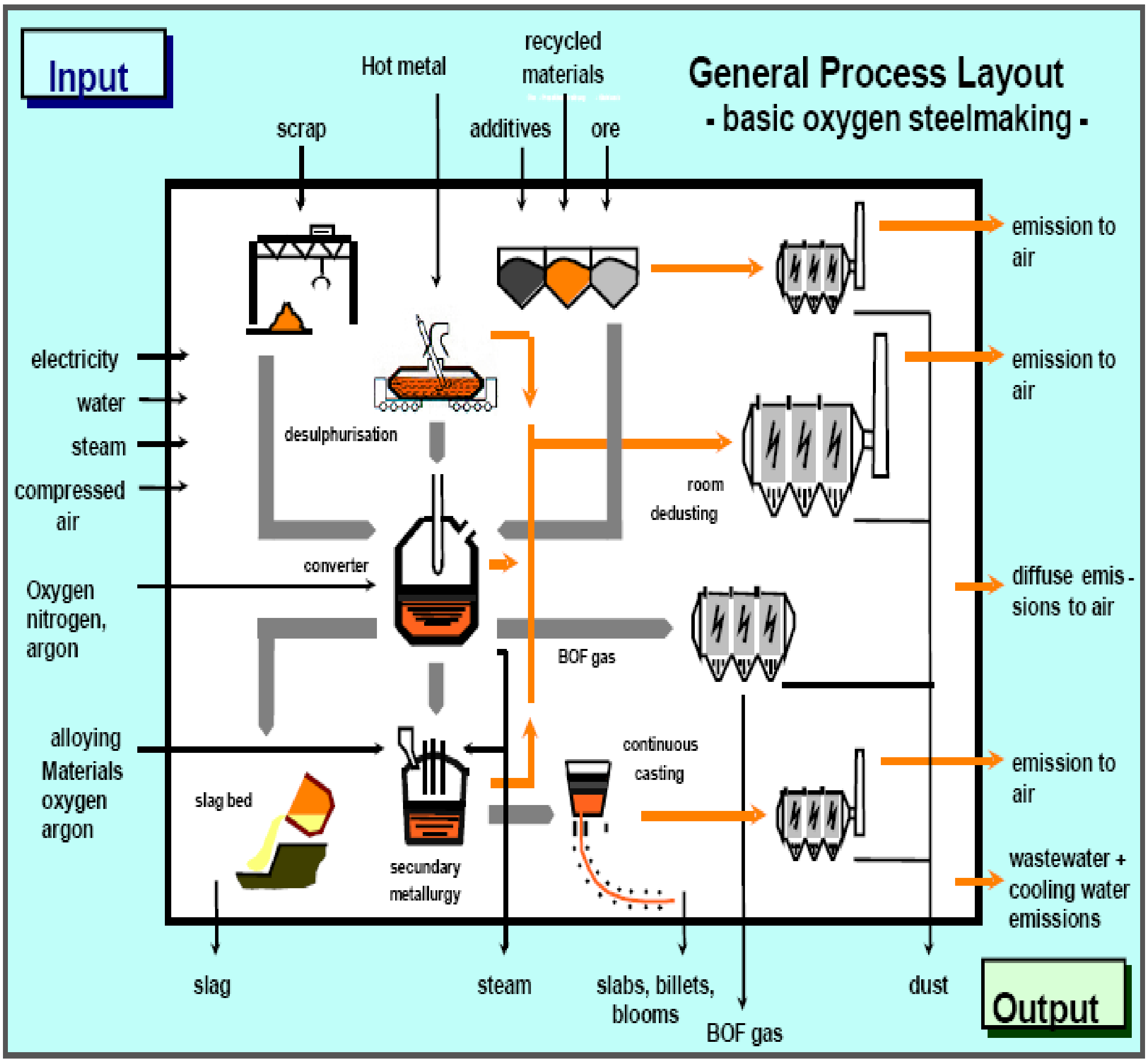


Figure 13: General Process Layout of Basic Oxygen Steelmaking

7.3 Air Emissions

The air emissions consist of off-gases listed as below:

Off-gas emissions:

Primary off-gases from the following unit operations:

- pig iron pre-treatment
- oxygen blowing and BOF gas (converter gas)
- adles, ladle furnaces, converters and other equipment used in secondary
- metallurgy

Secondary off-gases from

- reladling and deslagging of hot metal
- BOF charging
- tapping of liquid steel and slag from BOF (converters) and ladles
- secondary metallurgy and tapping operations
- handling of additives
- continuous casting

The effluent gases contain particulate matter, SO_x, NO_x, CO.

7.4 Techniques to Consider in the Determination of BAT

Process-integrated measures include:

- Energy recovery from the BOF gas
- Lowering the zinc-content of scrap
- On-line sampling and analysis of steel

End-of-pipe techniques include:

- Primary de-dusting
- Particulate matter abatement from pig iron pre-treatment
- Secondary de-dusting
- Dust hot-briquetting and recycling
- Treatment of wastewater from wet de-dusting
- Treatment of cooling water from continuous casting

8.0 ELECTRIC STEELMAKING AND CASTING

8.1 Process Description

The direct smelting of iron-containing materials, such as scrap is usually performed in electric arc furnaces (EAF) which play an important and increasing role in modern steel works concepts. Today the electric arc furnace (EAF) dominates the overall steel production in the Malaysia.

The major feed stock for the EAF is ferrous scrap, which may comprise scrap from inside the steelworks (e.g. off-cuts), 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 both to its low gangue content and variable scrap prices. A slag is formed from lime to collect undesirable components in the steel.

An overview of the electric steel making process is given in **Figure 13**.

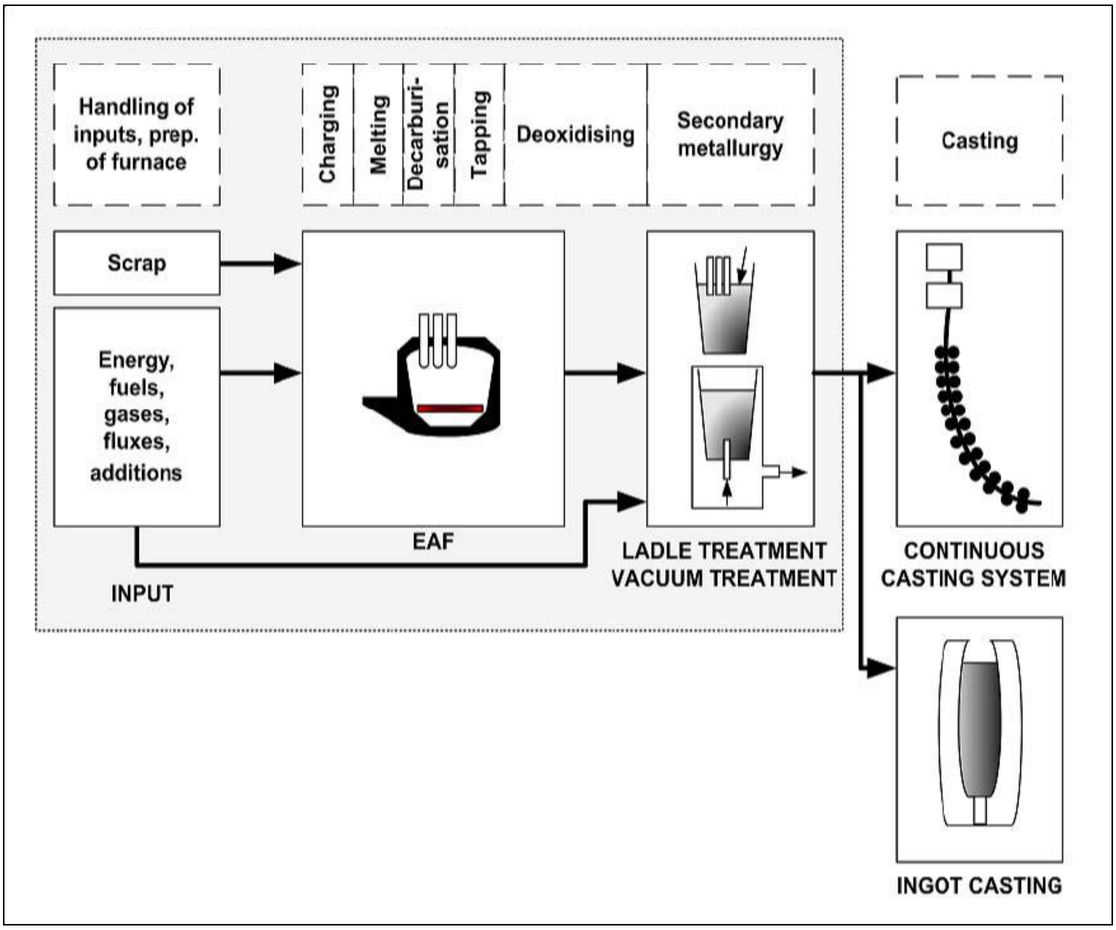


Figure 14: Overview of the Processes Related to Electric Arc Furnace Steelmaking

With respect to the end-products, distinction has to be made between productions of ordinary, so-called carbon steel as well as low alloyed steel and high alloyed steels/stainless steels.

For the production of carbon steel and low alloyed steels, the following main operations are performed:

- raw material handling and storage
- furnace charging with/without scrap preheating
- EAF scrap melting
- steel and slag tapping
- ladle furnace treatments for quality adjustment
- slag handling and continuous casting

For high alloyed and special steels, the operation sequence is more complex and tailor-made for the end-products. In addition to the mentioned operations for carbon steels various ladle treatments (secondary metallurgy) are carried out like:

- desulphurisation
- degassing for the elimination of dissolved gases like nitrogen and hydrogen
- decarburisation (AOD = Argon-Oxygen-Degasser or VOD = Vacuum-Oxygen-Degasser)

8.1.1 Raw Materials Handling and Storage

The main scrap storage areas are usually outside in large uncovered and unpaved scrap-yards which may lead to soil pollution, however in most cases scrap yards are left open but there are also certain plants having covered and paved scrap-yards. Depending on weather conditions volatile inorganic and organic compounds may be emitted. Today control of radioactivity of input scrap has become an important issue but this relevant problem is not covered by this document.

Some scrap sorting is carried out to reduce the risk of including hazardous contaminants. In-house generated scrap can be cut into handle-able sizes using oxygen lancing. The scrap may be loaded into charging baskets in the scrap-yard 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 (see scrap preheating).

Other raw materials including fluxes in lump and powder, powdered lime and carbon, alloying additions, de-oxidants 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.

8.1.2 Scrap Preheating

EAF facilities may also be equipped with a system for preheating the scrap by the off gas in order to recover energy. Today the so-called shaft technology and the Consteel Process are the two proven systems which have been successfully introduced into practice [Haissig, 1997].

The shaft technology has been developed in steps [Voss-Spilker, 1996]. With the single shaft furnace normally only about half of the charged scrap can be preheated, meanwhile with the finger shaft furnace (which means a shaft having a scrap retaining system) 100% of scrap can be preheated. The first basket is preheated during refining of the previous heat and the second during melt down of the first one. A further modification is the double shaft furnace which consists of two identical shaft furnaces (twin shell arrangement) positioned next to each other and is serviced by a single set of electrode arms. The scrap is partly preheated by off gas and partly by side wall burners.

8.1.3 Charging

The scrap is usually loaded into baskets together with lime or dolomite which is used as a flux for the slag formation. The furnace electrodes are raised in 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 20-30 mm above the scrap they strike an arc. After the first charge has been melted the remainder of the scrap is added from a second or third basket.

A proprietary available system is known as the shaft furnace which allows part of the scrap to be preheated by charging it through a vertical shaft integrated in the furnace roof (see scrap preheating) [Voss-Spilker, 1996]. Another new charging system has been developed. In the Consteel Process the scrap is continuously fed via a horizontal conveyor system into the arc furnace

[Vallomy, 1992]. But this system is not generally considered as a proven technique.

8.1.4 Arc Furnace Melting and Refining

During the initial period of melting, the applied power is kept low to prevent damage to the furnace walls and roof from radiation 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 melting. Oxygen lances and/or oxy-fuel burners are increasingly more and more used 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 found increasing considerations within the last 30 years not only for metallurgical reasons but also for increasing productivity requirements. The increase of oxygen usage can be attributed to today´s availability of liquid oxygen and on-site oxygen plants [Knapp, 1996].

Oxygen for metallurgical reasons is used for decarburisation of the melt and removal of other undesired elements such as phosphorous, manganese, silicon and sulphur. In addition it reacts with hydrocarbons forming exothermic reactions. Oxygen injection results in a marked 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 case of post-combustion the CO content is below 0.5 vol %.

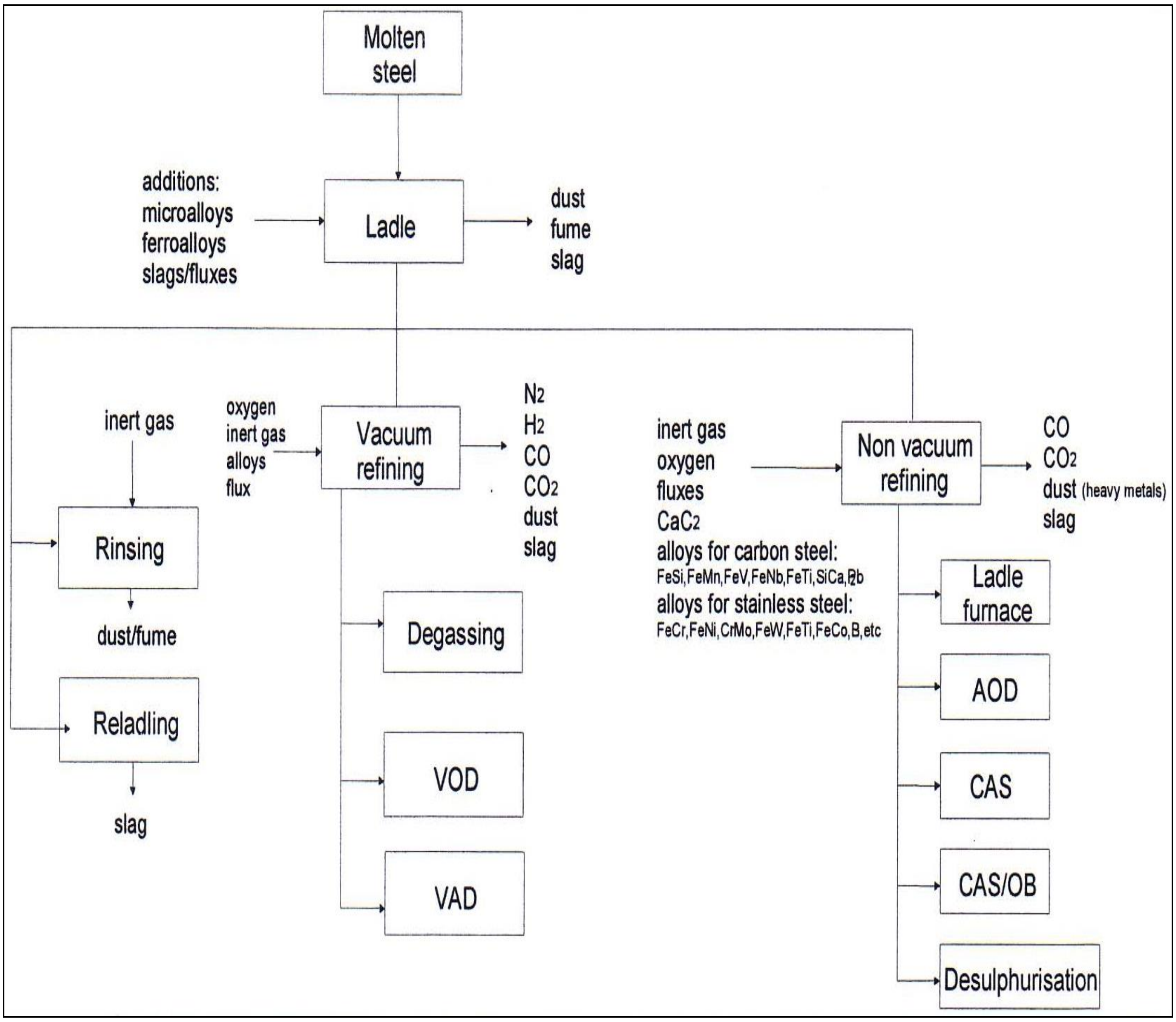
Argon or other inert gases may be injected into the melt to provide bath agitation and temperature balancing. The slag-metal equilibrium is also improved by this technique.

8.1.5 Steel and Slag Tapping

In plants without separate secondary metallurgy facilities, alloying elements and other additions are often given to the steel ladle before or during tapping. Such additions can noticeably increase the fume arising during tapping. 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 run off or raked into a pot or on the ground below the furnace resulting in dust and fume generation. Today the steel is normally tapped through a bottom tapping system with minimum slag carry over into the ladle.

8.1.6 Secondary Metallurgy

Secondary metallurgy which is carried out in ladles covers the processes and treatment of molten steel after the tapping of the primary steel making furnace up to the point of casting. It is typically carried out at ladle treatment stations. These stations in bulk steel production plants are usually located around a vacuum generation system or arc heating unit. Other minor stations are based on inert gas or powder injection equipment. These processes are shown schematically in **Figure 14**. In case of production of leaded steel, off gases containing lead has to undergo special treatment



Legend: VOD=Vacuum-Oxygen-Degasser; VAD=Vacuum-Arc-Degasser; AOD=Argon-Oxygen-Degasser; CAS=Compositional Adjustment by Sealed Argon Bubbling; CAS/OB = CAS plus Oxygen Blowing

Figure 14: Secondary Metallurgy/Ladle Treatment –[UK EAF, 1994]

8.1.7 Slag Handling

Besides slag tapping further dust and fume are created during retrieval of the slag which may still be hot, using excavators. Outside the furnace building the slag may be cooled by water spraying before it is crushed and screened to allow metal recovery. In case of slag with free lime-alkaline fumes may be emitted. Slag breaking (or in some cases cutting with oxygen lances) and metal recovery can create dust emissions.

8.1.8 Continuous Casting

The liquid steel is usually cast continuously. Ingot casting is also still applied for some grades and applications. 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. Steel is tapped from the ladle into a tundish from which it is distributed at a controlled rate into water-cooled copper moulds of appropriate dimensions.

To prevent the solidified shell from sticking, the mould is oscillated in the direction of casting at speed greater then the casting speed and a mould lubricant is added in powder form or vegetable oil. The strand is continuously withdrawn and is further cooled using direct water sprays. At a point where solidification is complete the strand is cut to required lengths using automatic oxy-gas cutters. In case of oxygen cutting or hydraulic shears of stainless steel iron powder injection is employed.

8.2 Mass Stream Overview and Input/Output Data

Figure 15 provides an overview for the input and output of electric arc furnaces.

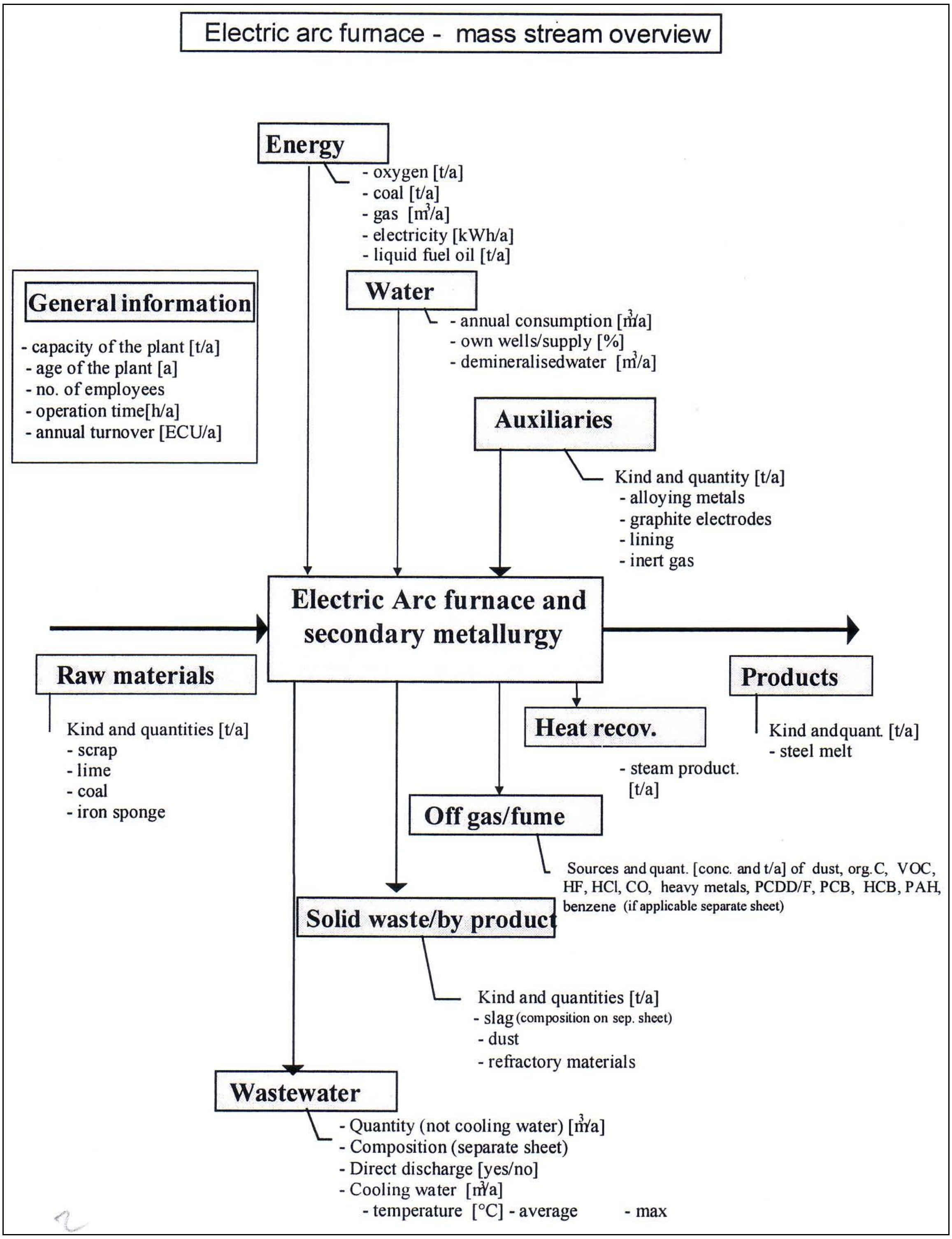


Figure 15: Mass Stream Overview of an Electric Arc Furnace

8.3 Single Emission Mass Streams, Noise Emissions and Energy Demand

The following emissions of off gases, solid wastes/by-products and wastewater can be recognised in electric arc furnace steelmaking.

- Off gas emissions
  -Primary off gases
  -Off gas directly collected from the EAF
  -Off gas directly collected from secondary metallurgy processes
- Secondary off gases from scrap handling and charging, steel tapping, secondary metallurgy with tapping operations and from continuous casting
- Fumes from slag processing
- Solid wastes/by-products
  - Slags from production of carbon steel/low alloyed steel/high alloyed steels
  - Dusts from off gas treatment
  -Refractory bricks
- Noise emission

8.3.1 Off Gas Emissions

Primary off gases represent approximately 95% of total emissions from an EAF [EC EAF, 1994]. Most of the existing plants extract the primary emissions by the 4th hole (in case of three electrodes) or by the 2nd hole (in case of one electrode) (**Figure 16**). Thus 85 – 90% of the total emissions during a complete cycle “tap-to-tap” can be collected [EC EAF, 1994]. In addition to the 4th hole, a system for evacuation the building atmosphere, especially hoods (see **Figure 16**).

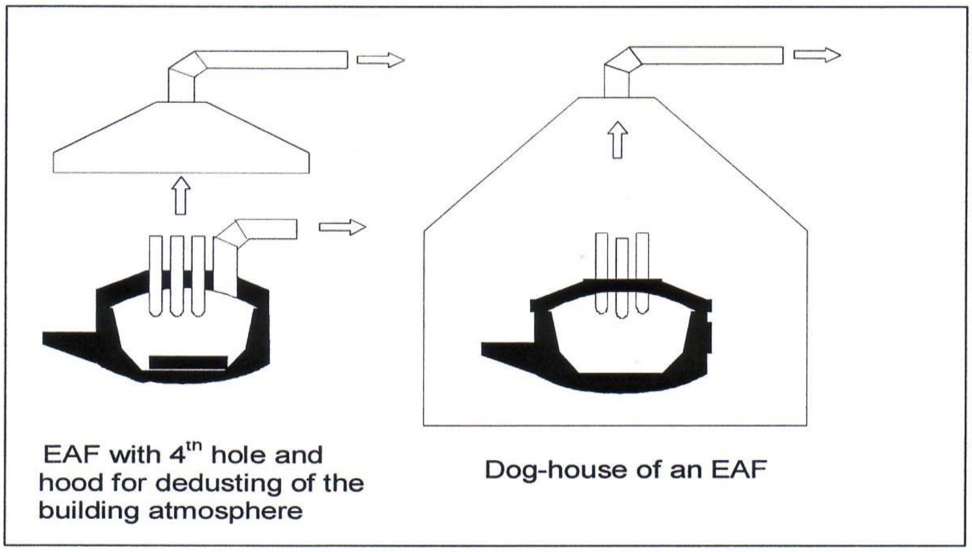


Figure 16: Dust Collection Systems at EAF – based on [O. Rentz, 1997]

In this way also most of secondary emissions from charging and tapping as well as from EAF leakages during melting can be captured. If secondary metallurgy is carried out in the same building also these emissions can be collected. Very often the treatment of primary and secondary emissions are performed in the same device, mostly in bag filters.

The primary off gas contain 14 – 20 kg dust/t liquid carbon/steel or low alloyed steel and 6 –15kg dust/t in case of high alloyed steel [EC EAF, 1994]. 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). The heavy metals, especially mercury, which are present in the gas phase, are not associated with particulate matter. Thus they can not be eliminated by filtration or ESP. However most of the heavy metals are mainly associated with particulate matter and are removed from the off-gas with the separated dust.

a. Heavy metals

Some emissions show wide ranges. Higher values can be of high environmental relevance. Zinc is the metal with the highest emission factors. Mercury emissions can strongly vary from charge to charge depending on scrap composition/quality [Theobald, 1995; UBA-BSW, 1996]. The SO_2 emissions mainly depend on the quantity of coal and oil input but is not of high relevance. NO_x emissions also do not need special consideration.

8.3.2 Off Gas Directly Collected from Secondary Metallurgy Processes

Information about emissions from secondary metallurgy (mainly dust emissions) is very limited. [EC Study, 1996] reports dust emission factors before abatement from seven AOD/VOD refining installations between 6 – 15 kg dust/t LS and a single low figure of 1.35 kg dust/t LS. These seven installations have a de-dusting device independent from the de-dusting of EAF. Emission factors or concentrations after abatement are not reported.

8.3.3 Secondary Off Gases from Scrap Handling and Charging, Steel Tapping, Secondary Metallurgy with Tapping Operations and from Continuous Casting

Secondary emissions mainly mean the emissions of dust except fume leakages from EAF which may contain all the pollutants described under primary emissions. Information about secondary emissions is also limited. From charging the EAF usually 0.3 – 1 kg dust/t LS and from tapping 0.2 – 0.3 kg dust/t LS are emitted (emissions before abatement) [EC EAF, 1994]. For fume leakages during EAF operation dust emission factors between 0.5 – 2 kg dust /t LS are reported [EC Study, 1996].

Emission factors as sum of the mentioned three sources (charging, tapping, fume leakages) are between 1.4 – 3 kg dust/t LS [EC Study, 1996]. This can be considered as a confirmation that primary emissions are about ten times higher than secondary emissions.
Information about quantities of dust emissions from scrap handling as well as from continuous casting is not available.

Usually the secondary off gases are treated together with the primary ones. Bag filters are widely in use (about 90% of the installations [EC Study, 1996]) but in a few cases ESP and wet scrubbers are also applied.

8.3.4 Fumes from Slag Processing

The processing of slags includes cooling down by water spraying 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

8.4 Techniques to Consider in the Determination of BAT

Process-integrated measures include:

- EAF process optimisation
- Scrap preheating
- Closed loop water cooling system
- Hot DRI for energy saving and minimize dust

End-of-pipe techniques include:

- Advanced emission collection systems
- Efficient post-combustion in combination with advanced off gas treatment

8.4.1 EAF Process Optimization

Description: The EAF process has been steadily improved in order to optimise it and to increase productivity which correlates with the decrease of specific energy consumption.

Figure 17 indicates some of the most important measures/techniques which are briefly described in the following. These are:

a. (Ultra) High power operation (UHP),
b. Water cooled side walls and roofs,
c. Oxy-fuel burners and oxygen lancing,
d. Bottom tapping system,
e. Foaming slag practice,
f. Ladle or secondary metallurgy,
g. Automation.
h. Hot metal charging for energy saving and minimize dust

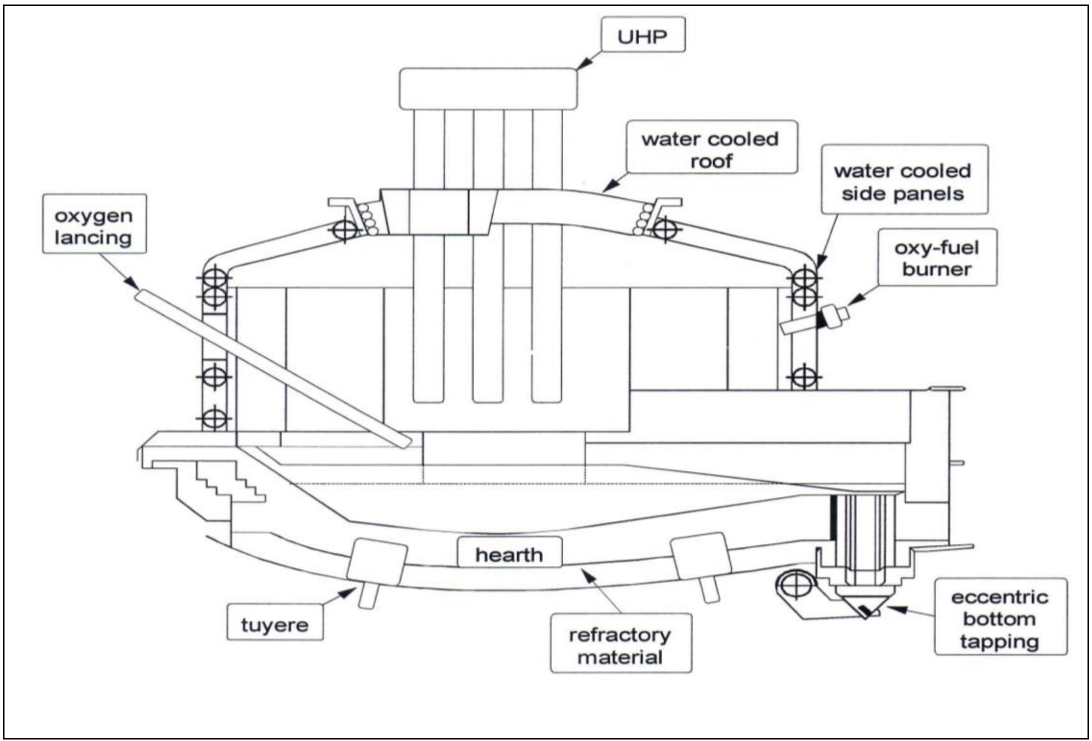


Figure 17: Schematic of an EAF With Indication of Techniques for Optimisation – [O. Rentz, 1996]

a. (Ultra) High power operation:

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

b. Water cooled side walls and roofs

Within the last two decades, furnace walls and roofs have been lined with water cooled panels, providing the opportunity to save refractory material, to use the (ultra) high power furnace technology, and also to re-use waste heat by the application of measures for energy recovery. However, it has to be checked on a plant by plant basis, if the recovery of energy is economically viable. In principle, two cooling systems can be distinguished. So-called cold or warm cooling draws off power losses by an increase of the cooling water temperature flowing through the pipe coils. Evaporation cooling works by 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 (see below) is not possible, a computer controlled regulation of the melt-down process helps to prevent tears in the panels caused by mechanical tension and also saves refractory material [Knoop, 1997].

c. 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 of total energy input required.

d. Bottom tapping system:

The practice of bottom tapping is widely adopted nowadays, as it makes possible to minimize the amount of oxidic slag (carry over) to the ladle during tapping. 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. While some older furnaces are still equipped with spouts, usually most of the new electric arc furnaces are equipped with bottom tapping systems.

e. 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 less 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 (eg. between slag and melt). The density of foaming slag is less than common FeO containing EAF slag (1.15-1.5 t/m^3 compared to 2.3 t/m^3). For this reason, the volume of slag arising during steelmaking is rising and may require larger slag buckets. After tapping, the slag partly degasses again. Information on adverse impacts of the foamy slag practice on the possibilities to use the slag has not been encountered.

f. 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). These tasks have been shifted from the EAF to ladles, ladle furnaces, or other vessels nowadays [EPRI, 1992; 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, increasing the productivity, a better control of 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 of the emissions from the EAF itself [EPRI, 1992]. A possible drawback of using ladles or other vessels with respect to air pollution control is the increase in the numbers of emission sources, requiring higher investments for air pollution control equipment, as additional fume capturing devices like hoods are needed.

g. **Automation:**

Computer control in electric arc furnace plants has become necessary within recent years, 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 permit an increase in productivity, a reduction in energy consumption, and also a decrease in dust emissions [Linninger, 1995].

Applicability: The described techniques are applicable both to new and existing plants but have to be checked on a plant to plant basis.

Cross-media effects: Oxy-fuel burner's increase the off gas flow but on the other hand it decreases the overall energy demand. Water cooled side walls and roof need additional energy consumption of about 10-20 kWh/t but may be compensated 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 HP or UHP furnace.

8.4.2 Scrap Preheating

Description: The recovery of waste heat from off gases is a well-known approach. In seventies about twenty plants have been erected to preheat the scrap in the basket prior to its discharge into the furnace. But all these systems have been taken out of operation, due to technical and emission problems. New furnace concepts with shaft integrated scrap preheating. With the single shaft furnace at least 50 % of the scrap can be preheated [Smith, 1992] whereas the new finger shaft furnace (**Figure 18**) allows the preheating of the total scrap amount [Voss-Spilker, 1996].

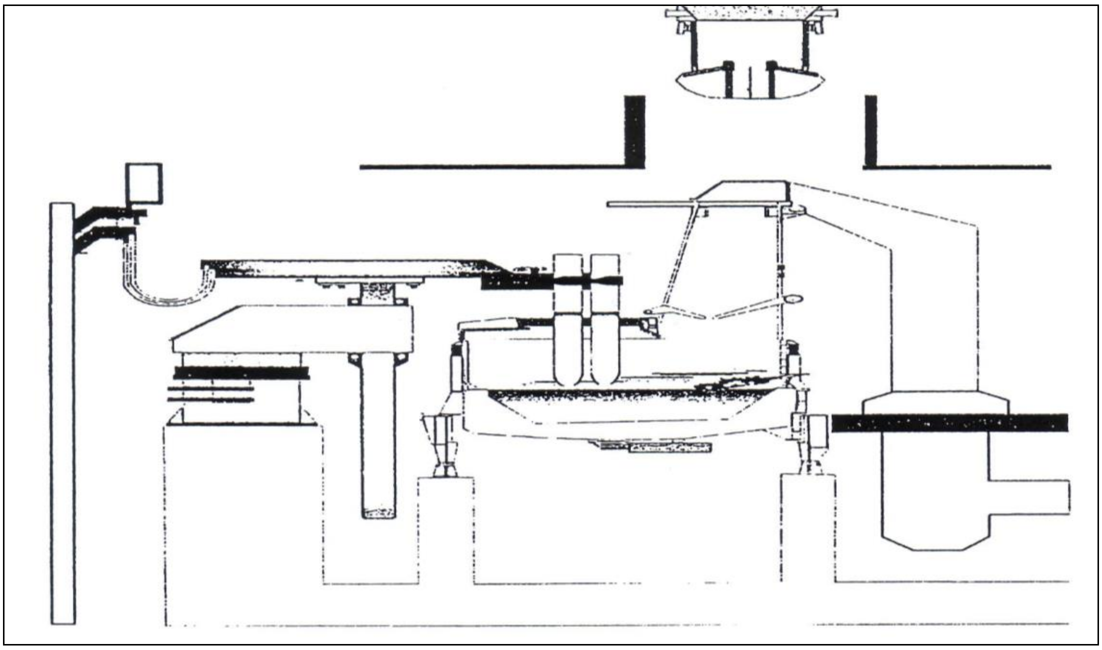


Figure 18: Schematic of an EAF with a Shaft Equipped With "Fingers" in Order to Retain the Scrap (Finger Shaft Furnace) for Preheating – [Voss-Spilker, 1996]

With finger shaft EAF tap-to-tap times of about 35 minutes are achieved which is about 10-15 minutes less compared to EAF without efficient scrap preheating. This allows a very short pay back time which is in the order of one year. Another available process for scrap preheating is the Consteel process [McManus, 1995] (**Figure 19**) but this system is not generally considered as a proven technique.

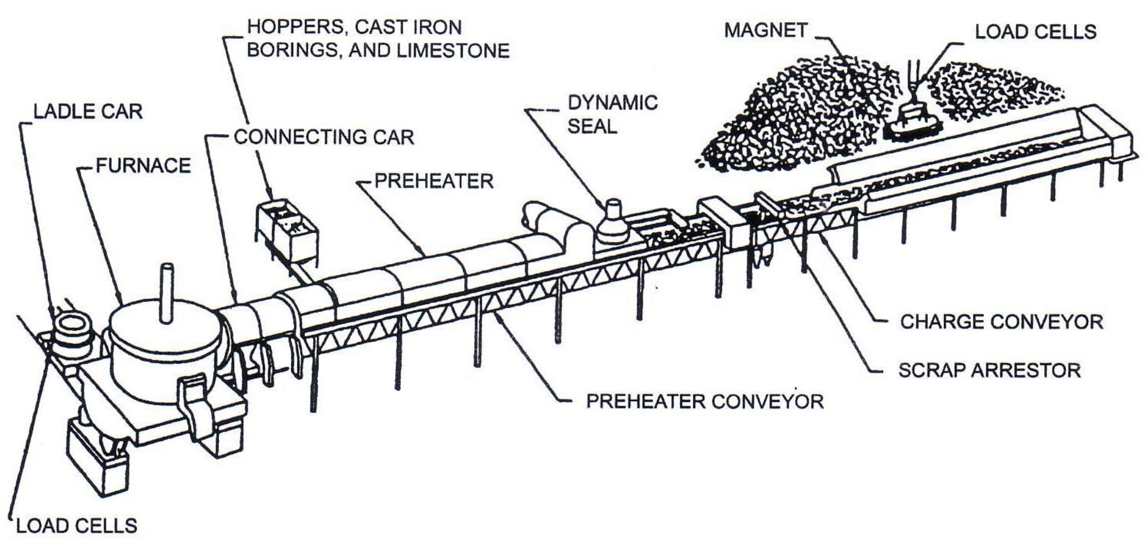


Figure 19: Schematic of the Consteel Process – [Vallomy, 1992]

Main achieved emission levels: With the single shaft furnace up to 70 kWh/t LS of electric power can be saved. Calculated on the basis of primary energy the savings are about three times higher because of the low efficiency of electricity supply. In addition the scrap preheating significantly reduces the tap-to-tap time which means a considerable increase of productivity.

The finger shaft furnace allows energy savings up to 100 kWh/t LS which is about 25% of the overall electricity input. In combination with an advanced off gas treatment scrap preheating may play a significant role in optimisation of electric arc furnace steelmaking not only related to productivity but also minimise emissions.

As a side effect scrap preheating reduces raw dust emissions about 20% because the off gas has to pass the scrap which acts as a filter. This reduction correlates with an increase of the zinc content in the dust which supports its recycling.

Applicability: Applicable both to new and existing plants. In case of existing installations the local circumstances like space availability or given furnace concept have to be checked on a plant by plant basis.

Cross-media effects: The scrap preheating in a shaft may lead to an increase of organic micro-pollutants and smell, such as PCDD/F unless adequate thermal treatment of the off-gases is performed. Additional off gas treatment may be necessary which needs additional energy. But in relation to the energy saving by scrap preheating this additional energy consumption may be reasonable and acceptable, especially when taking into account that electric power is generated from thermal energy with a yield of about 35% and for post-combustion natural gas is used.

8.4.3 Closed Loop Water Cooling System

Description: Generally, water is only used in the EAF steelmaking processes in connection with non-contact cooling, and 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 the following. 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 section. The water needed with respect to the cooling elements amounts to 5-12 $m^3/(m^2h)$ [D Rentz, 1997].

Modern plants operate with closed cooling systems in the EAF and secondary metallurgy Sections

Main achieved emission levels: No discharge of wastewater.

Applicability: Applicable both to new and existing plants

Cross-media effects: The closed loop system requires additional energy for water pumping and water re-cooling.

8.4.4 Advanced Emission Collection Systems

Description: The primary and secondary emissions to air are of high relevance. The available abatement techniques should be fed with the raw emissions as complete as possible. Thus the collection of the emissions is important. The combination of 4th hole (in case of three electrodes) respectively of 2nd hole (in case of one electrode) direct extraction with hood systems (or furnace enclosure) or total building evacuation are the most favorite systems.

A 4th or 2nd hole should collect practically quantitatively the primary emissions generated during the melting and refining periods. 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 hood system, 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 [EC EAF, 1994]). Hood systems are commonly used within the electric arc furnace steel industry. Combined with direct extraction systems, the collection efficiency of primary emissions and also secondary emissions improves up to 98%. Hoods are also installed to collect emissions arising at secondary metallurgy vessels, hoppers and conveyor belts.

Furnace enclosures, also called dog-houses, 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 makeup air enters through openings in the operating floor [EPRI, 1992]. More complex handling steps, causing time losses and possibly higher investments (e.g. 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 dog-houses are similar or usually slightly higher to 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) [Kuhner, 1996]. Furnace enclosures may also be applied at secondary metallurgy processes [EC EAF, 1994] but it needs a treatment of the shop walls to eliminate reverberation.

Another way to collect secondary emissions from the furnace, as well as preceding and succeeding installations, is a complete enclosure of all plants in one sealed building. It can be regarded, roughly speaking, as just a larger type of furnace enclosure, mainly containing more process steps.

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

Main achieved emission levels: 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 [EC EAF, 1994]. A combination of a direct extraction device and a furnace enclosure even achieves collection rates of over 97% up to 100% of the total dust emissions [Heinen, 1997]. Total building evacuation also achieves practically 100% emission collection.

Applicability: Applicable both to new and existing plants.

Cross-media effects: The emission collection systems need energy, especially the fan

8.4.5 Efficient Post-Combustion In Combination With Advanced Off Gas Treatment

Description: The optimisation of EAF operation, especially the increasing use of oxygen and fuels have increased the amount of chemical energy in the primary off gas (CO and H_2 content) [Evenson, 1996]. In order to use this energy post-combustion trial in electric arc furnace steelmaking were started in the mid of eighties and significant progress had been made. Post combustion in the furnace is developed to use a maximum of chemical energy of the CO in the furnace and to improve the energy balance, but CO and H_2 are never completely oxidised in the furnace; for this reason, it needs post combustion. Post combustion in a combustion chamber aims primarily at the full combustion of CO and H_2 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, reduces the emission of organic compounds. The heat produced by this combustion is generally not recovered unless recovery from cooling water is possible. Today the optimisation of the post combustion chamber can reduce organic micro-pollutants, such as PCB or PCDD/F. **Figure 20** shows such a plant originally equipped with post combustion chambers. Because of relevant de novo synthesis of PCDD/F the heat exchanger been replaced by a quenching tower for rapid cooling of the off gas.

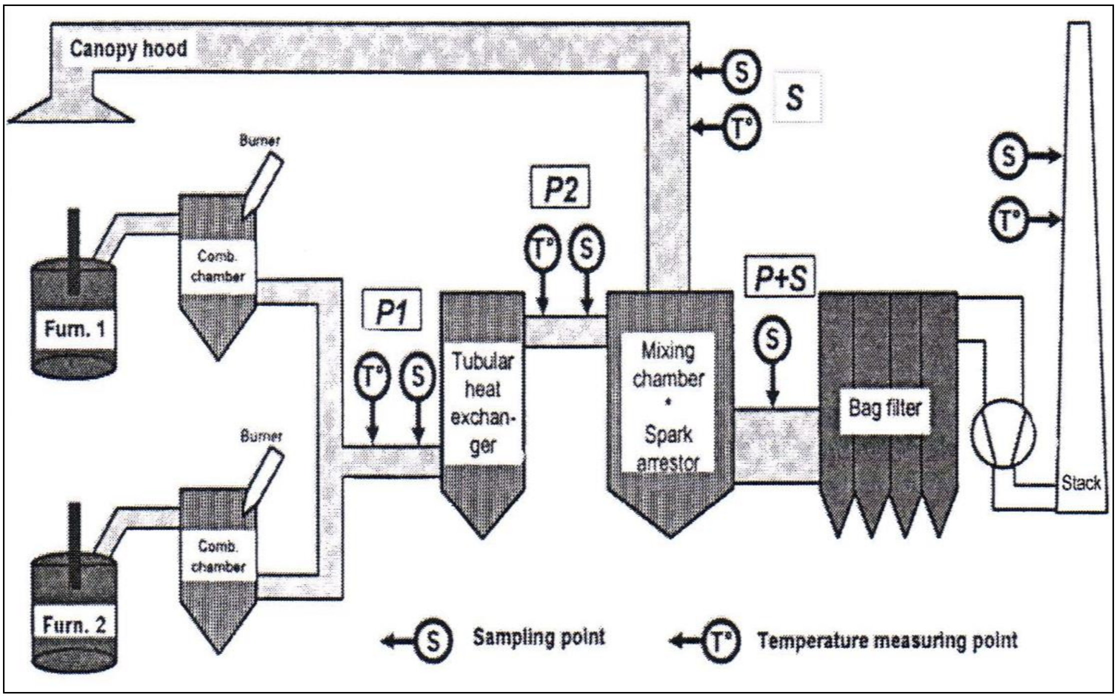


Figure 20: Schematic Layout of the Treatment of Primary Off Gas from an Twin Shell EAF

Because of de novo synthesis of PCDD/F in the tubular heat exchanger, this device has been replaced by a quenching tower for rapid cooling of the off gas. Post-combustion with the additional aim to minimise organic micropollutants needs necessary retention time, turbulence and temperature (3 T`s). If a separate combustion chamber can not be introduced, suitable post-combustion can also be achieved in the off gas duct system (**Figure 21**).

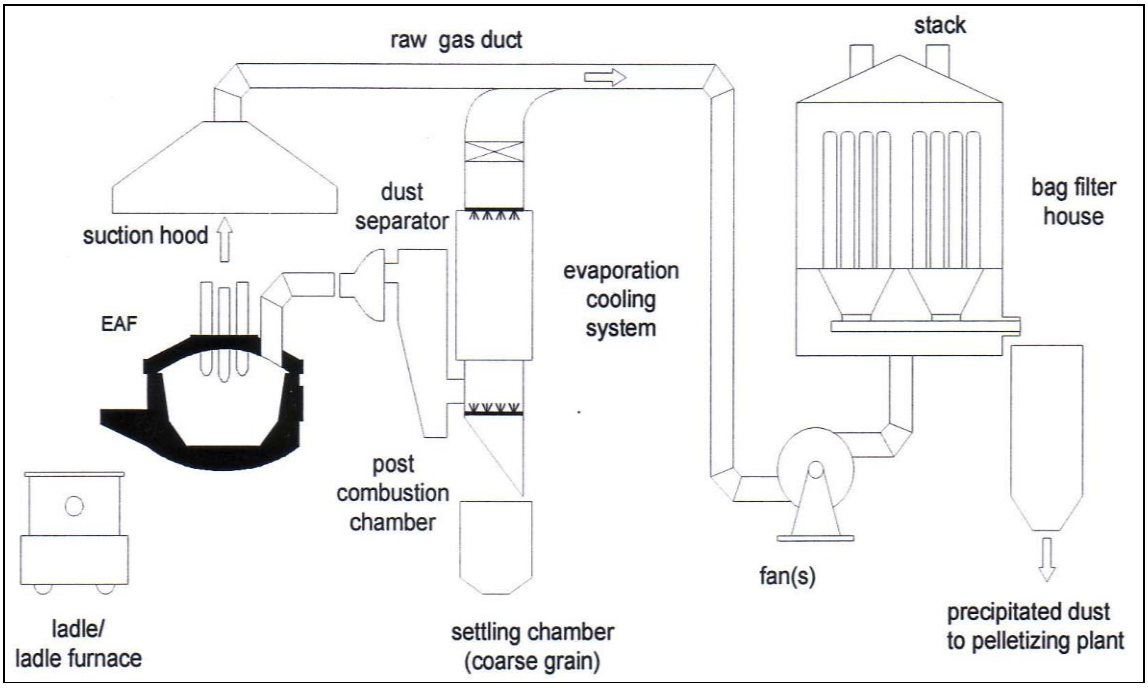


Figure 21: Post-Combustion of the Primary Off Gas Within the Given Duct System from an EAF with Subsequent Rapid Cooling – [D-Rentz, 1997]

Recent developments have separate post-combustion chambers with additional burners to achieve the necessary “3 T`s). To avoid the novo synthesis of PCDD/F, it is necessary to have a fast cooling of the fumes before filtration in a bag filter. In some cases, this is obtained by dilution of the secondary circuit; in other cases, as presented in **Figure 21**, a solution is the water quenching tower.

Main achieved emission levels: With a proper post combustion followed by a rapid cooling (by dilution or water quenching) emission concentration of PCDD/F lower than 0.5 ng I-TEQ/Nm^3 can be achieved.

8.4.6 Injection of lignite coke powder for off gas treatment

Description: In order to reduce organic micropollutants in the total off gas (primary and secondary emissions), especially PCDD/F lignite coke powder can be dosed to the duct before the bag filters. The necessary amount is in the order of 100 mg lignite coke powder/Nm^3 off gas. The lignite coke powder is separated in the gas phase in the subsequent bag filters. Attention has to be paid to sparks and principally possible glow fires. The explosion risks have been assessed to be low.

Main achieved emission levels: Residual PCDD/F emission concentrations of < 0.5 ng I-TEQ/Nm^3 are achievable in practice; some measurements show values < 0.1 ng I-TEQ/Nm^3.

Applicability: Applicable to both new and existing plants

Cross-media effects: The amount of energy for lignite coke powder dosage is not considerable. The filter media dusts contain the lignite coke powder and slightly increased PCDD/F amounts but this does not interfere with dust recycling.

Attention has to be paid to carbon content of the dust mixture abated at the bag filter which is about 3% average with local concentrations up to 5% which could be ignitable.

8.5. Emerging Techniques and Future Developments

In this paragraph, a number of techniques are mentioned which are not (yet) applied at industrial scale.

Scrap sorting

The emissions of organo-chlorine compounds, specially PCB and other non-ferrous material such as plastic, tyre, batteries, wood etc. can be significantly reduced by minimising the input with the scrap. PCB are mainly contained in small non-ferrous material in several technical devices like washing machines, (hair)driers, cooker hoods, oil burners, fluorescent lamps etc.. The removal of non-ferrous materials is a task for the operators of shredder plants. Nevertheless this possibility may be important for the Emissions of EAF. The most important reason that the removal of capacitors is not performed yet seems to the high costs for it.

New furnace concepts

In recent years a number of new furnace types have been introduced, that might be realised at industrial scale. Such furnaces belonging are presented in the following.

Comelt EAF:

The Comelt furnace is an EAF on a DC basis with side electrodes provided by VAI [Berger, 1995]. In most cases the furnace is featured with four slanted electrodes, resulting in electric energy transmission by four inclined DC arcs. Other features of this concept are integrated shaft scrap preheating, a complete off gas collection in each operating phase and a lowered sound level. The essential advantages, according to the manufacturer, are

- High productivity (tap-to-tap times of less than 45 min),
- Reduction of total energy consumption by integrated scrap preheating (appr. 360 MJ/t compared to conventional EAF),
- Reduction of electrode consumption (approximately 30%),
- Complete off gas collection at all times and a reduction of off gas volume by up to 70%,
- Reduction in maintenance costs due to a simpler plant design,
- Reduced noise level by up to 15 dB(A).

State of Development / Realisation:

A pilot electric arc furnace using the Comelt melting principle has been implemented and investigated by revamping a 50 t plasma primary melting furnace in the former LD steel shop in Linz [Berger, 1995].

Contiarc furnace:

The Contiarc electric arc furnace is a continuously operating annular shaft furnace with a central DC electrode, though in principle it can also be heated by alternating current [Reichelt, 1996]. The shaft, consisting of an outer and an inner vessel, is charged continuously with scrap. By doing so, the scrap is preheated by ascending hot furnace gases (integrated high temperature scrap preheating). This concept with tapping during the melting operation reaches a power-on time of almost 100%. Further advantages according to the furnace providers are:

- Reduced energy losses (720 MJ/t less than with conventional furnace systems),
- Waste gas and dust volumes are considerably reduced (waste gas: 150000 t m^3(STP) to 900000 t m^3(STP); dust content: up to 40% less for a 100 t/h Contiarc furnace) requiring a lower capacity of the gas cleaning system and also lower electric power consumption (82.3 MJ/t),
- Gas-tight furnace enclosure captures all primary and nearly all secondary emissions,
- Advantages in production costs,
- Reduced electrode consumption (DC furnace: 0.8 kg/t less than AC furnace).

A pilot electric arc furnace has been implemented and investigated at the laboratory of RWTH Aachen; as a next step a demonstration plant is planned [Reichelt, 1996].

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