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Summary <p>As one of several methods to improve the environmental conditions in Europe, the European Union (EU) has launched the concept of Best Available Techniques (BAT). The aim of the concept is to make environmental improvements in the EU industries by applying a high technological standard in production processes. The concept has been realised by the development of BREF documents describing the BAT conditions for different industries. These BREF documents have been developed according to the Integrated Pollution Prevention and Control (IPPC) directive.</p> <p>The present report covers a Nordic contribution to the revision process of the EU Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001. This project is initiated and financed by the Nordic Council of Ministers.</p> <p>The report covers metals produced in the Nordic countries. Metals covered in the report are mainly; copper, zinc, ferro-alloys (FeSi, FeCr, FeMn) and aluminium. Some other metals are also produced as by-product such as cadmium, lead and precious metals. This report covers updated data that was possible to collect in the frame of this project. The data are emission data, description of new abatement methods as well as direct corrections of the report. General aspects and experiences of the BAT concept are also covered.</p>	
Keyword European Union, Best Available Techniques, BAT, BREF documents, Integrated Pollution Prevention and Control (IPPC) directive, Non Ferrous Metals Industries, Nordic Council of Ministers, Nordic countries, copper, zinc, ferro-alloys (FeSi, FeCr, FeMn), aluminium, cadmium, lead, emission data, abatement methods.	
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Preface

The present report covers a Nordic contribution to the revision process of the EU Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001. The present project is initiated and financed by the Nordic Council of Ministers (NCM). Nordic reports on low environmental impact technology for different industrial areas are prepared under the direction of the Nordic BAT-group. The Nordic BAT-group in turn falls within the remit of the Products and Waste Working Group (the PA group) of the Nordic Council of Ministers. The BAT-group commissions Nordic consultants in selected industrial sectors to carry out reporting works (BAT-projects) for the Nordic Council of Ministers.

In this project IVL Swedish Environmental Research Institute Ltd. was commissioned by the BAT-group to organise and carry out the project work. All affected Nordic industries and authorities were given the possibility to contribute in this BREF revision project. However, most of the information originates from the industries. IVL has gathered the collected information and compiled the report. Thus, different text source coexist in the report with different revision styles. Some text revisions are made directly into the old BREF document and some revisions are made as comments with line by line editing. Other information is given more in report format. To some extent we have tried to first give an overview remark on the background of the proposed change and then to give the proposed change. All the Nordic countries have been represented in the project. IVL was represented by Håkan Stripplé and Magnus Klingspor. The project was followed by the NCM BAT-group consisting of the following:

Jóhanna Olsen, the Faeroe Islands (Chairperson)
Seppo Aspelund, Finland
Erkki Kantola, Finland
Þór Tómasson, Iceland
Stefán Einarsson, Iceland
Olaug Bjertnæs, Norway
Jard Gidlund, Sweden
Susanne Särs, the Åland Islands

The BAT-group partly also represented the authority. In addition the authorities were represented by Björn Christiansen, SFT, Norway, Husamuddin Ahmadzai, Swedish EPA, Sweden.

The Nordic industry was represented by several industries representing the Nordic industry structure and the metal production in this region. The industry contribution is important to achieve an adequate technical background in the project. The practical work was organised in three working groups: Aluminium production, Production of ferro-alloys and Production of other metals. The following industries and persons represented the industry group:

Ferro-alloys production

Vargön alloys AB, Sweden, Contact person: Eva-Lotta Stolt
Elkem, Norway, Contact person: Inger-Johanne Eikeland
Finnfjord, Norway, Contact person: Jacob Steinmo
Tinfos, Norway, Contact person: John Bustnes
Eramet, Norway, Contact person: Knut Mørk

Rio Doce Manganese Norway (RD MN), Norway, Contact persons: Kyrre Johansen
Fesil, Norway, Contact person: Lars Nygaard

Aluminium production

Alcan, Iceland, Contact person: Guðmundur Ágústsson
Nordural, Iceland, Contact person: Óskar Jónsson
Hydro Aluminium, Norway, Contact person: Stein Leistad
Elkem Aluminium, Norway, Contact person: Svein Harry Samuelsen
Soer-Norge Aluminium, Norway, Contact person: Arstein Eik
Stena Aluminium, Sweden and Denmark, Contact person: Ola Falk
SAPA, Sweden, Contact person: Malin Spångberg

Production of other metals (copper, zinc, lead, gold, silver etc.)

Boliden, Sweden, Norway, Finland, Contact person: Chatarina Nordeman
Boliden, Sweden, Contact person: Michael.Borell
Boliden, Norway, Contact person: Emil Jøsendal
Boliden, Finland, Contact person: Kai Nykänen
Boliden, Finland, Contact person: Vesa Törölä

Use of units in the document

SI units have been used in the document. However, of practice reasons the unit tonne is also used.
In all cases, it refers to metric tonne and is denoted t or tonne.

Summary

As one of several methods to improve the environmental conditions in Europe, the European Union (EU) has launched the concept of Best Available Techniques (BAT). The aim of the concept is to make environmental improvements in the EU industries by applying a high technological standard in production processes. The concept has been realised by the development of BREF documents describing the BAT conditions for different industries. These BREF documents have been developed according to the Integrated Pollution Prevention and Control (IPPC) directive.

The BREF document will now be revised and updated to the latest technical standard. The present report covers a Nordic contribution to the revision process of the EU Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, December 2001. The present project is initiated and financed by the Nordic Council of Ministers (NCM). In this project IVL Swedish Environmental Research Institute Ltd. was commissioned by the Nordic Council of Ministers to organise and carry out the project work. The project was performed as a co-operation project between environmental science, industry and the authority. All affected Nordic industries and authorities were given the possibility to contribute in this BREF revision project. All the Nordic countries have been represented in the project.

Not all metals, covered in the BREF document, are produced in the Nordic countries. The report covers only metals produced in the Nordic countries. Metals covered in the report are mainly; copper, zinc, ferro-alloys (FeSi, FeCr, FeMn) and aluminium. Some other metals are also produced as by-product such as cadmium, lead and precious metals. This report covers updated data that was possible to collect in the frame of this project. The data are emission data, description of new abatement methods as well as direct corrections of the report. General aspects and experiences of the BAT concept are also covered.

Swedish summary – Sammanfattning

Som en av flera metoder att förbättra miljöförhållandena i Europa har Europeiska Unionen (EU) lanserat konceptet med bästa möjliga tillgängliga teknik (BAT). Målet med BAT-konceptet är att göra miljöförbättringar i den Europeiska industrin genom att, så långt möjligt, förhindra att föroreningar uppstår och därefter rena kvarvarande utsläpp genom att tillämpa BAT. Ett utbyte av information om BAT har organiserats av kommissionen och resulterat i de s.k. BREF-dokumenterna vilka beskriver BAT för olika industrier och tillverkningsprocesser. BREF-dokumenterna har tagits fram enligt EU-direktivet för Integrated Pollution Prevention and Control (IPPC).

BREF-dokumenterna står nu inför en revidering som skall omfatta den senaste tidens utveckling d.v.s. vad som har skett sedan de ursprungliga dokumenterna togs fram. Den föreliggande rapporten omfattar en nordisk inlägga till revisionsprocessen av *Reference Document on Best Available Techniques in the Non Ferrous Metals Industries, december 2001*. Det föreliggande projektet är initierat och finansierat av Nordiska Ministerrådet (NMR). För projektet har IVL Svenska Miljöinstitutet givits i uppdrag av NMR att organisera och utföra projektet. Projektet har genomförts som ett samarbetsprojekt mellan forskningen, industrin och myndigheterna. Samtliga nordiska länder har representerats i projektet.

Långt ifrån alla metaller som behandlas i BREF-dokumentet utvinns eller produceras i Norden. Denna rapport behandlar endast sådana metaller som produceras inom de nordiska länderna. Metaller som behandlas i denna rapport är huvudsakligen; koppar, zink, ferro-legeringar (FeSi, FeCr, FeMn) and aluminium. Visa andra metaller produceras också som biprodukter som t.ex. kadmium, bly och ädelmetaller. Denna rapport innehåller updaterade data som var möjliga att samla in inom ramen för detta projekt. Data täcker främst emissionsdata, beskrivning av nya reningsmetoder samt direkta korrigeringar i BREF-dokumentet. Generella aspekter och erfarenheter på BAT-konceptet behandlas också.

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1 Introduction

As one of several methods to improve the environmental conditions in Europe, the European Union (EU) has launched the concept of Best Available Techniques (BAT). The aim of the concept is to make environmental improvements in the EU industries by applying a high technological standard in production processes. The concept has been realised by the development of BREF documents describing the BAT conditions for different industries. These BREF documents have been developed according to the Integrated Pollution Prevention and Control (IPPC) directive.

The BREF documents were produced over a long time-period by the European IPPC Bureau at the Joint Research Centre in Seville, Spain. The aim is now to revise and update these documents to the latest technical standard. The present report is a Nordic contribution and input to the revision process of the reference document on Best Available Techniques in the Non Ferrous Metals Industries. This BREF document covers the techniques for the production of both primary and secondary non-ferrous metals. The document was released in 2001 and developed during 2 years. The data in the document thus reflect a situation in mid 1990ies. A revision of the document is thus well founded.

2 Background, objectives and work procedure

This report summarises experiences from the Nordic non-ferrous industry as a background and a contribution to the revision process of the BREF document. The initiative to the present study was taken by the Nordic Council of Ministers (NCM) who also financed the work. The project work was commissioned to IVL Swedish Environmental Research Institute Ltd. to organise and carry out the practical work. The project work was supervised by the Nordic BAT group. The Nordic BAT-group in turn falls within the remit of the Products and Waste Working group (the PA group) of the Nordic Council of Ministers. The BAT-group commissions Nordic consultants in selected industrial sectors to carry out BAT-projects for the Nordic Council of Ministers.

The project is to a large extent a co-operation work between the Nordic countries and their different organisations. All the Nordic countries (Denmark, Finland, the Faeroe Islands, Iceland, Norway, Sweden and the Åland Islands) have been involved in this revision project. Materials to the report have been collected from the industry, from the authorities and from the scientific sector.

The BREF document covering the non ferrous metal industry is rather comprehensive and complex. There are many different metals and processes to cover with many different processes and environmental aspects. In addition the BREF covers both primary and secondary production. However, not all of the metals are produced in the Nordic countries. The practical work in this project has been carried out in three working groups consisting of similar industries and common processes. The following industrial working groups have been formed in connection to the revision work (details are given in preface).

- Aluminium industry group
- Ferro-alloy industry group
- Remaining metal group (e.g. Cu, Zn, Pb, Au, Ag)

The contributions from the authorities and the science sector are more specific and not divided into working groups.

3 Revision of General information

3.1 Ferro-Alloys

General comment: Text in **red** is changes made to the old BREF document. Text marked in yellow is comments. Remaining text is from the old BREF document.

*Proposed revisions of the BREF document (page 37 in BREF)
(BREF: 1.9. Ferro-alloys) [1, 2, 3, 4, 5, 6, 7]*

Ferro-alloys are master alloys containing some iron and one or more non-ferrous metals as alloying elements. **Silicon-metal is produced in the same metallurgical process as ferro-silicon and is therefore dealt with/treated/considered as a ferroalloy. Ferro-alloys are used as deoxidizing element in steel making and** enable alloying elements such as chromium, silicon, manganese, vanadium, molybdenum etc. to be safely and economically introduced into metallurgical processes, thus giving certain desirable properties to the alloyed metal, for instance increased corrosion resistance, hardness or wear resistance.

The importance of Ferroalloys **increased** with progress of steel metallurgy, **demanding** diversified alloying elements, **to achieve** better controlled quantities, purer and **more** advanced steel qualities. The ferro-alloy industry became a key supplier to the steel industry.

Silicon-metal is used as an alloying element in aluminium and in chemical and electronic industry, solar cells etc.

The ferro-alloys are usually classified in two groups:

- *Bulk ferro-alloys*, **basic specification** (ferro-chrome, ferro-silicon together with silicon-metal, ferro-manganese and silico-manganese), which are produced in large quantities in electric arc furnaces;
- *Special ferro-alloys* (ferro-titanium, ferro-vanadium, ferro-tungsten, ferro-niobium, ferro-molybdenum, ferro-boron, **alloyed or refined ferro-silicon, silicon-metal** and ternary/quaternary alloys) which are produced in smaller quantities, but with growing importance.

Bulk ferro-alloys are used **mainly** in steel making and steel or iron foundries. The uses of special ferro-alloys are far more varied, and the proportion used in steel making has diminished over recent years in favour of those used in the aluminium and chemical industries, especially silicon products. The following figures present the use of ferro-alloys, bulk and special ferro-alloys as a breakdown by sector for 1994.

*Proposed revisions of the BREF document (page 38 in BREF)
(BREF: 1.9.2. Sources of material)*

The raw materials (alloying elements) for the production of ferro-alloys are either **main products (~~mined for themselves~~)** (quartzite for silicon, chromite for chrome...) or **by-products(~~of another~~)**

of mining production (e.g. molybdenite from copper mining). Of course, the two sources can exist simultaneously. (In most cases for FeCr and FeMn production also the iron part is received from ore and no iron is added.)

...

- Chromite that is concentrated in two big deposits, which are mainly located in South-Africa and Kazakhstan. Smaller deposits are found in other places in the world such as India, Brazil and Europe (Finland, Turkey, Albania and Greece)
- ...
- ...
- ...

*Proposed revisions of the BREF document (page 39 in BREF)
(BREF: 1.9.3. Production and consumption)*

Over the last 15 to 20 years, the world pattern of the ferro-alloy market has deeply changed:

- ...
- ...
- The ferro-alloy industry is facing a growing proportion of imports, at first from the new industrialised countries and in recent years from the countries of East Europe, the CIS and China.

Comments figure 1.11: "others" ought to include Norway but is too small for that. There must be something wrong with the figure.

*Proposed revisions of the BREF document (page 41 in BREF)
(BREF: 1.9.3. Production and consumption)*

- ~~A stagnant~~ Carbon steel production is increasingly produced in electric arc furnaces from scrap, which allow recovery of the alloying elements, reducing the relative consumption of ferro-alloys.
- ...
- ...
- ...

*Proposed revisions of the BREF document (page 42 in BREF)
(BREF: 1.9.3. Environmental issues)*

Production of ferro-alloys generally involves the use of electric arc furnaces and reaction crucibles into which natural products (e.g. quartz, lime, various ores, wood etc.) with relatively fluctuating physical compositions are loaded. Due to this, the main environmental impact by producing ferro-alloys is the emission of dust and fume from the smelting processes. Dust emissions occur as well from storage, handling and the pre-treatment of raw materials where fugitive dust emissions play an important role. Depending on the raw material and the process used other emissions to air are mainly SO₂, NO_x, CO, CO₂, polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOC) and metals such as Hg, As and Cr. The formation of dioxins in the combustion zone and in the cooling part of the off-gas treatment system (de-novo synthesis) may be possible.

Process residues and by-products with a significant amount ~~is~~ are slag, filter dust and sludge and spent refractories. These materials are already recycled and reused to a large extent where it is possible. Rich slag, that means slag with a relatively high proportion of metal oxides, is used as raw material in other ferro-alloy productions. For instance rich slag from the production of ferro-manganese is one of the most important raw materials for the production of silicomanganese.

Water emissions are produced from cooling, granulation and other processes and site related effluents. The wastewater generated by a wet cleaning abatement system plays also an important role.

The ferro-alloys industry, whose basic tool is an electric arc furnace in which metal oxides are reduced by carbon, is a major consumer of energy and a producer of carbon dioxide (CO₂). It has therefore, always regarded reduction of energy consumption as a vital priority. The laws of thermodynamics, which govern the reactions used, limit the possible reduction of energy necessary for the smelting process. The reduction of the overall energy consumption is therefore in most cases only possible by using an efficient energy recovery system. The recovered energy can be transferred into electrical energy or used as heat for various purposes. CO-rich off-gas from closed furnaces can as well be used as secondary fuel or raw material for chemical processes. The recovery of energy reduces the use of other natural energy resources and therefore the impact of global warming.

3.2 References for General information

1. Elkem (FeSi), Norway, Contact persons: Inger-Johanne Eikeland
2. FESIL (FeSi), Norway, Contact persons: Lars Nygaard
3. Finnerfjord smelteverk (FeSi), Norway, Contact persons: Jacob Steinmo
4. Vargön Alloys AB (FeCr), Sweden, Contact persons: Evalotta Stolt
5. Tinfos jernverk A/S (FeMn), Norway, Contact persons: John Bustnes
6. Rio Doce Manganese Norway (RDMN) (FeMn), Norway, Contact persons: Kyrre Johansen
7. Eramet (FeMn), Norway, Contact persons: Knut Mørk

4 Revision of common processes and equipment

4.1 Metal Production and Process Control Techniques

General comment: Text in **red** is changes made to the old BREF document. Remaining text is from the old BREF document.

*Proposed revisions of the BREF document (page 90 in BREF)
(BREF: 2.6.2.3 Electric arc furnaces) [1,2,3,4,5,6,7]*

2.6.2.3 Electric **reduction** furnaces

The process work in an electric reduction furnace is normally to reduce an element in an oxide state into metallic form. The process work is normally to add the oxide and a reducing agent, often carbon, to the furnace. To bring the reactants up to the reaction temperature as well as to support the endothermic reactions, electrical energy is added. This electrical energy converts to heat energy in a concentrated reaction zone nearby the electrode in the furnace.

Some furnaces will use a slag layer to develop the necessary energy. Others are based on resistance in the burden itself or in a coke bed. Some processes seem clearly to keep a plasma arc from the electrode tip to the coke bed or crater. Such electric reduction furnaces are sometimes called “submerged arc furnaces”. The reason is that the submerged arc is an important part of the conversion from electrical energy to heat energy in the reaction zone of the process.

The electrical supply is normally based on three-phase electric power supply. The electric power supply will be transformed from high voltage to low voltage.

A DC (Direct Current) electrical supply can also be used and in this case the arc strikes (**develops**) between ~~a number of~~ the electrodes and the carbon furnace lining **or the electrodes and the raw materials in the lower part of the furnace.**

The electric reduction furnace can be divided in the following main components shown below and in figure 2.5.X: (The example is a standard silicon furnace):

- Equipment for adding **raw materials** as ores, concentrates and **reducing agents** or a mix of raw material to the furnace.
- Equipment to supply electrical energy to the furnace consisting of electrical grid, transformers, bus bars and ~~the~~ electrodes.
- The furnace body or shaft consisting of a shell, the lining and the furnace hood that protects the equipment from the heat.
- Equipment for tapping the metal and slag from the furnace. **Often the metal has to be sized afterwards in a crushing process.**
- The off-gas system (off-gas ducts connected to cleaning facilities such as cyclons, scrubbers or filters) - here with an energy recovery unit as well as the filter for the gas cleaning.

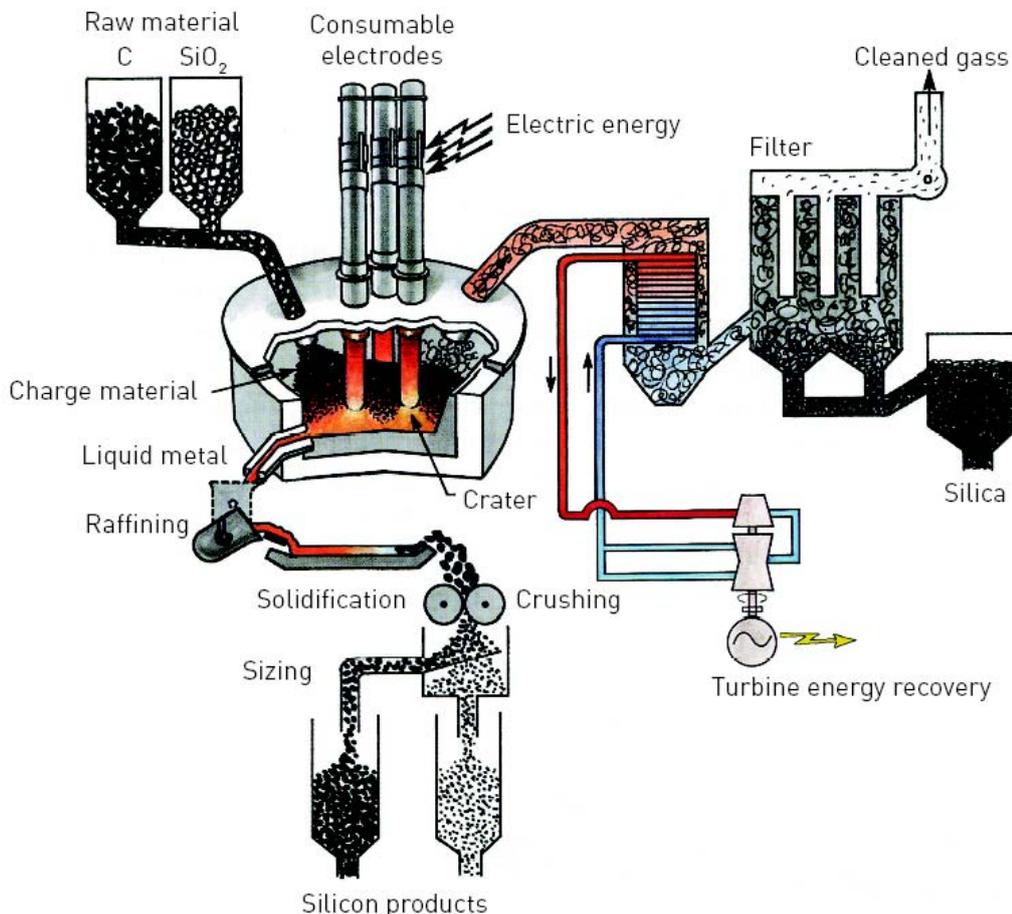


Figure 2.5.X: Electric reduction furnace process and auxiliary equipment

The raw material may be charged to the furnace in different ways. For smaller furnaces the raw material can be charged **manually** by using a charging car. The charging car may sometimes also be used for the necessary stoking **work** in order to break down crust formation in the upper part of the furnace charge. Large electric arc furnaces are normally charged by charging tubes where the charge flows from the tubes to **the furnace charge level. or hearth so that the material in the tubes form in case of a closed furnace a gas tight seal.**

The electrical supply system will transform the electrical energy that normally is at high voltage down to low voltage–high current **level** that is required for the process. **The furnace transformers are normally ~~Three furnace transformers~~ are situated (placed?) symmetrically around the furnace in order to obtain electrical symmetry and short electrical connection lines and to avoid unnecessary losses. On smaller and older furnaces there are sometimes installed one three phase transformer.** The operation of separate **single-phase** transformers has some advantages on the furnace control. The electrodes are connected to the electrical supply system through the bus bars. The electrodes can be pre-baked or of the Søderberg type. They are made from graphite or carbon material and are consumed in the process, so that they have to be replaced continuously.

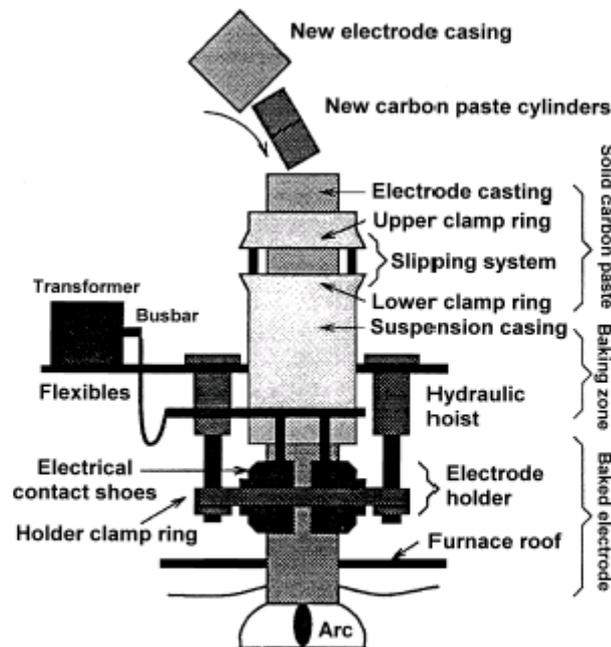


Figure 2.6: Söderberg electrode system in an electric arc furnace

The Söderberg system that is shown in figure 2.6 is based on an outer steel electrode casing which acts as a ~~former~~ mould for the carbon paste. The carbon paste is baked to a ~~fixed~~ solid electrode inside the steel casing when the electrode is heated, ~~passing the upper contact clamp area. as it approaches the warmer part of the furnace. Some of the heating is due to the electrical current in the electrode.~~ The solid carbon electrode will be consumed in the furnace – partly by thermal wear and partly by oxidation ~~Carbon from the electrodes can be consumed to reduce oxides to a metal or can be worn away by the action of the arc. Significant concentrations of carbon monoxide can be produced.~~ Some installations use hollow electrodes which allows material to be fed into the furnace through the electrode. The raw material provides part of the resistance in the electrical circuit and promotes the formation of the electric arc, which produces the high temperatures ~~needed~~. The depth of insertion of the electrodes regulates the resistance. Direct current arc furnaces exist and use anode pins or conducting hearths. The electric arc furnaces can be operated batch-wise or continuously. The furnaces can be open, semi-~~sealed~~ closed ~~(with extraction commonly from a fourth hole in the hood)~~ or totally ~~closed~~ sealed using feed chutes and sealing valves for charging. In the latter case all of the furnace gases are extracted efficiently, ~~and are~~ cleaned and can be used to pre-heat feed materials or used as a source of fuel. The hoods and occasionally the furnace body can be water-cooled to control the process and prevent damage.

Chapter 2

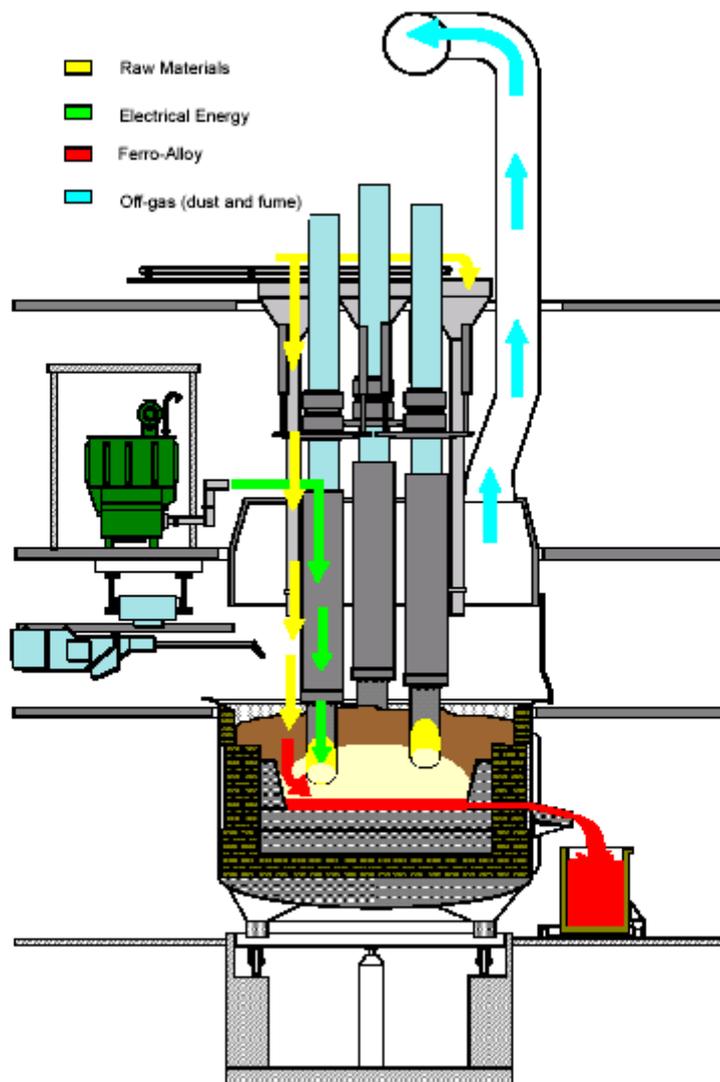


Figure 2.7: Rotary Electric Arc Furnace

NB! Electric Reduction Furnace

*Proposed revisions of the BREF document (page 92 in BREF)
(BREF: 2.6.2.4 Electric (resistance) furnace)*

...

Molten or solid raw materials are fed in a number of ways using launders, feed pipes or through a hollow electrode. ~~Closed Sealed or semi-closed sealed~~ conditions are easy to maintain. In smelting processes the roasted ore concentrates are transferred on to the liquid melt either through the top of the furnace or sideways by individual chargers and the electrodes are immersed in the molten slag layer.

4.2 Air Abatement and Recovery Techniques

4.2.1 Applied processes and techniques

4.2.1.1 Removal of other impurities

4.2.1.1.1 Mercury

Apply in BREF document: Mercury chapter 2.8.1.7.2 page 134, Removal of mercury chapter 2.17.6 page 190, Gas collection and abatement chapter 9.3.6 page 558.

Overview remarks and comments

Some ores, for example manganese ores, have an increased mercury concentration. The volatile mercury is released in the processes and methods are needed to reduce the emissions and to take care of the mercury. Additional information concerning mercury cleaning techniques is provided here.

Proposed revisions of the BREF document

Method 1: Tinfos developed together with Miltec, a mercury cleaning process, which is based on oxidation of Hg⁰ in the off-gas using sodium hypochlorite. After oxidation in a washing tower, the mercury is precipitated as mercury sulphide (HgS) by addition of disodium sulphide. The mercury sulphide is removed from the process in a press filter. The mercury containing sludge is treated as hazardous waste and disposed in a sealed landfill. After the installation of the mercury cleaning plant the emission of mercury has been reduced by approximately 94 %. The mercury cleaning plant at Tinfos was thoroughly described by Haaland et. al. at Infacon 9.

Method 2: An alternate method for Hg cleaning was developed by Lurgi. The Lurgi Hg removal unit consists of an electrostatic precipitator to remove residual dust and tars, a gas heater, a packed bed absorber, a fan-damper system to control the gas flow through the unit and extensive gas analysis-nitrogen purge equipment to maintain low O₂ levels in the gas. The heater is required to warm the gases to the optimum temperature of 60-85°C; lower gas temperatures result in lower reaction rates and moisture condensation in the packed bed, higher temperatures can result in sulphur being lost from the absorbent. Eramet commissioned a Hg removal unit in 2001 and reports trouble free operation since. Gas flow rates through the unit are around 15,000 Nm³/hour. Hg absorption efficiency is 98 % and allowing for plant starts-ups, etc, 94 % of the total Hg in the raw gases is captured. Absorber mass is changed after about 8 months operation and is disposed of in a secure landfill. Only trace amounts of Hg report to the scrubber water.

Method 3: Boliden-Contec selenium coated spheres in a packed bed. The method works but the experience in the Scandinavian ferro-alloy industry is limited for this technology.

4.3 Waste Minimisation and Handling

Apply in BREF document: (chapter 2.10. page 165-176, Waste Minimisation and Handling both Applied process and techniques and Techniques to consider in the determination of BAT, Best Available Techniques chapter 2.17 (may be in a new subchapter), Reduction of process residues chapter 9.3.10 page 562)

Overview remarks and comments

To reduce the amount of residues formed in the processes is an important task and an example of such a work is given below. Another important strategy is to convert the formed residues into useful products and in that way save resources in the society. An example of that is also given below.

Large amounts of different residues are formed in the production processes of non-ferrous metals e.g. slag and residues from the abatement systems and the effluent treatment system. In many cases these residues have to be landfilled. The landfill process is here an important issue that needs to be addressed more thoroughly in the BREF document. The composition and the chemical/physical property (e.g. leaching characteristics) of the residue is here important as well as the design and control of the landfill. The waste handling processes are natural and important part of the production system.

In some cases the residues can be pre-treated prior to landfill to reduce harmful substances in the residue. An example of such a process is given below that reduce the presence of Cr^{VI}.

Example of resource minimisation by use of residues

To reduce resource use in the society is an important issue today. If wastes can be converted into useful products these products can be used to replace virgin products and thus reduce the resource use in the society. Different slag uses are good example of this strategy. Several slag are relatively inert and can be used e.g. as construction materials to replace aggregates.

Example of residue minimisation

Several techniques exist to reduce the amount of residues that is formed in the production processes. Important techniques are here to reduce the amount of slag, to recover metals in the slag and to reduce the amount of metals in the residue slag. For example Tornio ferro-chrome works in Finland has managed to reduce the amount of residue with a ferrochrome slag extraction process. A machine, working with a spiral separates chrome from processed fine slag. Chrome is heavier so it is concentrated in the centre of the spiral. The recovered chrome can be reused in the melting shop and the slag is used as a material for new filler products. Filler products are used, for example, in cement and asphalt. Earlier this fine material ended up in the landfill unseparated. This process has reduce the amount of residue with about 10000 tonnes.

Example of residue treatment to reduce harmful substances

Treatment of filter dust with ferrous sulphate

Filter dust from the ferrochrome production is mixed with ferrous sulphate in a mobile concrete mixer for reduction of the hexavalent chromium and is deposited in the form of slurry on the landfill, where it cures into solid material.

The concrete mixer method

During 2005 a plant for reduction of the hexavalent chromium in filter dust was taken into operation. It consists of equipment for collection of filter dust and an installation where the filter dust is mixed with ferrous sulphate (FeSO₄*7H₂O). The filter dust from the production of ferrochrome is collected in a silo with a volume of 250 m³.

The collected dust is mixed with ferrous sulphate in a mobile concrete mixer truck for reduction of Cr^{VI}. The volume of the tank on the truck is 7.5 m³ which makes it possible to treat 6.5 tonnes of dust each time.

The concrete truck is parked by the station for filling-up of water and ferrous sulphate. After being filled-up with fluid, the truck is moved to the silo concerned. The concrete truck is placed on a scale under the silo and is filled with dust until the scale displays the desired weight. The HC FeCr filter dust is more fine-particular than the charge-Cr filter dust and therefore needs more water to get the same consistence in the slurry. The weight of the truck's load is registered on the way to the landfill. The resulting slurry is spread out in cells on the landfill, where it cures into solid cake. By the end of the day the concrete truck is cleaned by tumbling slag (16-32 mm) and water in the mixer. The slag and water is put on an assigned place on the deposit.

Results

The treatment of filter dust in a concrete truck has successively resulted in lower levels of Cr^{VI} in the leaching water. When the pilot plant project started in April 2006 the water from the leaching ditch contained about 3-4 mg Cr^{VI} per litre. One year later the chromium level has dropped to around 0.5-0.1 mg Cr^{VI} per litre. Deposit of slurry in cells with L-support resulted in a solid surface in just a few days. Under ideal circumstances the slurry hardens quickly into a homogenous material. The dry strength of the material is high and its hydraulic conductivity, e.g. permeability of water, is low. The fluidity of the slurry, when landfilled, gives it a sealing quality. The slurry fills up the cracks in the underlying layer in the cells.

The method has almost eliminated the environmental impact regarding the handling of fine-particular ferrochrome dust:

- The spread of dust from the depository has in principle ceased.
- The number of transports back and forth from the depository has been halved.
- The dusting from the handling of containers has been minimised.
- The content of water-soluble chromium has decreased with more than 99 % since the hexavalent chromium was reduced to trivalent chromium precipitating as chromium hydroxide.
- The treated dust is no longer classified as hazardous waste.

Additional specific comments.

Chapter 2.10.2.1 (page 169) Table 2.25. The table is only a single example and say very little of other plants and processes. The table can be removed.

Chapter 2.10.2.5 (page 171) The sentence "In some circumstances they can be used as a source of energy on site." is no longer applicable.

Chapter 2.10.3.5 (page 175) Recycling and reuse of residues from non-ferrous metal smelting processes. Figure 2.42. This figure say very little of the industry and is just an example.

4.4 Environmental Monitoring in the Surroundings of the Site (proposed new chapter) [8]

Overview remarks and comments

The determination of BAT should also consider the recipient. The location of the plant is always an important aspect when choosing the best production technology and the supervision of the surrounding can be seen as a part of a BAT concept. In the Nordic countries several production sites have mandatory measurement programs covering the environmental situation in the surroundings of the production unit. In other cases measurements can be performed as part of larger research studies financed by other parts than the production site. The aims can be to measure certain components e.g. metals in the surrounding air, water or land. Studies of the recipients such as air dispersion models, air transportation models or studies of the water flows are common. Biological or health effect surveys or accident warning systems can also be applicable. These aspects are not at all covered in the present BREF document. It is proposed that something is mentioned about these techniques. This research area is complex and covers many different methods and the formulation of such a chapter should be developed with great care. As an example we show some data from plants in the Nordic countries.

Example of ambient air quality measurements

The example below shows a very brief presentation of some aspects concerning air quality in the surrounding of a smelter. In Table 1 the annual average concentrations of some metals are shown.

Table 1 Annual average metal concentrations in ambient air ($\mu\text{g}/\text{m}^3$) or (ng/m^3).

Substance	Location relative to emission point	2003	2004	2005	2006
PM-10 ($\mu\text{g}/\text{m}^3$)	2 km from smelter	12	11	12	14
Zinc (ng/m^3)	2 km from smelter		13.3		
Cadmium (ng/m^3)	2 km from smelter		0.14		
Nickel (ng/m^3)	2 km from smelter		2.2		
Arsenic (ng/m^3)	2 km from smelter		0.57		

In this case local authorities maintain ambient air quality monitoring system and a co-operation contract between different parties taken part in the air quality monitoring program have been written. The system includes 4 measuring stations at distance of 2-4 km from plant. The PM-10 collector is totally automatic and continuous working (TEOM 1400 A). The analyzer (TEOM 1400 A) is based on a filter-based direct mass measurement. Particles for metal analysis were collected with accessory ACCU system. One sample was collected for a 2 weeks period.

At the measurement stations several other parameters are also measured such as: SO_2 and NO_x . All analyzers are working automatically and continuously. The analyzers are calibrated four times a year by an external expert. Results from monitoring stations are transferred automatically to computer located in the office of municipal environmental authority. The authority collects the data and handles reporting to participants and communication to different interested parties.

The land-sea wind effect may influence in spring and autumn quite strongly to concentrations at some stations. Emissions fall down near of the site (in spring and autumn) and the measured concentrations are in this kind of situation usually higher than in normal situations.

In some plants a quite broad bioindicator study is performed every 5th year (effects of emissions in the surroundings of centre and industry area). This study includes also survey of metals in particulate matter and survey of airborne metal concentrations in the soil. Sample points (about 100) in bioindicator and metal study are located at distance of 0.1-30 km from zinc plant.

Example of surrounding water quality measurements

Also for the recipient water quality, a comprehensive monitoring program is set up. The monitoring of recipient water (sea) is based on authority approved and co-operated monitoring program. In one example there exists, at the sea area, 18 sample points. Samples for water quality analyses are taken 8 times per year so that samples will be taken both in summer and winter (ice covered season). The Seawater monitoring program includes many different environmental parameters e.g. quality of seawater (salinity, pH, O₂, temperature, colour, P-total, N-total.) biological survey (phytoplankton, bottom macrofauna, macroalgae, periphyton, fish) metal survey (metal concentrations in fish, sediment and bottom fauna). The monitoring program (sample collection, analysis and reporting) is entirely carried out by external experts.

Characteristics of the recipient (effluent receiving water)

The recipient, example fjord at the west-coast of Norway.

Topography

The length of the fjord is approximately 37 km and the average width 1.7 km. On both sides of the fjord there are steep mountains with rivers and streams flowing into the fjord.

The inner part of the fjord (“Havnebassenget”) form a “shelf” with a depth of approximately 40 m. The bottom then starts to incline as shown in Figure 1.

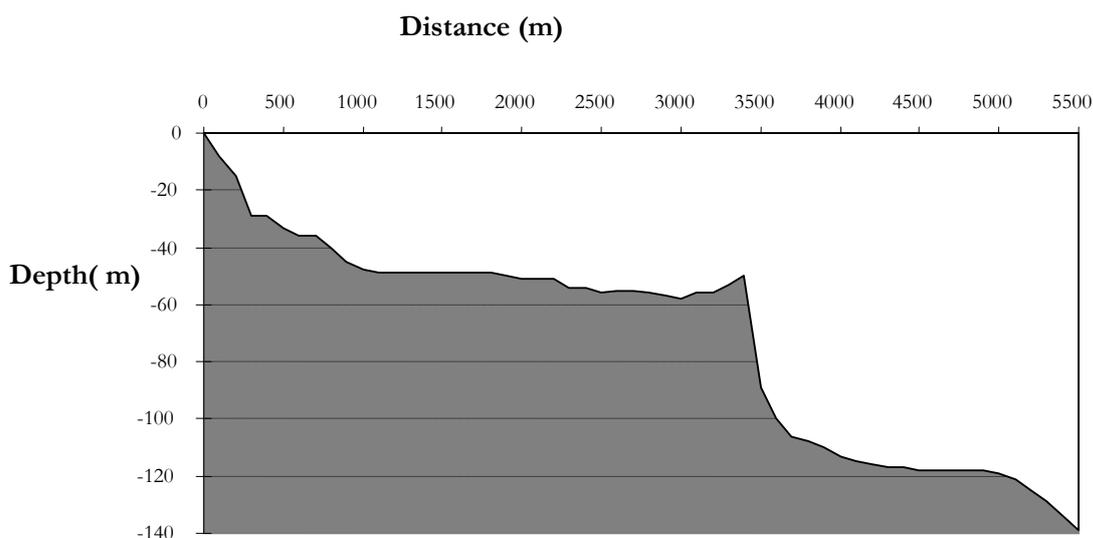


Figure 1 *Bottom profile of the fjord*

Maximum depth is 400 m at a distance of 12 km north of the smelter. At the outlet of the fjord there is a threshold of approx 250 m.

The rivers are carrying quite big amounts of fresh water into the fjord. As an average the two main rivers are carrying approx 2000 million m³ annually into the fjord. The thickness of the brackish water layer varies between 5-15 m. The outlets from the water treatments plants are at a depth of 20 and 30 m. The normal pH value of sea water is approximately 8. The salinity at 20 – 30 m depth is shown in Figure 2. At the emission points the average salinity is 30-34 and the average temperature approximately 9 °C.

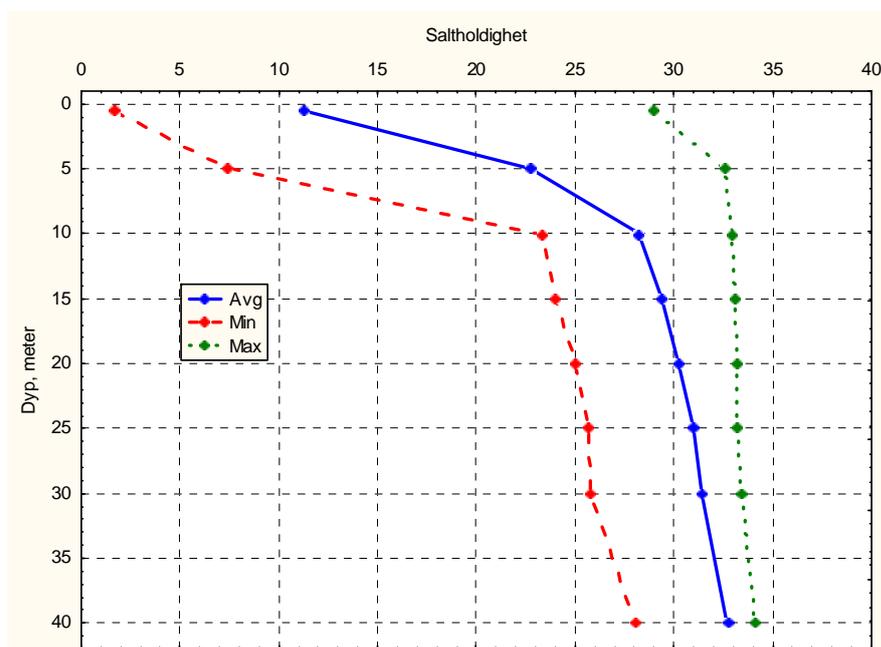


Figure 2 Salinity vertical profile. Blue graph: Average values year 2002. Red graph: Min. values Green graph: Maximum values.

4.5 References for common processes and equipment

1. Elkem (FeSi), Norway, Contact persons: Inger-Johanne Eikeland
2. FESIL (FeSi), Norway, Contact persons: Lars Nygaard
3. Finnfjord smelteverk (FeSi), Norway, Contact persons: Jacob Steinmo
4. Vargön Alloys AB (FeCr), Sweden, Contact persons: Evalotta Stolt
5. Tinfos jernverk A/S (FeMn), Norway, Contact persons: John Bustnes
6. Rio Doce Manganese Norway (RDMN) (FeMn), Norway, Contact persons: Kyrre Johansen
7. Eramet (FeMn), Norway, Contact persons: Knut Mørk
8. Boliden, Norway, Finland, Contact persons: Emil Jøsendal, Kai Nykänen.

5 Revision of processes to produce copper and its alloys

Two different copper production plants in the Nordic countries have been covered in this study. The plants are denoted plant A and plant B. Information and data for the plants originate from [1].

5.1 Applied processes and techniques

Overview remarks and comments

Both production plants are copper smelters with electrolytic refinery and sulphuric acid production. The copper production at the two plants is mainly based on copper concentrates but metal containing wastes (e.g. electronic scrap) are also used. The concentrates are dried or roasted and melted in a flash furnace or an electrical furnace. The electronic scrap or the lead concentrate is treated in a kaldo furnace. After e.g. a Peirce-Smith converter and fire refining most of the copper is cast into copper anodes (main product). The anode copper is then refined further in an electrolytic process to the final product, cathode copper. In the electrolytic refinery, by-products such as precious metals, nickel sulphate and copper sulphate are produced. Formed sulphur dioxide from the roasting, smelting and converting processes are collected and sent to the sulphuric acid production plant.

Since the previous BREF document was published in 2001 and the data were collected ten years ago several changes have been made to the processes. Some of the process improvements are directly related to environmental issues. In Table 2 an overview of changes and process improvements are presented.

Table 2 Overview of process changes at the two production sites for copper in the Nordic countries.

Plant A	Plant B
<p><u>Increase of production from 140000 tonnes Cu/a to 240000 tonnes/a.</u></p> <ul style="list-style-type: none"> • Harbour expansion, 17m depth • Belt conveyor systems from harbour to concentrate storage, reduces dust emission & truck transports • New smelter feed mixing facility • New copper furnace - Flash smelter • Enlarged converter hall, new converters w. new charge system • New converter hall ventilation system & filter • New transport system for recirculated materials • New Anode casting plant • Expanded electrolysis plant (tankhouse) • New sulphuric acid plant, incl. new Hg-removal technique • New oxygen plant (operated by Air Liquide) <p><u>Other changes</u></p> <ul style="list-style-type: none"> • New Hg-cleaning of sulphuric gases (2001) • New equipment for silica slag granulation (2002) • Expansion of lead refinery (2002) • Improved As-cleaning technique in water treatment plant (2004) • New injection technique for Zn-dust in zinc fuming plant (2005) • Improved waste energy recovery & expanded distant heating system (2006) • New NiSO₄ plant (2006) 	<ul style="list-style-type: none"> • Bedding plant for concentrate handling • new electrostatic precipitator and dust handling system for copper flash unit, • converter gas cooling system, • new concentrate burner, • closed water circulation system for anode casting and anode preparation machine

Table 3 Raw material uses year 2006 for plant A and B.

Raw material	Plant A, year 2006 (tonnes/a)	Plant B, year 2006 (tonnes/a)
Copper concentrate	560500	537800
Cu-scrap, WEEE & Cu/Zn- secondaries	175500	
Lead concentrates	45300	
Lead scrap	600	
Nickel concentrate		205000
Scrap and Precipitates		14500
Anode Copper for electrolytic purification		162900

Table 4 Products and production year 2006 for plant A and B.

Raw material	Plant A, year 2006 (tonnes/a)	Plant B, year 2006 (tonnes/a)
Copper cathodes	229200	127200
Lead	25500	
Zinc clinker	33300	
Sulphuric acid	551300	632200
Liquid SO ₂	36600	45500
Crude nickel sulphate	2100	
Copper sulphate	1300	3760
Silver	374	40.4
Gold	15.7	3.97
Selenium	135	70.5
Total Copper Production		192300
Primary (New) Copper Production		164300
Nickel matte		27600
Platinum/palladium concentrate		0.71
Nickel sulphate		1520
CCA wood preservative (as salt)		600
Copper telluride		26
Iron sand (slag)	approx. 250000	
Doré slag		375

Energy recovery

In the last years several energy saving programs have been launched. At plant A, waste energy is used for internal heating of processes and buildings and for external district heating. Electric power is also produced from excess steam. Different types of energy recycling are important methods to increase the overall energy efficiency for the plant. An example of a development project for energy recycling is the project ECOEL. In this project, the electric power production has been significantly increased by recycling of excess heat from the sulphur product production to internal use at the plant. In this way, high pressure steam from the processes can be released and used for electric power production. In this way the total energy recycling has been increased by 30 % and the electric power production has been increased by 30 GWh/year.

5.2 Present emission and consumption levels

Overview remarks and comments

Environmental issues have been in focus for a long time in the Nordic countries. The two plants have been working with energy and emission reduction for many years. The plants are equipped with gas cleaning equipments and water treatment plants. Actions are taken to reduce fugitive emissions and waste handling programs are in place.

The process units; drying, roasting, smelting, converting and casting are all equipped with particle filters (electrostatic precipitators or bag house filters) to reduce metal containing dust emissions. Dust from the filters is recycled back to the process. Sulphur dioxide from the exhaust gas is taken care of in the sulphuric acid plant. In one plant, the sulphur dioxide emissions from the copper and nickel smelters to air were reduced by 68 % and the dust emissions by 97 % between 1990 and 2005, even though the production capacity was doubled during the same period of time. Scrubbing the nickel matte granulation gases with a sodium hydroxide solution before passing it to the steam

stack also minimizes the sulphur dioxide emissions. Examples of installed abatement systems are given in Table 5.

Diffuse dust emissions are mostly caused by material handling together with internal traffic. A number of actions have been taken to reduce the fugitive emissions from the production. Transporting concentrates is carried out in closed/covered systems. Concentrates are moist and non-dusty during rapid discharge of carriers. Closed conveyer belt systems are used. The material is stored in closed storage buildings. Asphalt covered plant areas are regularly wet-cleaned from dust by a special vehicle. Slag is pumped as slurry to land filling area and it forms a dense non-dusting surface as it dries out. Roads on the sides and on top of land filling heap and also the outer side of land filling site are covered either with gravel or soil with vegetation. Ventilation gases from copper converters are expelled via a ventilation hood and bag filter to the stack. Diffuse emissions caused by matte transportation and other converting operations in the converter aisle are collected in ventilation units. The collected gases are then routed via bag filter to the stack. In addition, auditing, providing advice and encouragement for careful operation and housekeeping also minimize diffuse emissions.

Table 5 Example of environmental abatement systems installed at the plants for different emission points.

Installation	Abatement System
<i>Ventilation gases from electric furnace, flash furnace and dryers:</i>	<i>Stack after bag house (textile filters).</i>
<i>Converter aisle ventilation:</i>	<i>Stack after bag house (textile filters).</i>
<i>Process gas from slag fuming plant; Process gas from zinc clinker furnace:</i>	<i>Common stack: gases fuming after double ESP; gases clinker furnace after bag house and HF scrubber.</i>
<i>Ventilation and process gas from anode furnaces:</i>	<i>Stack after bag house.</i>
<i>Ventilation gases, lead, from Kaldo plant:</i>	<i>Stack after bag house.</i>
<i>Furnace gases from precious metals plant:</i>	<i>Stack after scrubber, wet ESP and SO₂ wash tower.</i>
<i>SO₂ containing process gases from fluid bed roaster, electric furnace and converters as well as Kaldo lead smelting: To liquid SO₂ and acid plants:</i>	<i>Acid plant stack. Hg removal systems for example: Norzink calomel process, Dowa filter, active carbon filter, selenium filter.</i>
<i>Copper concentrate dryers</i>	<i>Stack (40 m) after bag filters</i>
<i>Pneumatic conveyors</i>	<i>Stack (140 m) after bag filters</i>
<i>Fugitive collection and dedusting units</i> <ul style="list-style-type: none"> • from flash smelting area • from converter area 	<i>Stack (140 m) after bag filter</i>
<i>By-pass gas after waste heat boiler during heating</i>	<i>Stack after bag filter</i>
<i>Anode furnace gases</i>	<i>To heating dryers and silos and/or stack (140 m) after bag filter</i>
<i>Acid plants</i>	<i>Acid plant stack (inside of 140 m stack)</i>
<i>Trof furnace off-gas</i>	<i>Stack of the precious metal plant after bag filter</i>
<i>Trof ventilation</i>	<i>Stack after bag filter</i>
<i>Tank house ventilation</i>	<i>Ventilation gases after condensation to atmosphere and condensate to process</i>
<i>Selenium furnace</i>	<i>Stack after scrubbing</i>

The water used in the processes is mainly cooling water even if process water also exists. Closed water circuits are used to reduce the total consumption of fresh water. Cooling waters are used e.g. for cooling of the different furnaces and for anode cast cooling. Contaminated water (rain water, snowmelt water, surface drainage and process water) are processed in waste water treatment plants before discharge. Metals are precipitated from contaminated waters using sodium hydroxide and flocculants. The solution is clarified and filtered using e.g. sand filters. Precipitates are recycled back to the flash smelting furnace.

Different wastes are produced in the processes. A large part of the generated wastes are recycled back to the processes or are used in other industries in the neighbourhood. Some other waste products are sold in the market e.g. iron sand (an iron containing slag) which is used as construction materials in e.g. roads and house foundations. Some wastes are also landfilled in controlled landfilling areas. In Table 6 different waste materials and their corresponding recycling at plant are shown for plant B. Table 7 and Table 8 show different wastes for final disposal and utilisation/recycling for plant B.

Table 6 Recycled materials at smelter, plant B.

Materials	Type of recycling
Dryer dust	To flash smelting furnace
Slag concentrate	To flash furnaces
Contaminated sand	To flash smelting furnace
Scraps	To flash smelting furnace and converter
Cu precipitate of Zn-plant	To flash smelting furnace
Cu precipitate	To flash smelting furnace
Mercury precipitate from acid plant	To external zinc plant for recovery
Smelter bag filter dust	To flash smelting furnace
Ventilation dust	To external zinc plant for recovery
Converter dust	To flash smelting furnace
Anode furnace dust	To flash smelting furnace
Anode furnace slag	To converter
Anode scrap	To converter
Reverts from ladle and launder	To flash furnace and converters
Water treatment precipitate	To flash smelting furnace
Weak acid	To smelter, to external zinc plant for use, to external mine
Used anodes	To converter
Blende acid	To external zinc plant
Trof-converter bricks	To smelter
Trof dust	To flash smelter
Leaching residue of CCA production	To acid plant tailings bond
Impure cathode	To converter

Table 7 Wastes for final disposal at plant B.

Material	Year 2006 (tonnes/year)
Fine slag from copper process	360700
Gypsum/ferriarsenate	1520
Granulated slag from nickel process	150000
Industrial waste to dumping area	292
Municipal waste to dumping area	99
Hazardous waste	97

Table 8 Wastes for utilization and recycling at plant B.

Materials	Year 2006 (tonnes/year)
Biomaterial waste, t/a	6
Paper waste, t/a	19
Energy waste, t/a	26
Rubber waste, t/a	43
Wood waste, t/a	199
Glass waste, kg/a	320
Cable scrap, t/a	14
Ladle scrap, t/a	80
Iron scrap (bright), t/a	6
Iron scrap (black), t/a	377
Barrel scrap, t/a	13
Soil and stone materials	360

5.3 References for Copper

1. Boliden, Sweden, Contact person: Catharina Nordeman

6 Revision of processes to produce aluminium

In this chapter primary and secondary aluminium production in the Nordic countries have been covered. There are all together 11 primary, and 11 secondary aluminium production plants in the Nordic Countries.

6.1 Applied processes and Techniques Primary aluminium production

Information has been received covering 9 plants. The production methods by electrolysis have not changed much from the description in the original BREF Document. New information is available regarding treatment of fumes and gases and emission levels.

6.1.1 Primary aluminium production using prebaked anodes

Prebaked anodes are used at most plants today. Pot gases, collected and treated in a dry alumina scrubber system or fluidised alumina bed will result in the following emission levels. (Hydro Aluminium, Elkem Aluminium, Norway)

Emission levels:

Fluoride < 0.38 kg/t Al

SO₂ 4-6 kg/t Al

Dust 0.8 – 1.0 kg/t Al

A dry cleaning system combined with seawater scrubber can reduce SO₂ to < 2.00 kg/t Al (Soer-Norge Aluminium, Husnes, Norway).

6.1.2 Primary aluminium production using the Søderberg method

Søderberg anodes are made in situ from a paste of calcinated petroleum coke and coal tar pitch, which is baked by the heat arising from the molten bath. Fumes are collected and combusted in burners to reduce the emission of tars and PAHs. Pot gases are treated in a dry scrubbing system to reduce HF, fluorides and dust. Pot-room ventilation gases may also be collected and treated in a wet scrubbing system to reduce HF, fluorides, SO₂ and dust.

The Søderberg method is used at three plants in the Nordic countries. Kubal, Sundsvall, Sweden, Elkem Aluminium, Lista and Hydro Aluminium, Karmøy, Norway.

At the Hydro Aluminium, Karmøy pot gases are collected and treated in a dry alumina scrubber and a wet scrubber. At this plant also pot room gases are treated in a wet scrubber. With this method the following emission levels have been reached:

Emission levels:

Fluoride 0.51 kg/t Al

SO₂ 0.88 kg/t Al

Dust 2.06 kg/t Al

6.1.3 Emission of perfluorocarbons (PFC)

The primary aluminium production process is probably the largest anthropogenic source of emissions of PFC (tetrafluoromethane, CF₄ and hexafluoroethane, C₂F₆). Since the BAT document was published on non ferrous metals in 2000 the aluminium industry has decreased the PFC emission considerably. According to the latest report from IAI (International Aluminium Institute) the global PFC emission in 2005 is 0.96 t CO₂ eq/t Al.

Anode effects cause carbon from the anode and fluorine from the dissociated molten cryolite bath to combine, producing CF₄ and C₂F₆. The frequency and duration of anode effects depend primarily on the pot technology and operating procedures. Emissions of CF₄ and C₂F₆, therefore, vary significantly from one aluminium smelter to the next, depending on these parameters. At Alcan, Iceland, the present result for anode effect frequency is 0.04 with duration of 0.9 minutes, which gives 0.04 t CO₂ eq/t Al. To be able to maintain low anode effect frequency a well developed process control is required along with well maintained alumina point feeding system. Crust breaker with bath contact sensing could also help to decrease the anode effect frequency. If an anode effect occurs it is killed by moving the beam aggressively down using an automatic anode effect killing system.

For prebaked furnaces anode effects are no longer required for adjustment of the simulated alumina concentration.

6.1.4 Emission performance and measurements

Today measuring method and frequency of measurements vary considerably within Europe, which can lead to variation of emission results. This has to be taken into account when comparing performances, e.g. emission of fluoride and dust, from one site to another. The emission method and frequency needs to be known when performance figures are given. (Alcan, Iceland)

6.1.5 Solid waste

Primary aluminium production generates solid waste; spent pot lining (SPL). SPL generation is approx. 20 kg/t Al, which results in the following figures for Norway 23 000 t/year, Iceland 11 000 t/year and Sweden 3 000 t/year.

SPL, which contains mainly carbon with traces of other materials, can be re-used, treated or deposited. Problems connected with deposition of SPL are leaching of fluorides and cyanides. Elkem, Norway, has developed a treatment process where SPL is used as slag former and reducing agent in iron making. Elkem is planning a demonstration in industrial scale of "Elkem SPL Process", in Bjølvfossen, April – September, 2008.

6.2 Applied processes and Techniques

Secondary aluminium production

6.2.1 Emission levels

Information has been received covering 4 plants. The production methods for secondary aluminium production by refining and remelting do not differ from the description in the original BREF Document. New information is available regarding emission levels.

6.2.1.1 Refiners

Refining secondary aluminium production plants use mostly aluminium scrap as raw material. Collected emissions contain combustion gases and dust from scrap or fluxes used. Cleaning with textile filters combined with injection of lime and carbon results in the following emission levels (Stena Aluminium, Älmhult, Sweden and Kolding, Denmark):

Chloride (HCl) < 10 mg/nm³ (120 g/t Al)

Fluoride < 1 mg/nm³ (6 g/t Al)

Dust < 1 mg/nm³ (50 g/t Al)

Dioxine < 0.01 ng/nm³

6.2.1.2 Remelters

Remelting of primary produced aluminium. Collected emissions are cleaned with textile filters combined with injection of lime. Emission levels (SAPA, Finspång, Sweden):

Chloride (HCl) 0.1 mg/nm³ (3 g/t melted Al)

Fluoride 0.02 mg/nm³ (0.4 g/t melted Al)

Dust 0.5 mg/nm³ (10 g/t melted Al)

6.2.2 Solid waste

Skimmings containing aluminium are recovered in plant. Due to a new EU-regulation salt slag can no longer be deposited. Salt slag is sent to Norway or Germany for recovery. Recovery of salt slag is performed mechanically and chemically. Mechanically by crushing and grinding the slag and sieving in different fractions to separate aluminium from the salt. The salt (mostly NaCl and KCl) is dissolved, refined and recrystallized. The salt can be reused or deposited. Potassium (K) can be reused as fertilizer. (Stena Aluminium, Älmhult, Sweden and Kolding, Denmark)

6.3 References for aluminium

1. Hydro Aluminium, Norway. Contact person: Stein Leistad
2. Elkem Aluminium, Norway. Contact person: Svein Harry Samuelson

3. Soer-Norge Aluminium, Norway. Contact person: Arstein Eik
4. Alcan, Iceland. Contact person: Gudmundur Augústsson
5. Nordural, Iceland. Contact person: Gunnar Olason
6. Stena Aluminium. Contact person: Sweden and Denmark, Ola Falk
7. SAPA, Sweden. Contact person: Malin Spångberg

7 Revision of processes to produce lead, zinc and cadmium

In this chapter in the BREF document only zinc production has been covered from the Nordic countries. Other metals can be considered as trace elements or by-products. References for zinc processes are [1]. The data covers two production sites in the Nordic countries.

7.1 Applied processes and techniques

Overview remarks and comments

The processes cover production of zinc from ore using roaster, sulphuric acid leaching with electrolytic zinc production. The main product is zinc but cadmium, mercury and copper cement are also produced in minor quantities in the Nordic countries. The production was in total for the plants as follows:

Table 9 Total production for the two plants in year 2003-2006 (tonnes per year).

Total production	tonnes/year			
	2003	2004	2005	2006
Zinc metal	412 480	425 260	433 298	442 908
Cadmium metal	1 164	1 088	963	950
Mercury	25	24	34	23
Copper cement	2270	1450	2549	1531

The main products and application areas are:

Zinc metal:

- Massive form (ingots, Zn-slabs 8-4500 kg) incl. Euro-Norm Zn –alloys.
- Main downstream use: European steel- and galvanizing industry

Cadmium metal:

- Massive form: Cd-cake is temporarily a waste for deposition or internal recovery of cadmium.
- Main downstream use: Ni- Cd batteries

Copper cement:

- Wet filter cake in big-bags.
- Main downstream use: Recovery of copper metal.

7.2 Present emission and consumption levels

*Proposed revisions of the BREF document (page 359 in BREF)
(BREF: 5.2.2 Emissions to air)*

As shown from the production table the ore, the production and the products are different. It is therefore difficult to relate the emission to a specific production and to give general figures for the emissions. They all vary from site to site. However, general data for the European production will be compiled by the industrial organisation for zinc producers.

Monitoring programs are in place to control the emissions. In Table 10 below emission reduction measures taken on point sources are shown for the production sites.

Table 10 Emission reduction measures taken on point sources.

Roasting calcine transport:	Industry/cassette filters, continuous measurement of dust concentration. Covered/enclosed transport systems. Concentrate stored inside building.
Roaster gas to sulphuric acid plant:	Cyclones, venturiscrubbers, hot and wet electrostatic precipitators (EPS), mercury removal (washing with HgCl ₂ in absorption tower).
Acid plant:	Mist/drop eliminators in absorption towers. SO ₂ tail gas treatment in absorption towers using sea water as a washing fluid.
Leaching, purification and Cd-production:	Wet scrubbers, drop eliminators (95 % efficiency), industry/bag filters.
Cellhouse, cooling towers:	Drop eliminators
Foundry:	Industry/bag filters. Filter connected to zinc powder production has continuous measurement of dust concentration

Research activities for fugitive measurements are going on. The techniques used are based on OSIRIS optical measurement. No data are yet available. Emission reduction measures are also taken for fugitive/diffuse emissions. Some examples of measures taken are mentioned below:

- cleaning/hosing of contaminated areas
- measures to improve “tightness” /enclosing of concentrate/calcine transport and storage systems
- covering of residue containing big-bags etc. stored outside buildings

Example on air emissions and control program

Emission control is based on emission control program that is accepted by authorities. The most important sources have been selected to control program. External expert has at least once

measured all point sources and sources under control program are measured or checked by external expert every 1-3rd year. Other point sources with lower emissions are measured with longer intervals, once every 5-10th years.

Sampling is mainly carried out in accordance with ISO-9096; "Stationary source emissions - determination of concentration and mass flow rate of particular material in gas carrying ducts - Manual gravimetric method" ICP-SMS is used for chemical analysis of the dust samples. Emission accuracy is in the range of +/- 13-20 %.

Until the source is measured the latest measuring result is acting as a base for the emission calculations. Volumetric flow is measured continuously in most of the sources and total emission is calculated based on the formula: $m^3/h \times \mu g/m^3$. This calculation is done continuously and automatic for all point sources. Data are transferred to special database from where the current emission to air can be read continuously. Emission abatement technique and emission control comply with BAT requirements.

Due to measures carried out by the companies, air emissions have been significantly reduced during the latest years. Air emissions and control have been given increased focus. An extensive measurement program of point sources is in place as described above. As an example the most critical fabric filters are or will be equipped with continuous measurements of dust concentration to discover leakages (holes in bags) at an early stage.

In addition to the measurements of emissions from point sources, following measurements/monitoring are carried out:

- Dust fall on-site and in the neighbourhood of smelter (regular).
- Air quality – PM10 and metal content (not regular).
- State monitoring program of trace element deposition on moss.
- State monitoring program in water recipient.
- Measurement and location of most important sources/contribution to fugitive emissions (ongoing research program but very complicated).

*Proposed revisions of the BREF document (page 363 in BREF)
(BREF: 5.2.3 Emissions to water)*

In the Nordic countries, rigorous measurement and control program exist for water emissions. An example of data from such a program for a plant in the Nordic countries is given in Table 11. The table shows the average concentration of substances in different effluent discharge and the variation span of the data.

Table 11 Average concentration of substance in different effluent discharge (mg/l). Average data and the variation span of the data are given.

Treatment plant	Average concentrations in effluent from treatment plants (mg/l):					
	Zn Average (Variation)	Cd Average (Variation)	Hg Average (Variation)	Cu Average (Variation)	As Average (Variation)	Pb Average (Variation)
Weak acid treatment	0.68 (0-143)	0.023 (0-2.3)	0.00040 (0-0.018)	0.0075 (0-0.51)	7.72 (0-51.6)	0.03 (0-1.65)
Treatment plant, highly contaminate process water	1.04 (19.4-0.074)	0.015 (0.003-0.1)	0.00011 (0-0.0003)	0.007 (0.002-0.052)	0.0045 (0.002-0.012)	0.011 (0.005-0.064)
Treatment plant, lower contaminated surface/run-off waters	1.75 (0-13)	0.024 (0-0.17)	0.00011 (0.0001-0.0003)	0.012 (0-0.099)	0.036 (0-0.036)	0.013 (0-0.07)

Emission reduction measures taken on point sources

Treatment of weak acid:

1. Precipitation using sodium sulphide and copper sulphate
2. Filtration. Filter cake is a stable mercury sulphide for deposition in special concrete sarcophagus inside mountain caverns deposits.
3. Neutralising of filtrate and precipitation of metals using sodiumhydroxide and sodiumsulphide.
4. Sedimentation/thickeners – slime from thickeners recycled to roasters.
5. Filtration in filter press before discharge to sea.

Treatment of highly contaminated process waters:

- 1 Precipitation of metals using lime (CaO/Ca(OH)₂).
- 2 Polishing using Na₂S.
- 3 Thickening/thickeners.
- 4 Overflow thickeners to sand filters and recipient. Slurry from thickener recirculated to the Zn process for recovery of Zinc.

Treatment of low contaminated waters (surface/run-off)

- 1 Precipitation using sodium hydroxide and then Na₂S for polishing.
- 2 Filtration through sand filters before discharging to sea. Washing water/slurry from sand filters recirculated to the Zn- process.

An example of treatment plant for contaminated waters is shown in Figure 3.

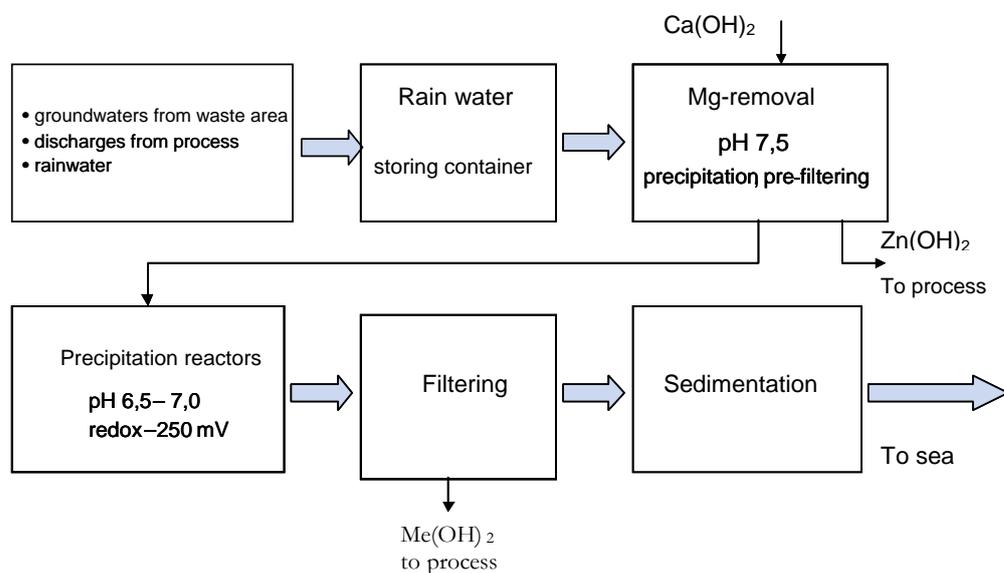


Figure 3 Figure showing chemical treatment of discharges and sedimentation basin. Efficiency of metal removal in chemical treatment is 97.5-99.9 %.

Emission reduction measures taken for fugitive/diffuse emissions

Extensive system for collecting of surface/run-off waters in a mountain cavern located in the solid rock underneath the zinc smelter. Collected water is treated before discharge to sea (see above treatment of surface waters) or may be reused in the process. Significantly increased rain/precipitation during the latest years has made the treatment of run-off/surface waters a challenging issue due to large volumes. Increased precipitation due to climate change can eventually increase this problem.

General remarks on water emissions and control (for point and diffuse emissions)

Controlling and monitoring of discharge waters is organized according to control program that is accepted by authorities. In the point just before common sedimentation basin (last point after zinc process) and in the point just before discharge to sea, automatic sample collectors are located.

A sample (200 ml) is collected in both monitoring points every 15th minutes and a composite sample is collected for 24 hours. Laboratory personnel picks up the sample every morning at 6.00 am., analyses it and transfers the results to database from where the current emission level can be read for any time period.

Water flow is measured continuously and total emission (kg/h, kg/d) is calculated according to the formula: (water flow (m^3) at certain time period \times Zn-concentration ($\mu\text{g}/\text{m}^3$)).

Calculation for any time is based on latest analysed concentration and on continuously measured water flow. Emission control/monitoring is handled as self-monitoring, validity of results have to be proved annually by external expert. Authorities have the possibility to take control samples at any time they want to.

Bubble limits given for emissions to water and air including all types of emission, also diffuse. Also weekly average limits are specified in the permit. No concentration limits are specified. Analytical techniques, detection limits, accuracy are very important issues to discuss before limits are fixed. What is possible in practice and also cost beneficial. There must also be given room for process variations.

*Proposed revisions of the BREF document (page 368 in BREF)
(BREF: 5.2.4 Process residues and wastes)*

The wastes consist mainly of jarosite, sulphur residues and sedimentation sludge. Two types of deposits for the wastes are in use; mountain caverns and landfills.

A mixture of jarosite and sulphur residue (mixed residue) is pumped as slurry to the mountain caverns. Solids precipitate in the caverns. Contaminated, excess water from mountain caverns including ground water from the mountain massive leaking into the caverns is reused for mixing of slurry or reused in the process. Surplus water is treated before discharge into the sea.

For safety verifications with respect to pollution, extensive geological and hydrogeological investigations are performed. Furthermore, piezometers are installed for evaluation of the ground water table, gradient and seepage picture around the caverns. Water samples from control wells are analysed regularly in order to monitor the pollution seepage from the caverns towards the sea. Geological and hydrogeological models are established to perform stability analyses and seepage evaluations from the mountain cavern deposits. The seepage from the mountain deposits is included in the bubble limits given for the Zn-smelter.

In case of landfill, the waste area is closed with barriers and seepage water collection system. Ground water inside the barrier is kept at lower level than outside. All seepage and surface water is pumped to the Zn-process and used in leaching or treated in wastewater treating process and pumped out to sea via sedimentation together with process discharges.

Data for the main wastes (jarosite and jarosite+elementary sulphur) are provided below. In Table 12 the content of different metals and other substances are presented. In Table 13 data from leaching tests are shown for the same wastes. Leaching test data refers to L/S=2.

Table 12 Example content of metal and other substances in Jarosite (years 2003-2005) and common waste (jarosite + elementaric sulphur) year 2006.

	S [%]	Ca [%]	Mn [%]	Fe [%]	Cu [%]	Zn [%]	As [%]	Cd [%]	Hg [%]	Pb [%]	S(ell)+S [%]	NH4+ [%]	Na [%]
2003	12.41	4.22	0.22	22.94	0.34	4.48	0.63	0.086	0.000	5.67	2.04	1.07	0.79
2004	15.75	4.47	0.31	19.67	0.21	2.67	0.58	0.049	0.002	5.76	4.92	0.52	1.40
2005	26.14	3.80	0.22	17.62	0.20	2.82	0.50	0.055	0.004	5.03	16.35	0.15	1.52
2006	35.07	3.20	0.19	15.09	0.13	3.15	0.43	0.051	0.004	4.89	26.83	0.17	1.12

Table 13 Leachability characteristics for Jarosite (years 2003-2005) and common waste (jarosite + elementaric sulphur) year 2006 in mg/kg for L/S 2.

	S [mg/kg]	Fe [mg/kg]	Zn [mg/kg]	As [mg/kg]	Cd [mg/kg]	Hg [mg/kg]	Pb [mg/kg]
2003	12303	1.39	84.9	0.043	2.78	0.0031	5.06
2004	13434	1.42	62.6	0.070	0.90	0.0030	4.95
2005	12768	1.25	165.8	0.043	1.24	0.0023	7.39
2006	8885	1.08	94.3	0.023	0.93	0.0023	6.57

Different waste streams are also recycled. Examples of this are:

Internal recycling streams:

Dross from foundry recycled to roaster.

Residue from the water treatment plants recycled to process

External recycling of “intermediates”:

E.g. leaching residues for recovery of Cu and Pb (copper-cake and lead slag).

Proposed revisions of the BREF document

(BREF: 5.1. Applied Processes and Techniques, 2.3 Management systems)

The environment and quality work at the industries are carefully controlled by different management systems. The following systems are in use at the Nordic production sites.

ISO 14001 (Environment)

OHSAS 18001 (Health & Safety)

ISO 9001 (Quality)

Annual EHSQ (Environment, Health, Safety and Quality) report produced and made public.

7.3 References for Pb, Zn and Cd

1. Boliden, Norway, Finland, Contact persons: Emil Jøsendal, Kai Nykänen.

8 Revision of processes to produce ferro-alloys

8.1 Applied processes and techniques

Ferro-manganese and manganese alloys, ref [5, 6, 7]

Overview remarks and comments

Rev 1:

The term Low-carbon is not a static definition. It has evolved over time and the customer demands are setting the limits. For example, in Japan 0.5 % C is regarded LC. Depending on the producer's raw material situation, limits for P also varies.

Rev 2:

Blast furnace as production unit for the production of FeMn is not in use in Western Europe.

Rev 3:

The temperatures used in the process description of MC production seem low.

Rev 4:

Low carbon FeMn is traditionally produced by a silicothermic process route. Recent process development has made de-carburisation of HC an economical and environmental favourable process route for the production of LC. C-content of less than 0.5 % can be reached, but usually LC is offered just below 0.75 % C.

Rev 5:

SiMn production route could use as a reference.

Proposed revisions of the BREF document

Rev 1:

1. High-carbon ferro-manganese (HC FeMn) with max 7.5 % C
2. Medium-carbon ferro-manganese (MC FeMn) with max 1.5 % C
3. Low-carbon ferro-manganese (LC FeMn) with max 0.75 % C
4. Silicomanganese (SiMn) with max 2.0 % C
5. Low-carbon silico-manganese (LC SiMn) with max 0.10 % C

Rev 2:

The chapter regarding BF production of FeMn can be left without comments or deleted all together. Focus should be switched to Submerged Arc Operation.

Rev 3:

Increase all upper temperature limits with 100°C.

Rev 4:

Low carbon FeMn is traditionally produced by a silicothermic process route. Recent process development has made de-carburisation of HC an economical and environmental favourable processing route for the production of LC. C-content of less than 0.5 % can be reached, but usually LC is offered just below 0.75 % C.

Rev 5:

Add the ref. S. Olsen, M. Tangstad and T. Linstad. "Production of Manganese Ferroalloys" Tapir Academic Press 2007. ISBN 978-82-519-2191-6.

Proposed revisions of the BREF document (page 505 in BREF document)
(BREF: 9.1.2. Ferro-silicon and silicon alloys) ref. [1,2,3,4]

General comment: Text in red is changes made to the old BREF document. Text marked in yellow is comments. Remaining text is from the old BREF document.

Ferro-silicon, silicon metal and silico-calcium (SiCa) (CaSi) are used as additives in different industrial activities products. As an alloying element, ferro-silicon increases the strength of steel and is therefore used to melt in steel that is needed to produce for instance wire-cords for tyres or ball-bearings. High purity FeSi is used to produce high permeability steel for electric transformers. Silicon metal is important as alloying element in aluminium and for the production of chemicals and electronic equipment products. The major user for silico-calcium is also the steel industry. The above mentioned metals can be classified by their silicon-content as follows.

1. **Ferro-silicon**, silicon content less than 96%
2. **Si-metal** silicon content above 96%
3. **Silico-calcium** silicon content about 60 – 65% and calcium content of 30 – 35%

(BREF: 9.1.2.1. Raw materials)

The raw materials that are commonly used for the production of ferro-silicon, silicon metal and silico-calcium are listed in the following table.

Raw material	Ferro-silicon	Si-metal	Silico-calcium
Quartz	■	■	■
Coke	■		■
Petrol coke		■	
Coal	■	■	■
Charcoal	■	■	
Woodchips	■	■	
Limestone			■
Iron-ore/steel scrap	■		
Amorphous carbon		■	
Graphite electrodes		If a combined graphite/ Soderberg-electrode is used	
Soderberg electrode paste	■		■

Table 9.1: Raw material for the production of ferro-silicon, Si-metal and silico-calcium

Table 9.1: Add compound electrode to the table and mark this electrode and graphite electrode for FeSi production. Change “amourhous carbon” to “amourhous carbon electrode” in the table.

Proposed revisions of the BREF document (page 506 in BREF document)

In order to achieve good process results the selection of the raw material is due to some-strict quality requirements. The thermal strength of the quartzite for example is of special importance, because it is connected to the gas permeability of the charge where too much fine sized material may prevent gas flow. The carbon quality is important for the environmental performance of the process, because the coal and coke normally contains normally sulphur and some other unwanted trace elements which can be emitted to the environment. If, for instance, carbon contains mercury or other volatile elements, they will evaporate in the process and will be emitted transferred as part of the off-gas into the environment.

(BREF: 9.1.2.2. Production of ferro-silicon, silicon metal and silico-calcium)

Raw material is normally supplied to ~~or closed to~~ the plant by ship, truck or train. Several ferrosilicon and silicon plants are located near the sea or a river where boats are mainly used for transportation of raw materials and products. The loading and unloading of raw material is done with the use of crane grips, front-end loaders or dumper trucks.

The different raw materials that are used for the Si, FeSi and CaSi-production are preferably stored on hard surfaces in order to prevent contamination. The reductants are normally stored indoors, to avoid the material from humidity caused by rain. Some of the reductants can have self-igniting characteristics. In these cases, appropriate ~~methods ways of surveying~~ have to be implemented to avoid self-combustion ~~in~~, e.g. charcoal or coal with a high content of volatile matter or woodchips.

Ferro-silicon, silicon metal and silicon-calcium are commonly produced ~~in low-shaft three-phase submerged electric arc furnaces~~. The ~~electric furnaces~~ can be of the open or semi-closed type. The furnace normally rotates ~~e.g. once a week~~, in order to connect the reaction areas around each electrode ~~tip to break down crust in between the electrodes~~. ~~This homogenises the molten metal in the furnace and saves 5 to 10% of electric energy~~. The rotation gives rise to some difficulties in obtaining good capture efficiency of the fugitive emissions at the tap-hole as the location of the tap-hole will rotate with the furnace. A typical electric arc furnace for the production of ferro-silicon is shown in the following figure.

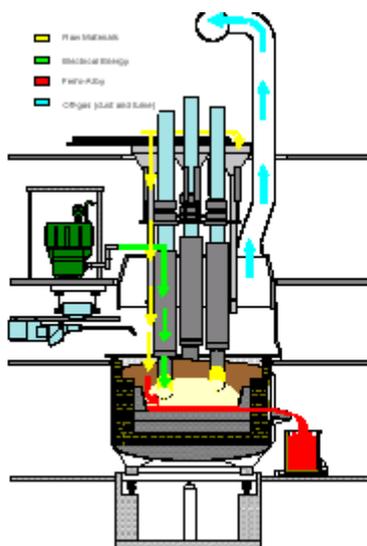


Figure 9.2: Electric arc furnace for the production of Si-metal, ferro-silicon and CaSi

Furnace called Electric submerged arc furnace.

Proposed revisions of the BREF document (page 507 in BREF document)

The raw material is fed from storage bins above the furnace, through feeding tubes ~~into the smelting zone around the electrodes~~. In small furnaces the raw material can also be feed by using of stocking charging cars.

The smelting of silicon metal and silicon alloys normally takes place in open or semi-closed furnaces. The open furnaces are commonly built up with moveable curtains or gates around the ~~furnace hood to secure access~~ for maintenance and ~~possible~~ manual feeding. The furnace/~~smoke~~

hood is the upper part of the furnace. The hood has several tasks, first of all it collects the process off-gas and shields the equipment from the process heat. Secondly the hood is the site for electrode arrangements, raw material charging and cooling arrangement for the furnace. For the FeSi and CaSi production the Söderberg-technology is used. For silicon production the electrode is often pre-baked and screwed on top of the previous electrode according to the electrode consumption. In recent years an electrode has been developed utilising a combination of the Söderberg technology and a graphite core with a stable iron electrode casing. This combined electrode allows the implementation of the Söderberg-technology in the production of silicon metal. The aim is to reduce the iron impurities caused by the electrode casing and reducing the high costs of pre-baked graphite electrodes. The semi-closed furnace has been introduced to control the suction of air into the furnace top and thereby reducing the total gas stream from the furnace.

Proposed revisions of the BREF document (page 508 chapter 9 in BREF document)

The liquid metal is tapped ~~off~~ at continuous or at regular intervals. The metal is cast from the ladle after the tapping is finished. Transportable tapping vessels can be brought to the tapping position by suitable vehicles or by overhead cranes. The metal can also be directly tapped to the casting area without using transport vessels. The silicon alloy is then cast into moulds and crushed by using jaw-, rotary or roll crushers or granulated in water. A process flow diagram for the production of ferro-silicon, silicon metal and calcium silicon is presented in the next figure.

Additional changes and comments to Applied Processes and Techniques:

Chapter 9.1.1 Ferro-chrome (page 502). Bullet 1. (1. **High-car on ferro-chrome (HC FeCr)** with 4 – 10 % C (“ferro-chrome carbure”). Change 4-10 % to 2-12 %.

Page 503 (last sentence): change “in the ~~from~~ of steam” to “in the ~~form~~ of steam”

Page 504 (second sentence from the end) The chrome ore can efficiently ~~be~~ preheated for example in a fluidised-bed system (insert “be”).

8.2 Present emission and consumption levels

(chapter 9.2 page 528 in the old BREF document)

Ferro-manganese and manganese alloys, ref [5, 6, 7]

<i>Overview remarks and comments</i>	<i>Proposed revisions of the BREF document</i>
Rev 1 (page 528): Bullet “Emission to air” point “Emission of noise and vibrations” should be a bullet point on it’s own.	Rev 1 (page 528): Bullet “Emission to air” point “Emission of noise and vibrations” should be a bullet point on it’s own.
Rev 2 (page 528): Bullet “Energy recovery” should cover energy recovery from cooling water in a separate point.	Rev 2 (page 528): Add point energy recovery from cooling water to the bullet “Energy recovery”.
Rev 3: Table 9.6 – electrode consumption in SiMn production is too high, best performance is less than 11 kg/t.	Rev 3: Range should therefore be 10-30 kg/t.

Rev 4.

Table 9.10 – regarding dust emission from various processing steps, SiMn column should be filled in with data.

Rev 5:

Chapter 9.2.2.1.2: N₂O and CH₄ should be discussed in the text. Dioxins can not be formed in a closed SAF operation with a wet scrubber cleaning system for the off-gas. Mercury in Mn production and cleaning of off-gases should be more thoroughly described.

Rev 6:

Table 9.12 – not complete.

Rev 7:

9.2.2.2 limit at most exposed neighbour – 50 dB(A)

Rev 8:

PAH limits given in mid page 542 are too high.

Rev 9:

Table 9:18; data given is for silicothermic production of refined FeMn. MOR production of LC/MC should also be mentioned.

Rev 10:

Table 9.19 Norwegian numbers are too old.

Rev 4:

Emission from the smelting step has been reduced to less than 0.02 kg/t product. Lots have been achieved in emission control. Table should be reconsidered.

Raw material handling: <0.1 mg/Nm³

Weighing/dosing: <0.1 mg/Nm³

Smelting: about 2 mg/Nm³

Tapping: 3.2 mg/Nm³.

In the NOTES section of the table N1 it should be: a venturi scrubber.

Rev 5:

Chapter 9.2.2.1.2: N₂O and CH₄ are emitted from sinter and pellets production facilities. This should be mentioned in the text. First paragraph lists gaseous compounds emitted from ferro-alloy plants. The paragraph also mention dioxin, please clarify that closed furnaces does not give time for the dioxin formation. Mercury should be treated as a more important topic. Cleaning of off-gases was thoroughly discussed in a presentation at Infacon X by L. Hunsbeth et al. The authors will give their consent to use parts of the text.

Rev 6:

See revised table for manganese below.

Rev 7:

9.2.2.2 Limit at most exposed neighbour – 50 dB(A).

Rev 8:

PAH should be 0.04-0.2 g/t Mn alloy

Rev 9:

Should be up to 100 kg/t, all dust recycled to furnace.

Rev 10:

See proposed changes for manganese below.

Proposed revisions of the BREF document

Rev 6: (Table 9.12 in the BREF document)

To air				
FeMn		MC and LC FeMn		
HCFeMn		EAF		
	kg/t	mg/Nm ³	kg/t	mg/Nm ³
SO ₂	0.1-0.2	n.a.	n.a.	n.a.
CO	n.a.	n.a.	n.a.	n.a.
CO ₂	1000-1500		60-100	
NO _x	n.a.	n.a.	n.a.	n.a.
Hg	0.0001-0.00015	0.001-0.2		
Pb	0.0002 - 0.0004			
As	2E-05			
Cd	5E-06			
Cr	2E-05			
Cu	8E-05			
Sum	0.0001	0.0002		
To air				
SiMn				
SiMn				
	kg/t	mg/Nm ³		
SO ₂	0.002-0.1	n.a.		
CO	n.a.	n.a.		
CO ₂	1100-1800			
NO _x	n.a.	n.a.		
Hg	0.00003-0.0001			
Pb	0.0002 - 0.0006			
As	2E-05			
Cd	5E-06			
Cr	2E-05			
Cu	8E-05			
Sum	0.0001	0.0002		

Proposed revisions of the BREF document

Rev 10: (Table 9.19 in the BREF document)

Correct numbers are as follows (for Norwegian Mn producers)

3 producers, Tinfos Jernverk AS, Eramet, RDMN

Number of plants: 4, Kvinesdal; Porsgrunn and Sauda; Mo i Rana

9 furnaces in operation

Tinfos: 3X45 MVA, Eramet: RDMN:

Electrical energy used: 2290(GWh/a)

Possible recovery: (GWh/a)

Electrical energy 100

Thermal energy 790

Total	890
Actual recovery: (GWh/a)	
Electrical energy	90
Thermal energy	386
Total	476

Tabl 9.19:

Information about Norwegian HC-FeCr can be excluded from the table. FeCr production has been terminated in Norway.

*Proposed revisions of the BREF document (page 528 in BREF document)
(BREF: 9.2. Present Emission and Consumption Levels) ref. [1,2,3,4]*

General comment: Text in red is changes made to the old BREF document. Text marked in yellow is comments. Remaining text is from the old BREF document.

The manufacturing of ferroalloys is in general an energy consuming processes that take place at high temperatures. The energy and raw material consumption per ton product varies greatly from one product to the other. Different types of carbon materials are used as reducing agents to remove oxygen from the ore. Large amounts of electric energy must be used in order to reach the high process temperatures in the range of 1200-2000 °C that are required for the metal producing chemical reactions to take place. The common carbon sources are coal, coke, charcoal and wood chips. Some of these are unsuited in some ferroalloy production processes for technical reasons, while some products require very low contents of selected trace elements such as titanium.

Coal contains considerable amounts of volatile compounds, tar, sulphur and water that leave the process together with the main process gases like CO, CO₂ and SiO. These gases burn, react and cool in the furnace hood and off-gas channels. The temperature and oxygen levels in the off-gases of open and semi-closed furnaces produce significant amounts of NO_x. The combustion inside the furnace hood and the off-gas ducts may be imperfect. The reason for this is due to the design of the furnace as well as the standard for operation. Cold air that mixes with gases may lead to sootingformation. Imperfect combustion may lead to high content of combustion controlled effluents such as PAH, dioxins and NO_x. Investigations have shown that the standard for raw material supply to the furnace is vital to the environmental performance of the process.

Particulate matters in the off-gas are collected by cyclones, filters or wet scrubbers. Some furnaces have recovery units for energy and/or cleaning facilities for specific elements like mercury.

The environmental impact on air, water and land varies considerably from one product to the other, and can be classified as follows.

Emissions to air

The emission to air mainly consists of

- dust and fume emissions
- SO₂, NO_x, CO, CO₂ and polycyclic aromatic hydrocarbon (PAH), volatile organic compounds (VOC), dioxins and heavy metals.
- noise and vibrations

Solid residues, wastes and by-products

- Dust, fume and sludge
- Slag

Wastewater emissions

- Wastewater from wet scrubbing systems
- Wastewater from slag and metal granulation
- Blow down from cooling water cycles

Energy recovery

Methods for energy recovery:

- Energy recovery in terms of the utilisation of the CO- rich off gas from closed furnaces.
- Energy recovery from high temperature off-gas either as electric energy or hot water for heating purposes.
- Energy recovery from cooling water.

(BREF: 9.2.1. Consumption of raw material and energy)

The raw material consumption mainly depends on the metal content of the ore, the metal yield in the furnace process, the composition of the product and losses during raw material and product handling (transport, screening etc.) and treatment (refining, solidification, crushing, packing etc.). Higher yields give less consumption of raw materials and energy per ton metal for a specific process. Production of special alloys may require cleaner raw materials that have less favourable process properties. If so, it gives less yield and higher consumption of raw materials and energy per ton metal produced.

The energy consumption per ton metal differs greatly from one ferro-alloy to another. One reason is the difference in the chemical bonding strength for different elements to oxygen in the ore and the temperature required for the chemical reactions to proceed. Silicon, for instance, both has higher bonding energy and requires higher process temperatures than Manganese. Other reasons are variations in the metal content of the ore and the final product, and the metal yield that it is possible to obtain for different ferro-alloys. The latter is mostly governed by the amount of slag that is produced per ton metal and the amount of metal containing gases that are present in the production furnace at different temperatures.

The consumption of raw material and energy listed below are figures for producing one ton of tapped liquid metal. Figures for the product as sold to the customers would have to be given on quality to quality basis because the metal losses and energy requirement for the post tap hole treatment differs greatly depending on the customer specifications. This is however beyond the scope of this document. As an example, standard ferrosilicon can be tapped directly into moulds filled with low value fines from previously crushed metal, adding several percent to the tapped tonnage. This gives low raw material and energy consumption per ton product sold. Production of

high purity, low titanium ferrosilicon, on the other hand, requires extremely clean raw materials with less favourable process properties and post tap hole refining, often involving both a tapping ladle and a refining ladle. The poorer raw materials give less silicon yield in the furnace process, while the post tap hole treatment gives substantial losses both through oxidation of elements to be removed by refining, imperfect slag-metal separation and through metal that solidifies in the ladles used. The raw material and energy consumption per ton product sold is therefore much higher for this quality. The consumption values are given as intervals covering normal variations in the metal yield.

The latent chemical combustion energy of the free carbon (Fix-C) in the carbon materials is listed even though this carbon is used as a reducing agent for the ore in highly energy consuming chemical reactions rather than energy production by combustion with oxygen. The substantial amount of volatile components in coal is, for instance, not possible to utilise in the silicon metal and ferrosilicon process since it does not react with the ore. Neither does it add any energy in parts of the furnace where energy is needed. The energy consumption in ferroalloy production is therefore always given by the amount of electric energy used per ton tapped metal. The values in the tables are for the metal production process only, and it does not include auxiliary energy for operating various support systems like fans, heat exchangers, raw material handling, keeping ladles warm etc. The auxiliary power normally amounts to between 5 and 10% of the given values in the tables.

Raw material	HC FeCr				MC FeCr	LC FeCr
Chromite kg/t	2400 – 3000 (N 1)	2300 – 2400 (N 2)	n.a.	n.a.	n.a.	1600
Reductant kg/t	550 – 700 (N 1)	500 – 550 (N 2)	600 (N 3)	n.a.	n.a.	675 (FeSiCr)
Fluxes kg/t	100 – 400 (N 1)	200 – 300 (N 2)	n.a.	n.a.	n.a.	1100
Others kg/t	Electrode 8 –25 Remelts 0 -300	Electrode 7 - 10	n.a.	n.a.	n.a.	Sand < 100 kg Si < 40 kg Electrode 10 kg Boric acid 3k
Electrical energy kWh/t	3800 – 4500 (N 1)	3100 – 3500 (N 2)	2600 – 3100 (N 3)	4500 (N 4)	n.a.	3400 (N 5)
Potential energy by using coke kWh/t	4235 – 5390 (N 1)	3850 – 4235 (N 2)	4620 (N 3)	n.a.	n.a.	n.r.
Total energy input kWh/t	8035 – 9890 (N 1)	6950 – 7735 (N 2)	7220 – 7720 (N 3)	n.a.	n.a.	3400
Notes: (N 1) Consumption data of a conventional open submerged arc furnace, lumpy and fine ore without agglomeration, pre-heating and/or pre-reduction processes. (N 2) Consumption data by using preheated pellets as raw material and no remelts. (N 3) Consumption by using pre-reduced pellets as raw material. In this case the energy consumption is dependent on the grade of metallisation (N 4) DC furnace without pre-reduction process (N 5) The presented energy consumption refers to the conversion of FeSiCr to LCFeCr. If the production of the intermediate product – FeSiCr – is included, the electrical energy is 8050 – 9500, potential energy by using coke 5750 – 6400 and the total energy input 13800 – 15900 kWh/t LCFeCr. The above-mentioned electricity and reductant consumption's are for the whole production process. The electrical energy consumption is about 95% of the total consumption. The main part of the remaining 5% is electrical energy needed for the off-gas treatment. n.a. = data not available n.r. = not relevant						

Table 9.3

Proposed revisions of the BREF document (page 529 in BREF document)

Generally, higher chromium content in the alloy requires more energy in the production. The energy consumption used for sintering chromite ore depends on the type of sinter furnace that is used and on the characteristics of the different chromite concentrates. Coke breeze consumption will generally be in the range of 60 - 90 kg/t of sinter. With sinter consumption between 2 and 2.5 tonnes per tonne of ferro-chrome, this equals to 120 – 225 kg of breeze per tonne of ferro-chrome. The external energy consumption of a steel belt sinter furnace ranges between 200 – 400 kWh/t pellets. The energy comes from coke breeze and CO-gas from smelting. The coke breeze consumption is 20 - 40 kg/t of pellets and the proportion of CO as external energy is about 20 – 40%. The external energy for coke drying in a shaft furnace is about 200 kWh/t of coke equalling to 100 kWh/t of FeCr.

Change “Plamadust process” to “Plasmadust process” in table 9.4 .

	Conventional submerged electric arc furnace	Plamadust process
Residues kg/t	1650 – 2500	1650 – 2500
Reductant kg/t	400 – 500	400 – 500
Electricity kWh/t	3000 – 3400	2800 – 3800
Metal contents% (input)		
Ni		
Cr	3 – 15	3 – 15
Mo	15 – 25	15 – 25
C	1 – 5	1 – 5
Si	4 – 6	4 – 6
Iron	0.5 – 8	0.1 – 1
	Balance	Balance
Water m ³ /t	1.0 – 1.5	2.8 – 3.2
Alloy recovery (output)		
Cr	> 80%	90 – 95%
Ni	> 90%	90 – 98%
Mo	> 90%	90 – 98%
Fe	> 90%	90 – 98%

Table 9.4: Consumption data for the recovery of ferro-alloys from steel mill residues as specific input factors based on one tonne of recovered metal

The consumption of energy and raw material for the production of ferro-silicon and silicon metal is presented in terms of specific input factors as an example in the following table. The amount of electrical energy that is given in the table is for the furnace process only and refers to one ton of liquid metal tapped from the furnace at the specified silicon yield, electric efficiency of the furnace and carbon loss from the top of the furnace.

The table below show new data for FeSi and Si-metal which are produced in the Nordic countries. No revised data for CaSi exists for the Nordic countries.

Input type	Ferro-silicon a), b) (65% Si)	Ferro-silicon a), c) (75% Si)	Si-metal a), d) (99% Si)
Quartzite [kg/t] e)	1430-1550	1700-1900	2440-2650
Fix-C [kg/t] f)	670-740	740-840	960-1060
Iron [kg/t] g)	340-350	240-250	0
Electrode [kg/t]	35-70	35-70	50-100
Lime stone [kg/t]	0-40	0-40	0-40
Woodchips [kg/t] h)	0-500	0-500	0-2000
Electric energy consumption [MWh/t]	7.1-8.4	8.0-9.8	11.0-13.1
Ideal electric energy consumption [MWh/t] i)	6.1	6.8	8.6
Combustion energy of Fix-C [MWh/t]	6.1-6.7	6.8-7.6	8.7-9.7
a) All values are calculated with raw material temperature = 25°C, metal temperature = 1600°C, off-gas temperature before combustion = 1400°C. All values except the ideal electric energy consumption assume electric efficiency for the furnace = [80% - 88%] and a carbon loss from the furnace top = [5% - 10%].			
b) Silicon yield (= 100% * the amount of silicon in the tapped metal / amount of silicon in the raw materials) = [90% - 97%] except for the value of "Ideal electric energy consumption".			
c) Silicon yield = [85% - 95%] except for the value of "Ideal electric energy consumption".			
d) Silicon yield = [80% - 87%] except for the value of "Ideal electric energy consumption".			
e) The quartzite is close to pure SiO ₂ , so the consumption varies little with the ore. The dominant factor for the consumption of quartzite is therefore the silicon yield.			
f) Fix-C is carbon that is available for reducing the ore. The amount of carbon materials needed to supply the Fix-C depends on the Fix-C content of the carbon materials actually used. Typical Fix-C values for coal, coke and charcoal as charged to the furnace are 50-80 (weight)% while woodchips typically contain 10-15% Fix-C. 680 kg of Fix-C can for instance be supplied either as 800 kg petrol coke with 80% Fix-C or 6800 kg woodchips with 10% Fix-C. This is why the carbon consumption is given as the amount of Fix-C rather than the total weight of the carbon materials. However, in reality woodship fix-C seldom exceed 10 % of total fix-C.			
g) The value is given for pure metallic iron. Iron pellets is almost pure Fe ₂ O ₃ , and therefore contains approximately 70% iron and 30% oxygen. The iron content is therefore almost the same in 100 kg of pure metallic iron and in 100 kg / 0.7 ≈ 143 kg of iron pellets.			
h) The amount of woodchips very much depends on the quality that is produced.			
i) The ideal electric energy consumption is calculated assuming 100% pure raw materials, 100% silicon yield, 100% electrical efficiency and no carbon loss; i.e. a theoretical process with no losses at all. [

Table 9.5 Consumption of raw materials and energy for production of silicon metal and ferrosilicon.

Recent development work has resulted in a new electrode type utilising a combination of the Söderberg-technology and a graphite core, to allow the system for the production of silicon metal. The aim for this compound electrode is to reduce the cost for the electrode while still keeping the iron impurities caused by the electrode casing at an acceptable level for production of silicon metal.

The specific input factors for the production of the different sorts of ferro-manganese as well as for silico-manganese and the sinter process of manganese ores and concentrates are given in the table below.

*Proposed revisions of the BREF document (page 533 in BREF document)
(BREF: 9.2.2.1.1. Dust and fume emissions)*

According to the raw material that is needed and the unit ~~operations ions~~ used, e. g. crushing, drying, sintering, **reduction**, tapping and product handling the most important source of environmental input are dust and fume emissions. The following figure shows the potential emission points for dust and fume emissions from a ferroalloy producing plant.

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Some raw materials contain considerable amounts of fines and dust. Unloading and storage of raw material can generate dust when the material falls from one conveyor to another. Dust can also be produced if the conveyor is running too fast (i.e. more than 3.5 m/s). If a front-end loader is used dusting is seen during the transport distance.

The dust that is produced by the **reduction** process is collected by hoods or in case of a closed furnace by the furnace sealing directly and transferred to an abatement plant and de-dusted (e.g. by a fabric filter or a wet scrubber). Scrubbing is used for closed furnaces.

Tapping off-gas consists of dust and fumes from **the furnace process**, oxygen lancing, dust from drilling, fumes from vaporised slugs if a tapping gun is used and fumes from all exposed metal and slag surfaces. These fumes that arise from tapping will mainly be **CO/CO₂** and oxides of the metals involved in the **reduction** process.

The following tables present the available emission data for the emission of dust by producing **different** ferro-alloys.

Note N2 in table 9.8 should be changed to “less than 1 %”.

note N3 in table 9.9: Difficult to understand the meaning of the sentence. “emissions are in the same range than the concentration”

(BREF: 9.2.2.1.1. Other emissions to air)

The most important pollutants from the production of ferro-alloys beside dust are SO₂, NO_x, CO, **CO₂**, HF, polycyclic aromatic hydrocarbons (PAH), volatile organic compounds (VOCs) and heavy **metals**. **The** formation of dioxins in the combustion zone and in the cooling part of the off-gas treatment system (de-novo synthesis) may be possible. The emissions can escape the process either as stack emissions or as fugitive emissions **depending on the design and maintenance status of the plant and the used technology**. Stack emissions are normally monitored continuously or periodically and reported by on-site staff or off-site consultants to the competent authorities.

In the carbo-thermic process only the fixed carbon content is used as a reductant, **which means that volatile matter, ash and moisture mostly leaves the process with the off-gases and slag**. For closed furnaces, the furnace gas can be sold for its combustion value or burned at the exit after cleaning, while the gases burn after being mixed with air in the furnace hood and off-gas channels for semi-closed or open furnace. ~~In both cases the energy content in the volatile matters is utilised.~~

The sulphur content in metallurgical coke varies between **0.3** and 1.0%. 60 – 85% of the sulphur remains in the slag and about 5% escapes the furnace as SO₂. The production of silicon alloys requires different reducing agents like coal, coke, petrol-coke and charcoal. This material contains different amounts of sulphur, typical variations are between 0.5 and 3%. In the silicon alloy production, which is almost slag free, nearly all sulphur escapes the furnace as SO₂ or as bounded

sulphur to the micro-silica. By using a reducing agent or a mixture of different carbon sources, which contains in total a high sulphur content of about 2 - 3%, higher SO₂ emissions may occur.

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Depending of the type of ore that is used, mercury may be emitted to air. ~~One~~ Some plants producing SiMn ~~has been~~ have reported ~~to have~~ high mercury-emissions due to a high mercury content in the raw material. Other producers of FeMn and /or SiMn may use the same raw material with a higher mercury content. Therefore control of mercury-input in the furnace and control of subsequent mercury-output of the processes is advisable, if such raw materials are used. In this case the raw material needs a pre-treatment to remove the mercury otherwise the mercury has to be removed from the furnace off-gas by using a mercury-removal step.

There are several commercial technologies available for mercury removal from off gases. Mercury removal from raw materials will involve large scale equipment. Ore dressing is only economical due to scale. For the converting step, the cleaning of the off gas might be feasible if a satisfactory gas collection system can be installed. Sintering plants are usually built for treatment of ore fines, often with an increased content of mercury and other trace elements. Since trace elements tend to accumulate in the grain boundaries, resulting in a high concentration in the fines, the production chain must be examined, when utilizing a high mercury raw material. If the material must be sintered due to size, mercury cleaning must be installed. For alloy production, online measurement and cleaning measures must be a minimum requirement.

In the production of FeMo, fluorspar may be used to improve slag and metal separation. Fluorspar is a calcium fluoride ore that is used as a flux and lowers the melting point and the viscosity of the slag resulting in an enhanced fluidity of the slag. Additionally, when mixed with lime, it reduces the phosphorus and sulphur content of the metal. Lower melting points favour the metal-slag separation, since the slag remains a longer time liquid during the cooling. This effect together with the reduced viscosity makes it possible for small dispersed droplets to sink, coagulate in the metal phase at the bottom. However, the use of fluorspar as a fluxing agent results in emissions of fluorides within the range of 150 to-260 mg/Nm₃. According to the biotoxic nature of fluoride the use of fluorspar should be minimised as far as possible.

Proposed revisions of the BREF document (page 540 in BREF document)

Comments to table 9.12: Cyanides is not formed in all processes for FeCr e.g. it is formed in the Outokumpu process.

HF is not produced in bulk production of FeCr, should be changed to n.r.

N7: A figure for a lower purity should be inserted to show an emission span.

The major emissions to air by producing primary ferro-nickel are listed in the table shown below.

Operation	Emissions to air									
	Dust/Fume			Gases						
	Total	Ni	Others	SO ₂	CO ₂	CO	NO _x	H ₂ S	Ni(CO) ₄	others
Ore crushing	HL	LL	-	-	-	-	-	-	-	-
Drying	HL	HL	-	LL	ML	LL	-	-	-	-
Roasting	HL	HL	-	HL	ML	LL	LL	-	-	-
Reductive calcination	HL	LL	-	LL	ML	LL	LL	-	-	-
Smelting	HL	LL	-	-	ML	ML	LL	-	-	-
Converting	HL	ML	SiO ₂	-	ML	LL	LL	-	-	-
Pouring	HL	LL	-	-	-	-	-	-	-	-

VL Very low level LL Low level - Absent
ML Medium level HL High level

Table 9.13: Emissions to air from Ferro-nickel [tm 109, UNEP 1993]

Emission concentration figures for the production of ferro-alloys recovered from steel mill residues in a submerged electric arc furnace are presented below.

Pollutants	Concentrations (gas and particles) mg/Nm ³
Dust	2 - 5
SO ₂	< 100
CN	0.002 - 0.006
HC	< 50
F	0.1 - 1.5
Cd	< 0.001
Cd +Hg + Ti	< 0.1
As	< 0.003
Se	< 0.002
Te	< 0.002
Zn	0.02 - 0.05
Pb	< 0.005
CO ₂	1.2 - 1.5 t/t of alloy

Table 9.14: Emission concentration figures by producing secondary ferro-alloys

In the production of silicon and ferrosilicon the combustion process in the smoke hood and off-gas channels may create emission to air. The main problems are the formation of NO_x, (PAH) and dioxins.

These emissions may be significantly reduced by introducing an improved process design. The environmental parameters are presented in table below:

		Silicon			FeSi - 75%		
Emission	Unit pr tonnes alloy	Standard batch charging technique	Improved charging technique	Improved charging + high off-gas temperature	Standard batch charging technique	Improved charging technique	Improved charging + high off gas-temperature
CH ₄	kg/tonnes	0.12	0.09	0.10	0.09	0.07	0.08
CO	kg/tonnes	3.50	3.60	0.00	1.80	3.50	0.50
Dioxin	µg/tonnes	1.90	0.00	0.00	5.50	1.10	0.20
NO _x	kg/tonnes	22.30	11.00	13.00	15.30	7.00	8.30
N ₂ O	kg/tonnes	0.04	0.02	0.03	0.03	0.01	0.02
PAH	g/tonnes	1.86	0.00	0.00	1.21	0.01	0.01
VOC	kg/tonnes	0.10	0.00	0.00	0.00	0.00	0.00

The table shows measured (bold numbers) and estimated parameters for silicon and ferrosilicon production. These parameters are now used by the Norwegian Ferroalloy Industry for emission reporting to the Norwegian Pollution Control Authority (SFT). (Ref: The Silicon Process - Improved Environmental Standards. Silicon for the Chemical Industry VII. MS Trollford, Tromsø-Bergen, Norway, Sept. 21-24, 2004)

(BREF: 9.2.2.4. By-products, process residues and wastes)

The production of ferro-alloys is related to the generation of a number of by-products, residues and wastes, which are also listed in the European Waste Catalogue (Council Decision 94/3/EEC). The most important process specific residues are filter dusts, sludge from wet scrubbers, slag from the smelting process, used furnace linings and packaging material like drums or big-bags. These residues are partly sold as by-products, recycled to the process or in cases of wastes without economic utility transported to a deposit or a landfill. The amount of slag and filter dust or sludge generated per tonne of produced ferro-alloy and their possibilities of valorisation are shown in the next tables.

Note to table 9.17 page 544: Recycling, reuse and discharge text for Alloy recovery from steel mill residues is also applicable for HCFeCr.

Note to table 9.18 page 545: Comments for the wet scrubber bullets: wet scrubbers are not used in semi-closed furnaces.

second raw, 5th bullet change to “can easily be...”

note N2 has no reference in the table. If this note is used it should also be mentioned that the waste material can be mixed with Fe(II) and in this way reduce Cr(VI) to Cr(III) before landfilling. In that case the concentration of Cr(VI) is almost 0 after treatment with Fe(II).

The silicon and ferrosilicon process has relatively low amount of trace elements (Ref: IMPORTANT SUB-PROCESSES IN THE SILICON PROCESS. THE BEHAVIOR OF TRACE ELEMENTS. Silicon for the Chemical Industry V. Tromsø, Norway, 2000)

The emission of trace-elements may be calculated from a mass balance by using the total input to the process of each element and use the emission parameters given in the table below.

Some elements will mainly be found in the ferrosilicon, silicon metal or the silica. Four elements (As, Hg, S and Se) may be found in the off-gas. There could be an environmental impact if silica

fume is not cleaned/filtrated from the off gases or if the silica has to be disposed/landfilled as waste instead of utilised as a product.

Table shows the distribution of elements for the silicon process. When the total input of each element is known the emission for a plant can be calculated.

Element into the process	Al	As	B	Ba	Bi	Ca	Cd	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Mo	Na	Ni	P	Pb	S	Sb	Se	Si	Sn	Sr	V	W	Zn	Zr
Distribution to silicon (%)	80	30	95	80	70	60	10	95	90	80	99	0	10	10	80	80	20	95	75	5	15	30	80	0	80	70	99	100	30	99
Distribution to silica (%)	20	65	5	20	30	40	90	5	10	20	1	60	90	90	20	20	80	5	25	95	10	70	20	60	20	30	1	0	70	1
In the off-gas (%)	0	5	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	0	75	0	0	40	0	0	0	0	0	0

Table shows the mass balance of some trace elements for a 10000 ton pr. year silicon plant. All numbers are in kg/year.

	Hg	As	Cd	Zn	Pb	Cu	Cr
	kg	kg	kg	kg	kg	kg	kg
Emission to air	0.108	6.2	0	0	0	0	0
Trace element in silicon product	0.000	6.2	1.2	11	5.6	161	577
Trace element in microsilica	0.046	112	10	207	107	40	64
TOTAL	0.155	124	12	218	113	202	641

Proposed revisions of the BREF document (page 546 in BREF document)
(BREF: 9.2.3. Energy recovery)

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The off-gas energy is mainly represented as process heat in case of a semi-closed furnace or by the content of CO, CH₄ and H₂O when a closed furnace is used. The process-gases are produced in the smelting process if carbon is used as a reducing agent. The CO can be utilised as a secondary fuel and transferred by means of pipelines within the plant area like any other fuel gas. It can be used by direct burning for instance in the sinter-furnace and for drying or preheating the furnace charge as well as for energy recovery in form of hot water, steam and/or electricity.

...

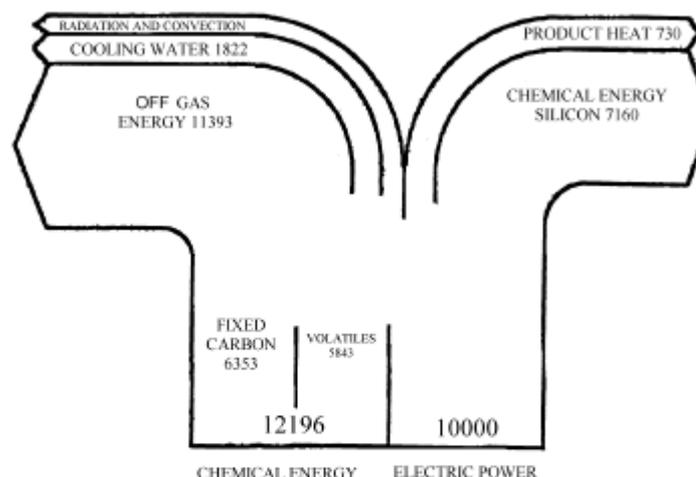


Figure 9.13: Energy flow in a 10 MW silicon furnace
[tm 152, A. Schei, J.K.Tuset, H. Tveit 1998]

Figure 9.13 indicates a large amount of waste energy from the silicon and ferrosilicon processes. There are today plants with different energy recovery. As figure 9.13 shows the volatiles in the reduction materials give a significant contribution to the energy input.

The best way to recover energy is to produce heat energy. The temperature from the furnace is determined by the total off-gas from the furnace and may vary from 200 to 750 °C. Due to lack of (economically) feasible usage of heat energy some places recovers energy as electrical energy. This gives a lower energy recovery.

Often energy recovery efficiency is defined as the amount of energy recovered in relation to the electrical energy input to the furnace:

Table: Energy recovery efficiency for silicon and FeSi furnaces.

	Electric power recovery (%) ^{*)}	Heat energy recovery ^{*)} (hot water or steam):
BAT today at plants	22 %	70 %
Optimised new plants	30-35%	70-100%

^{*)} Recovery is related to electrical input to the reduction furnace. The heat energy in the off-gas may be in the order of 20% higher than the electrical energy. (Ref: Improved Environmental and Energy Recovery Performance with New Furnace Hood Design at Elkem Thamshavn. Silicon for the Chemical Industry VI. Loen, Norway, June 17-21, 2002).

Proposed revisions of the BREF document (page 549 in BREF document)

Ferro-alloy	Number of plants	Electrical energy used [GWh/a]	Possible recovery [GWh/a]			Actual recovery [GWh/a]		
			Electrical energy	Thermal energy	Total	Electrical energy	Thermal energy	Total
FeCr	1	360		140	140			
FeSi	9	4940	856	1024	1880	115	183	298
Si-metal	3	1250	163	215	378		1	1
FeMn SiMn	3 (N 1)	1850	80	550	630	80	216	296
Total	16	8400	1099	1929	3028	195	400	595 (N 2)

Notes: Energy recovery data of 16 Norwegian ferro-alloy plants. [tm 159, INFACON 7, 1995]

(N 1) Gas is partly used as fuel or synthetic gas
(N 2) From the reported 16 ferro-alloy plants in 1989 energy has been recovered by 8 plants

Table 9.19: Overview of energy recovery in the Norwegian ferro-alloys industry in 1989 [tm 159, INFACON 7, 1995]

Ferro-alloy	HC FeCr		HC FeMn			SiMn		FeSi	Si
	Semi-closed EAF	Closed EAF	Blast furnace	Semi-closed EAF	Closed EAF	Semi-closed EAF	Closed EAF	Semi-closed EAF	Semi-closed EAF
Drying	■	■		■	■		■		
Ladle heating		■			■		■		
Sintering		■			■		■		
Pre-heating	■	■	■ Hot stoves		■		■		
Hot water	■	■	■	■	■	■	■	■	■
Steam	■	■	■	■	■	■	■	■	■
Electricity	■	■	■	■	■	■	■	■	■
Neighbouring mills		■			■		■		■

Remark:
Energy recovery is not always be used, because local conditions for instance local prices of energy, periods of production and the absence of possible customers should be taken into account.

Table 9.20: Energy reuse by producing bulk ferro-alloys

Revisions for table 9.19: see Rev 10 of ferromanganese chapter 8.2 of this document. Data for FeCr should also be removed. FeCr is no longer produced in Norway.

Note for rev of 9.20: For semi-closed furnace HCFeCr the material is not dried and not pre-heated.

8.3 Techniques to consider in the determination of BAT

Ferro-manganese and manganese alloys, ref [5, 6, 7]

Overview remarks and comments

Proposed revisions of the BREF document

Rev 1.

Techniques for Hg-cleaning should be described. A minimum requirement for a modern manganese producing facility must be to have a complete on-line monitoring system for Hg-emissions. The largest sources for Hg must be known and the Hg balance known in each phase of the production chain.

Rev 1:

Implementation and explanation of all known techniques for monitoring and cleaning of Hg. Some of the needed information is available in the paper mentioned earlier presented at Infacon X. (Infacon X by L. Hunsbeth et al)

Proposed revisions of the BREF document (page 558 in BREF document) (BREF: 9.3.6. Gas collection and abatement) ref. [1,2,3,4]

General comment: Text in **red** is changes made to the old BREF document. Text marked in yellow is comments. Remaining text is from the old BREF document.

Chapter 7

Taking account of the above advantages and disadvantages the smelting systems to consider are:

- Open furnace for special applications and small capacities connected with a bag filter
- Semi-closed furnace connected with a bag filter
- Closed furnace systems in different applications cleaned by a wet scrubber or dry cleaning system
- Blast furnace if the waste energy will be recovered
- Reaction crucibles with an appropriate hooding system connected with a bag filter
- Reaction crucibles in a closed chamber connected with a bag filter
- Multiple heard furnace for molybdenite roasting with an dust removal and an acid recovery

The open furnace for producing bulk ferro-alloys is not a technique to be considered in the determination of BAT. The main reasons are the higher electrical energy consumption due to the higher off-gas volume to be cleaned in the filter-house. This higher off-gas volume induces, even with a high standard bag house, a larger amount of fine dust emitted to the environment. In addition the energy used to operate an open furnace can not be recovered.

9.3.6 Gas collection and abatement

The techniques for fume collection and abatement discussed in Chapter 2 of this document are techniques to consider for the production of ferro-alloys. Bag filter and wet scrubbers are normally used for de-dusting the process off-gases.

There exist a number of different bag filter designs using different kinds of filter materials, which in principal all achieve low emission values that means dust emissions below 5 mg/Nm³. The use of the membrane filtration techniques (surface filtration) results additionally in an increasing bag life, high temperature limit (up to 260 °C) and relatively low maintenance costs combined with dust emissions in the range of 1 - 5 mg/Nm³. There are different suppliers in Europe who are able to provide bag filter with membrane filter bags. The membrane filter bags consist of an ultra-fine expanded PTFE membrane laminated to a backing material. The particles in the off-gas stream are captured on the bag surface. Rather than forming a cake on the inside or penetrating into the bag fabric, particles are repelled from the membrane thus forming a smaller cake. This technique is applicable for all new and existing plants and may also be used for rehabilitation of existing fabric filters [tm 144, Elkem 1998].

Bag house filters are in many cases in the ferro-alloy and metallurgical industry pressure filters with fans on the dirty fume/gas side. Recent developments led to a closed suction filter with fans on the clean-gas side. This combines the advantages of gentle bag cleaning that means longer bag life, low operating and maintenance costs and due to the closed filter a defined gas volume [tm 144, Elkem 1998].

By recovering ferro-alloys from steel mill residues the off-gas cleaning is done in a two stage bag house- In the first stage furnace dust is collected for recycling or further processing. In the second stage, absorbent granules (activated carbon or lignite coke) is injected. Volatile metals notably mercury and to a lesser extent cadmium and lead is chemi-sorbed on the surface of the carbon. Due to the highly toxic nature of mercury and cadmium emissions of this metals below 0.2 mg/Nm³ can be achieved. The absorbent also traps chlorine compounds including dioxin. Alternatively a 3-step venturi scrubber combined with a wet electrostatic precipitator and a selenium filter may be used. The selenium filter removes mercury from the off-gas.

Wet scrubbers are techniques to consider by operating closed furnaces where the CO-rich off-gas need to be washed and de-dusted at very high temperatures. Modern wet scrubbers achieve dust emissions below 10 mg/Nm³, with coarser dust, even achieved dust concentrations of 4 mg/Nm³ by using a cascade scrubber to clean the off-gas from a sinter furnace have been reported [tm 200, Kantola, 1999]. Venturi scrubbers used to clean the off-gas from a closed HC

No longer recent developments! May be the dust emissions can be changed from 1-5 mg/Nm³ to <5 mg/Nm³. Experiences have shown that underpressure filter works better than overpressure filter. Filter bag life time have shown to be approximately 10 years.

FeCr furnace achieve emissions below 50 mg/Nm³ due to very fine dust that is produced in the furnace, but which is not emitted directly to the atmosphere. The disadvantages of the wet scrubber are normally the slightly higher dust emissions and the washing liquid and sludge that needs a further treatment. Compared with a bag-filter that is normally used for a semi-closed furnace, the wet scrubber even with the higher dust emissions do not result in an higher environmental impact due to the reduced off-gas volume from a closed furnace. One case has been reported where a closed ferro-alloy furnace is provided with a wire-cloth filter instead of a wet cleaning system. This filter recovers heat from the exhaust gases and eliminates the need of a scrubbing unit. The collected dust is pelletised and **ritualised ???**, and the cleaned gas is burned in a boiler unit [tm 202, EnviroSense, 1995].

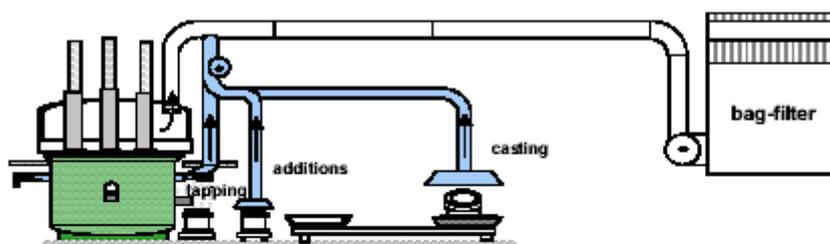


Figure 9.16: Collection of tapping and casting fume

Note to figure 9.16: Old-fashioned figure without energy recovery and with bag-house filter.

*Proposed revisions of the BREF document (page 561 in BREF document)
(BREF: 9.3.8. Post furnace operations)*

Using a pneumatic or hydraulic drill normally opens the tap hole of the smelting furnace. Oxygen lancing is also used, either as the only method or as a back up or complement to drilling. A tapping gun helps to remove blockages, but slugs containing lead and zinc should only be used if an appropriate hood is installed to remove tapping fumes. This is necessary because the lead and particularly the zinc, will to a large extent vaporise in the tap hole, and create zinc and lead fumes that otherwise would pollute the working area and subsequently participate in the ventilation air. The tap hole is closed using a mud gun (or shutting paste/clay).

Proposed revisions of the BREF document (page 562 in BREF document)

EXAMPLE 9.07 DENSIFICATION OF SILICA POWDER AND OTHER DUST COLLECTED IN BAG FILTERS FROM FERRO-ALLOY SMELTING FURNACES

Description: - To handle silica fume (micro silica) and other ferro-alloy filter dust a densification process involving a micro-pelletisation step has been reported. The process that forms a powder into small spheres about 0.5 - 1 mm in diameter.

Main environmental benefits: -Higher bulk density reduces the environmental impact of transportation. This means less air pollution and less noise problems from truck traffic.

Operational data: - The bulk density of raw silica dust is less than 0.2 t/Nm³. The process of micro pelletisation increases the bulk density to 0.5 – 0.6 t/Nm³. These reduce the transport costs by about 65% and the environmental impact of transportation.

Cross media effects: - Less truck traffic

Economics:- Not available

Applicability: - To new and existing plants where silica fume, SiMn-powder, ~~FeCr-powder~~ filter dust from FeCr-production, **furnace dust and** manganese and ferro oxides need to be handled.

Reference literature: - [tm 144, Elkem 1998].

Proposed revisions of the BREF document (page 563 in BREF document)

(BREF: 9.3.11. Post furnace operations)

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For instance in a Norwegian FeCr plant the balance for CO gas recovery and utilisation in 1998 was reported as follows:

Energy recovery and Utilisation	Energy kWh/t
Total recoverable energy:	2090
Total recovered energy, included internal use 190 kWh/t (sintering, coke drying, ladle heating):	1460
Flared:	630

Table 9.22: Recoverable and total recovered energy

Recoverable energy in this case is not a theoretical figure, but recovered and used CO gases internally and externally plus flared excess gas. The total energy balance for the whole plant was as follows:

Energy consumption and recovery	Energy kWh/t
Electrical energy:	4060
Potential energy in coke:	4430
Recovered CO gas, included internal energy use 190 kWh/t	1460
Total plant energy consumption:	7220

Table 9.23: Total energy balance for a FeCr smelter

Proposed revisions of the BREF document (page 564 in BREF document)

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Concerning the energy usage, the disadvantage of the smelting furnaces used without energy recovery is the high amount of energy lost as CO in the off gas and/or as waste heat **in the off gas**. For instance by producing FeSi and silicon metal only about 32 % of the energy consumed is chemical energy in the product, that means about 68 % of the energy is lost as heat in the furnace off-gas [tm 152, A. Schei, J.K.Tuset, H. Tveit, 1998]. Energy can be recovered from the cooling cycles as hot water and from the off gas as heat which can be transferred into high pressure steam and subsequently into electrical energy or by using the CO content directly as a secondary fuel.

Proposed revisions of the BREF document (page 566 in BREF document)

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EXAMPLE 9.09 ENERGY RECOVERY FOR A SEMI-CLOSED ELECTRIC ARC FURNACE

Description: - The energy (~~form~~) in hot off-gases from the furnace process can be recovered in a waste heat boiler, which produces superheated steam. Relatively conventional water pipe boilers with super heater, economiser and condenser sections are used, combined with an efficient cleaning system to keep the heating surfaces clean in the heavily dust polluted flue gas.

Proposed revisions of the BREF document (page 567 in BREF document)

Main environmental benefits: -The recovery of energy from the hot off gas reduces the overall energy consumption of the process, which consequently minimize/reduces the impact of global warming by emitting CO₂ from burning fossil fuel. The off-gas energy presented a large available, partly unexploited energy source that can provide new electricity without pollution and additional CO₂ emission.

Cross media effects: - The recovered energy replaces in most cases fossil fuel like oil or coal and reduces therefore at the same time the emissions of SO₂. The energy recovery produces no pollution, as the flue gas composition is not changed by the recovery. The emission of hot cooling air and water from the plant is reduced. The energy recovery creates no visual changes of the landscape

Economics: - There are two economic case studies, which have been reported. The following results should be seen as an cost indication because exact cost data is very much dependent on the specific circumstances of the plant.

First Case:

A plant with 3 furnaces and a total electric power consumption of about 117 MW has been taken into account. The furnaces are equipped with hoods of the conventional type. Net recovered electric energy will be 317.6 GWh/a, which equals 32.9% of the power consumption. Annuity depreciation for the investment of 43.1 M € over 15 years at 7% interest result in a capital cost of 4.73 M €/a. The electricity cost is approximately 0.016 - 0.017 €/kWh.

Capital cost 4.73 M €

Manning (5.5 Man-years) 0.25 M €

Total 5.76 M €

Second Case:

FeSi production with an electricity consumption of 60 MW uses a semi-closed furnace with about 750 °C off-gas temperature. The waste heat boiler consists of 3 sections and each section has 4 economisers, 2 evaporators and 2 super heaters. The gas exits the boiler at approximately 170 °C. The produces superheated steam is fed to a multistage turbine. The generator produces 17 MW of electric power equals to 90 GWh/a, which corresponds to 28% of the flue gas Energy and 16.5% of the electric power consumption in the furnace. The investment costs for the recovery plant has been in 1987 about 11.7 M € (20 Years annuity, 11.5% interest, electricity cost 0.02 €/kWh)

Capital cost 1.81 M €

Operation and maintenance, 0.45 M €

Manning (5.5 Man-years) 0.25 M €
Total 2.51 M €

8.4 Best available techniques

*Proposed revisions of the BREF document (page 572 in BREF)
(BREF: 9.4.2.4 Smelting process)*

The open furnace itself has not a significantly higher electrical or coke consumption, but huge amounts of cold ambient air are sucked into the furnace to burn the CO which is present in the off-gas. This consequently results in a very large volumetric flow of waste gas, which does not allow the recovery of its energy content because the temperature level is low and the flow rate large to build technically and economically efficient heat exchangers. The CO generated by the smelting process in this case is transformed into CO₂ and heat without using its energy content. ~~that is lost~~. Due to this the open furnace has not been considered as BAT, but can be tolerated if local conditions, for instance local prices of energy, periods of production and the absence of possible customers didn't allow the recovery of energy from a semi-closed furnace under economic viable conditions.

Comment to table 9.25 page 574: Energy recovery. Not only heat can be recovered from the semi-closed furnace (also electric power can be produced). May be change from "heat energy can be recovered" to just "Energy can be recovered".

8.5 References for Ferro alloys

1. Elkem (FeSi), Norway, Contact persons: Inger-Johanne Eikeland
2. FESIL (FeSi), Norway, Contact persons: Lars Nygaard
3. Finnfjord smelteverk (FeSi), Norway, Contact persons: Jacob Steinmo
4. Vargön Alloys AB (FeCr), Sweden, Contact persons: Evalotta Stolt
5. Tinfos jernverk A/S (FeMn), Norway, Contact persons: John Bustnes
6. Rio Doce Manganese Norway (RDMN) (FeMn), Norway, Contact persons: Kyrre Johansen
7. Eramet (FeMn), Norway, Contact persons: Knut Mørk

9 Revision of processes to produce carbon and graphite electrodes etc.

In this chapter prebaked anode production in the Nordic countries has been covered. Prebaked graphite electrodes are produced in two plants in the Nordic countries, Elkem Aluminium Mosjøen and Hydro Aluminium, Årdal, Norway.

9.1 Applied processes and techniques

Collected exhaust gases are cleaned in a fluidized alumina bed combined with Alstomscrubber (sea water). Used alumina from dry gas cleaning is recovered in the aluminium production. (Elkem Aluminium Mosjøen, Norway)

9.1.1 Present emission levels

Emission levels at Elkem Aluminium, Mosjøen, Norway:

PAH 0.33 g/t anode (0.01 kg/h)

SO_x 2.3 g/t anode (0.07 kg/h)

(Fluoride 0.00 kg/t anode)

9.2 References for production of graphite electrodes

1. Elkem Aluminium Mosjøen, Norway. Contact person: Helge Nes