IMPEL PROJECT: "*ENERGY EFFICIENCY IN PERMITTING AND INSPECTION*", EXCHANGE OF EXPERIENCES ON HOW THE ISSUES OF ENERGY EFFICIENCY AND REDUCTION OF GREENHOUSE GASES ARE DEALT WITH IN PERMIT PROCEDURES AND INSPECTIONS IN THE MEMBER STATES – DEVELOPMENT OF A TEMPLATE FOR DOCUMENTS AND DATA REQUIRED REGARDING ENERGY EFFICIENCY IN THE PERMIT APPLICATION (2011/2012)

2012/04/ANNEX 4

IRON AND STEEL PRODUCTION

SUMMARY OF ENERGY-RELATED INFORMATION FOR IRON AND STEEL PRODUCTION AND PROPOSAL FOR THE SECTOR SPECIFIC ANNEX TO THE DRAFT APPLICATION FORM FOR ENERGY EFFICIENCY

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IMPEL

European Union Network for the Implementation and Enforcement of Environmental Law

In cooperation with

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1 Summary of Energy-related Information – Iron and Steel

In the following, energy (efficiency)-related information has been extracted from the **Draft BAT Conclusions for Iron and Steel Production** and the **Draft BREF for Iron and Steel Production**. The collected information serves as a basis for the development of a proposal for the sector specific supplements to the Draft Application form for Energy Efficiency in Chapter 2 of this document.

1.1 Draft BAT Conclusions for Iron and Steel Production (Energy-related)

The Draft BAT Conclusions provide reference to other reference documents which are of relevance for the activities covered. Among these documents, the reference document on Energy Efficiency (ENE) has been pointed out.

1.1.1 General BAT Conclusions for Iron and Steel Production

Unless otherwise specified, the **general BAT Conclusions** apply to all instillations for IS production.

BAT 2

BAT is to **reduce thermal energy consumption** by using a combination of the following techniques:

I. improved and optimised systems to achieve smooth and stable processing, operating close to the process parameter set points by using
   i. process control optimisation including computer-based automatic control systems
   ii. modern, gravimetric solid fuel feed systems
   iii. preheating, to the greatest extent possible, considering the existing process configuration.

II. recovering excess heat from processes, especially from their cooling zones

III. an optimised steam and heat management

IV. applying process integrated reuse of sensible heat as much as possible.

In the context of energy management, **see the Energy Efficiency BREF (ENE).**

Description of BAT I.i

The following items are important for **integrated steelworks in order to improve the overall energy efficiency:**

- **optimising energy consumption**
- **online monitoring** for the most important energy flows and combustion processes at the site including the monitoring of all gas flares in order to prevent energy losses, enabling instant maintenance and achieving an undisrupted production process
- **reporting and analysing tools** to check the average energy consumption of each process
- **defining specific energy consumption levels** for relevant processes and comparing them on a long-term basis
- **carrying out energy audits** as defined in the Energy Efficiency BREF, e.g. to identify cost-effective energy savings opportunities.

Description of BAT II – IV

Process integrated techniques used to improve energy efficiency in steel manufacturing by **improved heat recovery** include:

- **combined heat and power production** with recovery of waste heat by heat exchangers and distribution either to other parts of the steelworks or to a district heating network
- the **installation of steam boilers or adequate systems** in large reheating furnaces (furnaces can cover a part of the steam demand)
- **preheating of the combustion air** in furnaces and other burning systems to save fuel, taking into consideration adverse effects, i.e. an increase of nitrogen oxides in the off-gas
- the **insulation of steam pipes and hot water pipes**
- **recovery of heat from products**, e.g. sinter
- where steel needs to be cooled, the **use of both heat pumps and solar panels**
- the **use of flue-gas boilers** in furnaces with high temperatures
- the **oxygen evaporation and compressor cooling** to exchange energy across standard heat exchangers
- the **use of top recovery turbines** to convert the kinetic energy of the gas produced in the blast furnace into electric power.

Applicability of BAT II – IV

Combined heat and power generation is applicable for all iron and steel plants close to urban areas with a suitable heat demand. The specific energy consumption depends on the scope of the process, the product quality and the type of installation (e.g. the amount of vacuum treatment at the basic oxygen furnace (BOF), annealing temperature, thickness of products, etc.).

BAT 3

BAT is to **reduce primary energy consumption** by optimisation of energy flows and optimised utilisation of the extracted process gases such as coke oven gas, blast furnace gas and basic oxygen gas (see BAT 3).

Description

Process integrated techniques to improve energy efficiency in an integrated steelwork by **optimising process gas utilisation** include:

- the **use of gas holders** for all by-product gases or other adequate systems for short-term storage and pressure holding facilities
- **increasing pressure in the gas grid** if there are energy losses in the flares – in order to utilise more process gases with the resulting increase in the utilisation rate
- **gas enrichment with process gases** and different caloric values for different consumers
- **heating fire furnaces with process gas**
- use of a **computer-controlled caloric value control system**

- **recording and using coke and flue-gas temperatures**
- **adequate dimensioning of the capacity of the energy recovery installations** for the process gases, in particular with regard to the variability of process gases.

Applicability

The specific energy consumption depends on the scope of the process, the product quality and the type of installation (e.g. the amount of vacuum treatment at the BOF, annealing temperature, thickness of products, etc.).

BAT 5

BAT is to **minimise electrical energy consumption** by using one or a combination of the following techniques (see BAT 5):

I. power management systems
II. grinding, pumping, ventilation and conveying equipment and other electricity-based equipment with high energy efficiency.

Applicability

Frequency controlled pumps cannot be used where the reliability of the pumps is of essential importance for the safety of the process.

BAT 13

BAT is to **measure or assess all relevant parameters necessary to steer the processes from control rooms** by means of modern computer-based systems in order to **adjust continuously and to optimise the processes online**, to **ensure stable and smooth processing**, thus **increasing energy efficiency** and maximising the yield and improving maintenance practices (see BAT 13 in Chapter 1.1.7, Monitoring).

Monitoring should be done according to the relevant EU or ISO standards. If EN or ISO standards are not available, national or other international standards should be used that ensure the provision of data of an equivalent scientific quality.

1.1.2 Process-specific BAT Conclusions for Sinter Plants

Process-specific BAT apply in addition to the above listed general BAT (e.g. BAT for sinter plants, BAT for coke oven plans, BAT for blast furnaces). With regard to Energy (Efficiency), a number of process-specific BAT are included within the document (i.e. separate sub-chapters on ‘Energy’). These are summarised in the following.

Unless otherwise stated, BAT conclusions presented in this section can be applied to all sinter plants.

BAT 32

BAT is to **reduce thermal energy consumption** within sinter plants by using one or a combination of the following techniques:

I. **recovering sensible heat from the sinter cooler waste gas**
II. **recovering sensible heat**, if feasible, **from the sintering grate waste gas**
III. **maximising the recirculation of waste gases** to use sensible heat (see BAT 23 for description and applicability).

Description

Two kinds of potentially reusable waste energies are discharged from the sinter plants:

- the sensible heat from the waste gases from the sintering machines
- the sensible heat of the cooling air from the sinter cooler.

Partial waste gas recirculation is a special case of heat recovery from waste gases from sintering machines and is dealt with in BAT 23. The sensible heat is transferred directly back to the sinter bed by the hot recirculated gases. At the time of writing (2010), this is the only practical method of recovering heat from the waste gases.

The sensible heat in the hot air from the sinter cooler can be recovered by one or more of the following ways:

- steam generation in a waste heat boiler for use in the iron and steel works
- hot water generation for district heating
- preheating combustion air in the ignition hood of the sinter plant
- preheating the sinter raw mix
- use of the sinter cooler gases in a waste gas recirculation system.

Applicability

At some plants, the existing configuration may make costs of heat recovery from the sinter waste gases or sinter cooler waste gas very high. The recovery of heat from the waste gases by means of a heat exchanger would lead to unacceptable condensation and corrosion problems.

1.1.3 Process-specific BAT Conclusions for Pelletisation Plants

Unless otherwise stated, BAT conclusions presented in this section can be applied to all pelletisation plants.

BAT 41

BAT is to **reduce/minimize thermal energy consumption** in pelletisation plants by using one or a combination of the following techniques:

I. **process integrated reuse of sensible heat** as far as possible from the different sections of the induration strand
II. **using surplus waste heat** for internal or external heating networks if there is demand from a third party.

Description

Hot air from the primary cooling section can be used as secondary combustion air in the firing section. In turn, the heat from the firing section can be used in the drying section of the induration strand. Heat from the secondary cooling section can also be used in the drying section.

Excess heat from the cooling section can be used in the drying chambers of the drying and grinding unit. The hot air is transported through an insulated pipeline called a 'hot air recirculation duct'.

Applicability

Recovery of sensible heat is a process integrated part of pelletisation plants. The 'hot air recirculation duct' can be applied at existing plants with a comparable design and a sufficient supply of sensible heat. The cooperation and agreement of a third party may not be within the control of the operator, and therefore may not be within the scope of the permit.

1.1.4 Process-specific BAT Conclusions for Coke Oven Plants

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all coke oven plants.

BAT 58

BAT is to **use the extracted coke oven gas (COG) as a fuel or reducing agent** or for the production of chemicals.

1.1.5 Process-specific BAT Conclusions for Blast Furnaces

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all blast furnaces.

BAT 71

BAT is to **maintain a smooth, continuous operation of the blast furnace** at a steady state to minimise releases and to reduce the likelihood of burden slips.

BAT 72

BAT is to **use the extracted blast furnace gas as a fuel**.

BAT 73

BAT is to **recover the energy of top blast furnace gas pressure** where sufficient top gas pressure and low alkali concentrations are present.

Applicability

Top gas pressure recovery **can be applied at new plants** and **in some circumstances at existing plants**, albeit with more difficulties and additional costs. Fundamental to the application of this technique is an adequate top gas pressure in excess of 1.5 bar gauge.

At new plants, the top gas turbine and the blast furnace (BF) gas cleaning facility can be adapted to each other in order to achieve a high efficiency of both scrubbing and energy recovery.

BAT 74

BAT is to **preheat the hot blast stove fuel gases or combustion air using the waste gas of the hot blast stove** and to **optimise the hot blast stove combustion process**.

Description

For optimisation of the energy efficiency of the hot stove, one or a combination of the following techniques can be applied:

- the use of a computer-aided hot stove operation
- preheating of the fuel or combustion air in conjunction with insulation of the cold blast line and waste gas flue
- use of more suitable burners to improve combustion
- rapid oxygen measurement and subsequent adaptation of combustion conditions.

Applicability

The applicability of fuel preheating depends on the efficiency of the stoves as this determines the waste gas temperature (e.g. at waste gas temperatures below 250 C, heat recovery may not be a technically or economically viable option).

The implementation of computer-aided control could require the construction of a fourth stove in the case of blast furnaces with three stoves (if possible) in order to maximise benefits.

1.1.6 Process-specific BAT Conclusions for Basic Oxygen Steelmaking and Casting

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all basic oxygen steelmaking and casting.

BAT 83

BAT is to **collect, clean and buffer BOF gas for subsequent use as a fuel**.

Applicability

In some cases, it may not be economically feasible or, with regard to appropriate energy management, not feasible to recover the BOF gas by suppressed combustion. In these cases, the BOF gas may be combusted with the generation of steam. The kind of combustion (full or suppressed combustion) depends on local energy management.

BAT 84

BAT is to **reduce energy consumption by using ladle-lid systems**.

Applicability

The lids can be very heavy as they are made out of refractory bricks and therefore the capacity of the cranes and the design of the whole building may constrain the applicability in existing plants. There are different technical designs for implementing the system into the particular conditions of a steel plant.

BAT 85

BAT is to optimise the process and reduce energy consumption by **using a direct tapping process after blowing**.

Description

Direct tapping normally requires expensive facilities like sub-lance or DROP IN sensor-systems to tap without waiting for a chemical analysis of the samples taken (direct tapping). Alternatively, a new technique has been developed to achieve direct tapping without such facilities. This technique requires a lot of experience and developmental work. In practice, the carbon is directly blown down to 0.04 % and simultaneously the bath temperature decreases to a reasonably low target. Before tapping, both the temperature and oxygen activity are measured for further actions.

Applicability

A suitable hot metal analyser and slag stopping facilities are required and the availability of a ladle furnace facilitates implementation of the technique.

BAT 86

BAT is to reduce energy consumption by **using continuous near net shape strip casting**, if the quality and the product mix of the produced steel grades justify it.

Description

Near net shape strip casting means the continuous casting of steel to strips with thicknesses of less than 15 mm. The casting process is combined with the direct hot rolling, cooling and coiling of the strips without an intermediate reheating furnace used for conventional casting techniques, e.g. continuous casting of slabs or thin slabs. Therefore, strip casting represents a technique for producing flat steel strips of different widths and thicknesses of less than 2 mm.

Applicability

The applicability depends on the produced steel grades (e.g. heavy plates cannot be produced with this process) and on the product portfolio (product mix) of the individual steel plant. In existing plants, the applicability may be constrained by the layout and the available space as e.g. retrofitting with a strip caster requires approximately 100 m in length.

1.1.7 Process-specific BAT Conclusions for Electric Arc Furnace Steelmaking and Casting

Unless otherwise stated, the BAT conclusions presented in this section can be applied to all electric arc furnace steelmaking and casting.

BAT 94

BAT is to reduce energy consumption by using continuous near net shape strip casting, if the quality and the product mix of the produced steel grades justify it.

1.2 BREF for Iron and Steel Production

The iron and steel industry is **highly intensive in both material and energy**. Following the two most important steelmaking routes via the sinter/pellet plant/coke oven/blast furnace/basic oxygen converted and electric arc furnace, the key environmental issues for action in response to environmental concerns can be summarised below:

Sinter plants

Sinter, as a product of an agglomeration process of materials which contain iron, represents a major part of the burden of blast furnaces. The main stack emissions of sinter plants account for up to 50 % of the total dust emissions from an integrated steelworks. Other relevant pollutants in the off-gas emissions from the sinter strand and the cooler are heavy metals, SO_2, HCl, HF, PAH and persistent organic pollutants (such as PCB and PCDD/F). **Furthermore, the recovery of sensible heat and the utilisation of solid wastes are severe issues. Environmental benefits are linked to this process with the recycling of iron-rich solid by-products of downstream processes and the potential for heat recovery.**

Pelletisation plants

Pelletisation is another process used to agglomerate materials which contain iron where emissions to air dominate the environmental issues. **Other main issues in pellet plants are the use of sensible heat,** the treatment of waste water and the internal utilisation of process residues.

Coke oven plants

A coke plant consists of one or more coke oven batteries with a coke oven firing system (underfiring) and the process gas treatment unit where emissions to air are the most significant. The main point source for emissions to air is the waste gas from underfiring. Additionally, many of the emissions are diffuse emissions from various sources such as the unloading, storage, handling, crushing and blending (preparation) of coal, the leakages from lids and adherences onto frames, oven and leveller doors, the ascension pipes and charging holes of coal into and the pushing of coke out of the chambers, and finally, coke quenching and coke grading (crushing and screening), transport, handling and storage. Diffuse/fugitive VOC emissions to air can occur from coke oven batteries and diffuse/fugitive ammonia and BTX emissions from by-products plants which all have the potential to create odour nuisances. In case coke oven gas is used as a fuel at coke oven plants and/or other plants, dust and SO_2 emissions can be a concern. Thus the desulphurisation of coke oven gas is a measure of high priority for minimising these emissions. Waste water disposal is another major issue for coke oven plants. **Optimised management of coke oven gas and its use in other processes of integrated plants allow energy savings and minimise air emissions.**

Blast furnace plants

Significant emissions to all media occur where the blast furnace process for producing hot metals from materials which contain iron are used. **Because of the high input of reducing agents (mainly coke and coal), this process consumes most of the overall energy input of an integrated steelworks.** Relevant emissions to all media occur and these are described in detail. **The main environmental issues are dust, waste water from blast furnace gas scrubbing, emissions from slag**

treatment such as SO_2 and H_2S which can lead to odour nuisances, dusts and sludge, and finally, the minimisation of energy consumption.

Basic oxygen furnace plants

Emissions to air from various sources such as primary and secondary dedusting, hot metal pre-treatment and secondary steelmaking and various solid process residues are the main environmental issues in oxygen steelmaking. In addition, waste water arises from wet dedusting (when applied) and from continuous casting. Particular attention should be paid to diffuse dust emissions which occur when secondary emission collecting systems are insufficient.

Electric arc furnace plants

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

Energy consumption

Energy consumption in iron and steel making is considerable. CO_2 as a greenhouse gas is generated when energy is consumed. There are many emissions points of CO_2 in the iron and steel processes and they are related to three main factors: a) providing the sufficient temperature in order to carry out the chemical reactions and physical treatment needed, b) providing a reductant (mainly CO) to the system in order to reduce the iron oxide, and c) providing the power and steam necessary to run the steelworks.

The specific energy consumption for steel production in electric arc furnaces in Europe is on average about 1.8 GJ/t liquid steel. **Considering the efficiency of energy supply, primary energy consumption will be considerably higher. Additionally there is a fossil fuel input of about 0.5 GJ/t liquid steel on average** (according to Table 8.1, BREF IS).

Specifically, because the CO_2 which is generated when energy is consumed is a greenhouse gas (GHG), energy savings have undergone a major change in purpose, and are now considered part of the solution to the problem of global warming which is a global-scale environmental issue.

Regarding iron and steel making, the CO_2 emissions depend very much on the types and amounts of reducing agents (e.g. coke, coal, and oil) used in the blast furnace (see Sections 6.1.3.1 and 6.2.2.4). **For this reason, the steel industry has actively implemented a variety of measures to reduce the energy consumption in general and emissions of GHG such as CO_2 in particular**. Extensive efforts have been made to reduce the reducing agent demand close to the stoichiometric minimum demand (see Section 6.3). **Since 1980 the specific energy demand has been reduced from 23 GJ/t of liquid steel to approximately 18 GJ/t liquid steel in 2004 for modern integrated steelworks** [35, Dr. Luengen, H.B. 2005].

The energy consumption has been constantly reduced by introducing energy-saving equipment in steel manufacturing processes and improving the efficiency of energy conversion facilities such as power plants. Energy-saving equipment includes waste energy recovery equipment. Another

measure is the optimisation of energy consumption and costs by the implementation of a total energy management system. To a certain extent, direct reduction (DR) can be an option to reduce CO_2 emissions (see Section 10.1).

1.2.1 Energy management in the Steelmaking Industry

Specific energy issues have been covered in each process-specific chapter of the BREF IS (i.e. Chapters 3-8). However, the following section serves to show the energy interdependencies between the different processes in an integrated steelworks.

Energy flow and process gas utilisation in integrated steelworks

Energy interdependency in an integrated steelworks can be complex. The dominant inputs are coal, heavy oil and, if bought from an external supply, coke. These inputs are mainly used for the production of coke in the coke oven plant and as reducing agents in the blast furnace. It is common to use alternative reducing agents in the blast furnace, such as coal, coal tar or oil that are injected to the blast furnace at the tuyère level. Used oils, fats, various gases (e.g. coke oven gas) and other hydrocarbons, such as waste plastics, may also be injected (see Section 6.3.12).

The quality (caloric value and cleanliness) and volume of the different gases vary significantly and these factors have an impact on where the fuels can be usefully used. **To optimise energy efficiency, it is necessary that each fuel gas is consumed at the most appropriate plant.**

The primary task of energy management in the steel industry is the efficient distribution and use of the process gases and purchased fuels. A good plant layout can further facilitate this task. Coke oven gas (COG), blast furnace gas (BF gas) and basic oxygen furnace gas (BOF gas) constitute the basis of the energy system in an integrated steelworks. Most of the energy demand is satisfied by these gases; the remaining part must be balanced with purchased energy, normally electrical power and natural gas.

Steam and heat management in integrated steelworks

In an integrated steelworks, there is a need for steam, on the one hand, for heating purposes. On the other hand, steam is needed for specific processes. The most important process steam consumers are blast furnace operations, the coking plant (steam turbine for gas exhausting, for example) and for vacuum treatment in the steel plant. Other activities, not covered in this document, such as for cleaning processes at the galvanising and annealing plants and pre-treatment in the pickling plants also consume steam.

Where appropriate and feasible, it should be possible to produce most of the steam demand by heat recovery. There are many sources such as gas treatment in the coking plant (e.g. sulphuric acid plant) and suppressed combustion systems in combination with waste heat boilers at the BOF plant. Other activities such as hot rolling (e.g. evaporative skid cooling in walking beam furnaces, boilers in pusher-type furnaces) and the use of reheating furnaces (e.g. continuous annealing line, continuous galvanising), are not covered in this document, but are also places where steam may be generated. **The heat should ideally be recovered as steam at as high a temperature and pressure as possible.** The amount of waste heat recovered is basically dependent on the continuous demand for steam. In some cases, the delivery of waste heat to district heating networks has a positive influence on the amount of waste heat recovered.

In order to achieve a suitable steam supply, it is necessary to have a backup system for steam production in order to supply the steam demand when the plants are off for maintenance, for example. The power plant can often be used to fulfil this role and additionally to control the pressure in the steam grid.

Heating for offices and occupied areas of the plant can be provided by the steam grid obviating the need for a separate heating system. An example of steam production and the use of industrial waste heat in an integrated steel plant is shown in Figure 2.5 of the BREF IS.

Energy flow in EAF steelmaking

In EAF steelmaking plants, heat recovery can be applied in a similar way to cooling systems. Depending on the suitability of existing systems and demand, this energy can be used either for internal or local external heating purposes. More information can be found in the Industrial Cooling Systems BREF (ICS) [41, European Commission 2001].

1.2.2 General Techniques to Consider in the Determination of BAT

Techniques to improve energy efficiency

There are some special and important items, which should be mentioned in connection with an integrated steelworks in order to improve the overall energy efficiency including:

- **optimising energy consumption.** Typically, a change in the energy supply of one process in the steel plant influences several other processes (e.g. the use of coke oven gas in the blast furnace can result in a higher caloric value in the BF top gas). Optimising tools that consider the whole integrated site may be preferable to ones that consider each process as a standalone unit
- **online monitoring.** This is often used for the most important energy flows and combustion processes at the site. The data are stored for a long time so that typical situations may be analysed. Very important is the online monitoring for all gas flares. It is the main technique used to avoid energy losses in the flares and combustion processes. Continuous monitoring systems for all energy-related process parameters can be used to optimise process control and enable instant maintenance, thus achieving an undisrupted production
- **reporting and analysing tools.** Reporting tools are often used to check the average energy consumption of each process. In connection with cost controlling, controlling energy is the basis for optimising energy consumption and cost savings. An energy controlling system offers the possibility of comparing actual data with historical data (e.g. charts)
- **specific energy consumption levels**. For each process, specific energy consumption levels may be defined. Typically, the reported energy levels can be used, although these values must be checked critically. The values are compared on a long-term basis
- **energy audits.** These audits are defined in the Energy Efficiency BREF as a crucial tool in energy management. These audits may also identify cost-effective energy savings opportunities

Achieved environmental benefits

The aim of energy management should be to maximise the productive use of gases arising from the processes, thereby minimising the necessity of importing supplementary energy sources into the system and optimising the specific energy consumption within the inherent constraints of the system. In order to achieve the goal, there must be an adequate system dealing with the technical possibilities and costs on the one hand, and on the organisation on the other hand. There are many attempts to explain energy management (e.g. Energy Efficiency BREF), therefore the general details are not discussed in this document.

Techniques to optimise process gas utilisation

Some potential process-integrated techniques used to improve energy efficiency in an integrated steelworks by optimising process gas utilisation include:

- **the use of gas holders** for all by-product gases or other adequate systems for short-term storage and pressure holding facilities for maximising the recovery of process gases
- **increasing pressure in the gas grid** if there are energy losses in the flares – in order to utilise more process gases with the resulting increase in the utilisation rate
- **gas enrichment with process gases** and different caloric values for different consumers – processes require gases with different caloric values for acceptable levels of fuel efficiency. The higher the required process temperature, the higher the amount of high caloric gases needed
- **reheating fire furnaces** with process gas in order to maximise the use of process gases and reduce the need to purchase natural gas or electrical power
- **use of a computer-controlled caloric value control system**
- **recording and using coke and flue-gas temperatures**
- **adequate dimensioning of the capacity of the energy recovery installations** for the process gases, in particular with regard to the variability of process gases.

Achieved environmental benefits

By the application of the aforementioned techniques, the specific energy demand for steel production in an integrated steelworks can be reduced. The energy efficiency can be improved through good combustion control and can eventually decrease air emissions.

Applicability

The specific energy consumption depends on the scope of the process, the product quality and the type of installation (e.g. the amount of vacuum treatment at the BOF, the annealing temperature, thickness of products, etc.). Each integrated steelworks and component therein has a different spectrum of products, process configurations, raw material strategies, etc. and therefore has its own specific energy demands. Climatic circumstances should also be taken into account when considering specific energy usage.

Techniques to improve heat recovery

Some potential **process-integrated measures used to improve energy efficiency** in steel manufacturing **by improved heat recovery** include:

- **the recovery of waste heat by heat exchangers** and distribution either to other parts of the steelworks or to a district heating network (if there are consumers in the vicinity)
- **the installation of steam boilers or adequate systems** in large reheating furnaces (furnaces can cover a part of the steam demand)
- **preheating of the combustion air in furnaces and other burning systems** to save fuel, taking into consideration adverse effects, i.e. an increase of NO_X in the off-gas
- **the insulation of steam pipes and hot water pipes**
- **recovery of heat from products**, e.g. sinter
- where steel needs to be cooled, the **use of both heat pumps and solar panels**
- **the use of flue-gas boilers in furnaces** with high temperatures
- **the oxygen evaporation and compressor cooling** to exchange energy across standard heat exchangers
- **the use of top recovery turbines** to convert the kinetic energy of the gas produced in the blast furnace into electric power.

Achieved environmental benefits

District heating is a safe, economically feasible heating method which requires little maintenance for the customer.

By application of the aforementioned techniques, the specific energy demand for steel production in an integrated steelworks can be reduced. CO_2 emissions and emissions of other pollutants may be avoided by replacing fossil fuel with district heating energy production.

A significant advantage of the district heating system is the cleanliness and high temperature difference of the circulating water. In this way, it is possible to connect the production of the heat and the specific process cooling solutions.

Applicability

The method is used primarily in all steelworks that use a similar cooling technique.

Combined heat and power generation is applicable for all iron and steel plants close to urban areas with a suitable heat demand. The same appears for many other process industries.

The specific energy consumption depends on the scope of the process, the product quality and the type of installation (e.g. the amount of vacuum treatment at the BOF, annealing temperature, thickness of products, etc.). Each integrated steelworks and component therein has a different spectrum of products, process configurations, raw material strategies, etc. and therefore has its own specific energy demands. Climatic circumstances also should be taken into account when considering specific energy usage.

Driving force for implementation

The driving forces for the implementation of heat recovery are the savings in primary fuels, thus a reduction of CO_2 emissions and other environmental impacts. The driving forces for the implementation of combined heat and power production are the environmental benefits, the improved BF operation and the avoidance of high investment costs.

Frequency-controlled pumps and fans

An analysis of the pumps used to supply district heating to the industrial area often shows that the pumps are all running continuously at high power, although the pumping power required is often very low.

Most modern pumps and fans can be frequency controlled and may therefore be set to any given rotation speed (rpm value) to obtain the desired set point value for the flow rate. The use of frequency-controlled pumps and fans and variable speed drives enables a better and faster adjustment of water flow rates and off-gas flow rates according to the demands of different process conditions. The optimisation measures of additional systems include:

- a complete separation of the pumps from the main supply when they are switched off
- a replacement of existing pumps with smaller, highly efficient pumps
- the installation of high-efficiency motors.

The highest energy savings are achieved if energy-using systems are optimised as a whole rather than considering the components of individual systems in isolation. The campaign therefore focuses on a systems analysis; the components in a pump system include, for instance, a variable speed drive, an electric motor, a gear box, a pump and pipes and instrument and control equipment. Measures to optimise the energy used must be developed individually for each pump system and be evaluated from an economic point of view. It is important to analyse the needs parameters (pressure, flow rate, temperature level, etc.), existing operating parameters and systems components of each system individually. The fine tuning of all components and their interaction also belongs in an optimisation plan. This ensures a step-by-step determination of the best possible overall efficiency of a system and the most efficient use of energy.

Achieved environmental benefits

The changes result in considerable savings in electrical energy as well as fewer maintenance costs and fewer production disturbances. The efficiency measures also play a considerable role in the mitigation of climate change. In SSAB Oxelösund AB, Sweden, savings in electrical energy on a yearly basis is 3.2 GWh. In CO_2 reduction, this means about 250 t/yr.

Applicability

The technique can be applied to the off-gas cleaning water, the cooling water of the hood and the lance, and the off-gas suction fans and similar equipment, for example, at the LD process. In case of applications where the reliability of the pumps is of essential importance for the safety of the process, frequency controlled pumps cannot be used. As pump system technology is an interdisciplinary technology widely used in industry and production, many different kinds of companies can profit from these experiences.

1.2.3 Techniques to Consider in the Determination of BAT for Sinter Plants

The European Blast Furnace Committee Survey of the operational data for sinter plants (2004) reveals that **sinter plants use 1290 - 1910 MJ/t sinter of thermal energy** (solid fuels including flue dust and ignition fuel), **with an average consumption of 1344 MJ/t sinter**. These are 39 – 64 kg coke breeze equivalents/t sinter, with an average of 50 kg. **Total electrical consumption is in the range of 92 to 155 MJ/t sinter** [299, Eurofer 2007]. The **consumption of heat for ignition is between 70 and 85 MJ/t sinter** [241, Poland 2007]. There is only a slight difference in fuel consumption between low basicity sinter (<1.7 CaO/SiO_2) and higher basicity sinter (e1.7 CaO/SiO_2) [200, Commission 2001].

Coke is the dominant sinter plant energy input (about 88 %), with electricity and gas (COG and/or BF gas and/or natural gas) making up the remainder. The main energy outputs are via waste gas, water evaporation, the reaction energy required and the sinter itself. Sinter cooling is often combined with the recovery of sensible heat [300, Eurofer 2007].

Process optimisation

A planned and carefully implemented maintenance practice can ensure that the sinter plant can be operated continuously and without significant disruption to the production of sinter. This is one of the most important of the process-integrated measures to reduce the emissions from sinter plants. Disruption to the smooth progress of the flame front through the sinter bed will result from unplanned stoppages of the strand. This has an adverse effect on the generation of dusts and some organic species.

Cross-media effects

Energy usage is minimised by consistency of operations. There are no negative cross-media effects. According to the application of the aforementioned techniques, there are added advantages in terms of operational performance reflected in increased productivity, reduced energy demand and consistent sinter quality.

Applicability

The described techniques can be applied at new and existing plants.

Example plants

The aforementioned techniques are usually applied in European plants. All operators endeavour to operate their sinter plants as smoothly as possible, minimising stoppages by ensuring that high maintenance standards are upheld.

Heat recovery from sintering and sinter cooling

Two kinds of **potentially reusable waste energies** are discharged from the sinter plants:

a) the **sensible heat from the main exhaust gas** from the sintering machines

b) the **sensible heat of the cooling air** from the sinter cooler.

Concerning item a), under normal operating conditions, the use of a heat exchanger to recover heat from the waste process gases would result in unacceptable condensation and corrosion problems. **These constraints have meant that the recovery of heat from the waste gases by means of a heat exchanger has not been practised.**

Partial waste gas recirculation is a special case of heat recovery and is dealt with in Section 3.3.5.2. The sensible heat is transferred directly back to the sinter bed by the hot recirculated gases. At the time of writing (2010), this is the only practical method of recovering heat from the waste gases.

Concerning item b), the sensible heat in the hot air from the sinter cooler can be recovered by one or more of the following ways:

- steam generation in a waste heat boiler for use in the iron and steel works
- hot water generation for district heating
- preheating combustion air in the ignition hood of the sinter plant (see Figure 3.20 of the BREF IS)
- preheating the sinter raw mix
- use of the sinter cooler gases in a waste gas recirculation system.

The amount of waste heat recovered can be influenced by the design of the sinter plant and the heat recovery system.

Five different examples of heat recovery are given below:

1. Sinter cooler waste heat **recovery with conventional sintering**

The sensible heat of the sinter cooling hot air gas is used for producing steam in a waste heat boiler and for preheating the combustion air in the ignition hoods.

Achieved environmental benefits

Reported energy recovery amounts to 18 % of the total energy input for the waste heat boiler and 2.2 % of total energy input for recirculation to the ignition hoods [65, InfoMil 1997].

2. Sinter cooler and waste gas heat **recovery with sectional waste gas recirculation**

At sinter plant No 3 at Sumitomo Heavy Industries, Kokura, Japan, sectional waste gas recirculation is applied. Before recirculation, the waste gases are led through a waste heat boiler. The gases from the sinter cooler are also led through a waste heat boiler.

Achieved environmental benefits

Energy recovery reported at this plant by means of this system is 23.1 % of the energy input.

3. Sinter cooler waste heat recovery to the sinter bed **with waste gas recirculation**

At sinter plant No 5 of Voestalpine, Linz, Austria, waste heat recovery from the sinter cooler is achieved through the EPOSINT process (see Section 3.3.5.2.1). When a waste gas recirculation system is used, the hot air from the cooler can be used instead of a fresh air addition to raise the oxygen content of the recycled gases returned to the sinter bed. Under these circumstances, the heat contained in the sinter cooler gases is recovered in the sintering process. A small proportion of the hot air from the cooler may also be used to preheat the ignition air in the ignition hood.

Achieved environmental benefits

A specific reduction of 2 – 5 kg coke/t sinter was achieved at Voestalpine Linz, Austria.

4. Strand cooling and waste heat recovery with **partial waste gas recirculation**

At the sinter plant No 4 at Sumitomo Heavy Industries in Wakayama, Japan, the sinter cooler is integrated into the sinter strand (strand cooling). At this plant, waste gases from both the sintering and the cooling zone on the grate are led through waste heat boilers and subsequently recirculated to the strand.

Achieved environmental benefits

Recovered heat amounts to 30 % of the input heat.

5. Sinter cooler heat **recovery for district heating**

At sinter plant No 3 at ArcelorMittal, Dunkirk, France, the sinter cooler hot air is collected and sold to a partner who transforms the heat into hot water (105 °C), which is delivered by pipelines to the city for district heating.

Achieved environmental benefits

Approximately 15 kW/t sinter are recovered.

CO_2 emissions may be prevented by replacing fossil fuels where the cooler waste gases are used for district heating energy production.

Applicability

Waste heat recovery from the stack or sinter cooling **can be applied both at new and existing plants**. It is recognised, however, that **investments are lower for a new plant incorporating heat recovery systems from the planning stage**, **but at some existing plants, the existing configuration may make costs very high.** In 1995, it was reported that 64 % of the Japanese sinter plants had heat recovery from sinter cooling and 43 % of the Japanese sinter plants applied waste heat recovery from the stack.

1.2.4 Techniques to Consider in the Determination of BAT for Pelletisation Plants

The pelletisation and sintering of iron ore are complementary process routes for the preparation of iron oxide raw materials for primary iron and steel making. Each has its own specific advantages and drawbacks. These are highly influenced by local conditions such as the availability and type of raw materials. For various reasons, **sinter is practically always produced at the steelworks site**: it allows solid wastes to be recycled; coke breeze is available at the steelworks for use as a fuel; sinter is prone to degradation during transport and handling. **Pellets are formed** from the raw materials (fine ore and additives of <0.05 mm) into 9 – 16 mm spheres using very high temperatures and this is mainly carried out **at the site of the mine or its shipping port**. In the EU, there is only one integrated steelworks which includes a pelletisation plant (in the Netherlands). In 2007, Sweden had five standalone pelletisation plants. Pellet production in these six plants in 2007 was about 27 million tonnes/yr. The consumption of pellets in the EU-25 is about 43 million tonnes.

Specific energy consumption has successively decreased during the last decades. The decrease has been made possible through systematic improvements of the process. In 2005 the specific energy consumption was in the range of 186 to 662 MJ/t of pellets.

There are some differences between the various types of plants both when it comes to the kind of energy used and the kind of energy consumed. The grate kiln process predominantly uses coal while the travelling grate process uses oil or gas.

At most pelletising plants in the world, as is the case in the Netherlands, carbon-bearing additives to the pellets provide part of the heat required for sintering. This case refers to the higher end of the range of external energy consumption, as mentioned above.

The Swedish standalone plants use ores predominantly from magnetite deposits which give great advantages by magnetite oxidation. In fact, approximately 60 % of the thermal energy required is supplied by magnetite oxidation, hence resulting in external thermal energy consumption at the lower end of the above-mentioned range.

To save energy, heat supplied from the oxidation of magnetite and fuel is recovered in the pelletising process. The main part of the surplus heat from the cooling sections of the machines is recirculated to the hot zones, thus reducing the need for external energy input. At some industrial sites, waste heat is recovered into the internal heating system. Where it is practically possible, waste heat is also transferred into municipal heating networks.

Recovery of sensible heat from the induration stand

A pelletisation plant is designed in such a way that the sensible heat of the flue-gases of the induration strand can be used efficiently. For example, the hot air from the primary cooling section is used as secondary combustion air in the firing section. In turn, the heat from the firing section is used in the drying section of the induration strand. Heat from the secondary cooling section is also used in the drying section.

For the Dutch pelletisation plant in an integrated steelworks, the cooling section generates more sensible heat than can be used in the induration strand. Formerly, this heat was not used, but since the mid 1980s, this sensible heat has been used in the drying chambers of the drying and grinding unit. The hot air is transported through an insulated pipeline called a 'hot air recirculation duct'.

The 'hot air recirculation duct' transports approximately 150 000 m^3/h hot air (250 °C) from the cooling section of the induration strand to the mills in the drying and grinding section. In the drying section, hot air (600 – 800 °C) is used to dry the concentrates and fines before grinding. By using the hot air from the cooling section, considerably less firing is needed in the drying chamber.

Achieved environmental benefits

Gross energy consumption of the above-mentioned pelletisation plant is approximately 1.4 GJ/t pellet (compared to the standalone plants in Sweden operating on a magnetite concentrate feedstock, this consumption is significantly higher – see Table 4.1 and Section 4.2.2.4). About 0.7 GJ/t pellet is supplied by means of heat recuperation, whereas approximately 0.7 GJ/t pellet is introduced by means of fuel. The 'hot air recirculation duct' is included in this calculation and accounts for an energy recovery of approximately 67.5 MJ/t pellet (approximately 4 % of gross energy consumption).

Applicability

Recovery of sensible heat is a process-integrated part of pelletisation plants. New plants can be expected to have a more efficient design than existing ones. The 'hot air recirculation duct' can be applied at existing plants with a comparable design and a sufficient supply of sensible heat.

1.2.5 Techniques to Consider in the Determination of BAT for Coke Oven Plants

Coal pyrolysis means the heating of coal in an oxygen-free atmosphere to produce coke (solid), gases and liquids. Coal pyrolysis at high temperature is called carbonisation. In this process, the temperature of the flue-gases from underfiring is normally 1150 – 1350 °C indirectly heating the coal up to 1000 – 1100 °C for 14 – 28 hours. The duration depends, e.g. on the width of the oven (in the case of heating by the side), the density of coal and on the quality of the desired coke (e.g. use in foundries or blast furnaces). The most important reducing agent in hot metal production is coke which removes the oxygen either indirectly by forming carbon dioxide or directly using its inherent carbon content. The gasification of the coke also serves to supply the heat necessary for the reduction process. Coke functions both as a support material and as a matrix through which gas circulates in the stock column. Coke cannot be wholly replaced by coal or other fuels.

Only certain coals, for example coking or bituminous coals, with the right plastic properties, can be converted to coke and, as with ores, several types may be blended to improve blast furnace productivity and extend coke battery life. Other materials which contain carbon can also be applied in small quantities (e.g. petroleum coke (petrol coke), used crushed rubber tyres) under the precondition that there is no negative influence on the environment. Oil or oil residues are added to give a better compaction of the coal.

Figure 5.11 in the BREF IS shows an example for the annual energy demand/balance of a coke oven plant in an integrated iron and steel works. **The COG produced by coke oven plants means that this plays an important role in energy supply and management in integrated steelworks** (see Section 2.1.1) [320, Eurofer 2007].

Coke dry quenching

A CDQ plant consists of two or more quenching chambers and their associated waste heat boilers and charging cranes as combined units. Coke is cooled in these chambers by means of circulation gas. The circulation gas is a mixture consisting mainly of nitrogen and other inert gases. This mixture is formed when the oxygen burns out during the start-up stage of the cycle. The temperature of the circulation gas after the chamber is about 780 °C and after the waste heat boiler about 150 °C. The temperature of the coke charged to the dry quenching chamber is about 1050 °C and after the chamber, about 180 °C. The coke flows through the chamber in about five hours. The nominal capacity of a typical CDQ plant is less than 100 t/h/chamber. A unit working at full capacity produces about 25 t/h high pressure steam (93 bar). Coke is transported with belt conveyors from the CDQ plant to the blast furnace coke screening station.

Achieved environmental benefits

A modern CDQ is equipped with charging and discharging dust collecting systems and boilers with primary and secondary dust collectors. During final collecting by bag filters, emission factors of dust of less than 3 g/t coke are achievable, corresponding to less than 20 mg/Nm^3. SO_2 emissions are at a level of 200 mg/Nm^3. Emissions to surface water are close to zero. Collected coke dust is supplied as fuel to the sinter plant.

With CDQ, about 0.5 tonne steam/t coke can be recovered and used for electricity production. Dust emissions from dry coke handling and sieving can make it necessary to install an additional cooling step or to use water to obtain a moisture content of 1 %. Steam (93 bar) production is approximately 470 000 t/yr and steam (8 bar) production is approximately 50 000 t/yr. 93 bar steam is used mainly in the power plant of Raahe Steel Works, Raahe, Finland, which means approximately 15 MW electricity output.

Emissions to water are close to zero. PAH and COD values are marginal. No dusty quenching steam clouds are released to the atmosphere. The H_2O content of the coke is lower compared to wet quenching which could be a benefit in the blast furnace.

Applicability

CDQ can be applied at new and existing plants. For the continuous operation of CDQ plants, there are two options. In one case, the CDQ unit comprises two to up to four chambers. One unit is always on stand-by. Hence no wet quenching is necessary but the CDQ unit needs an excess capacity against the coke oven plant with high costs. In the other case, an additional wet quenching system is necessary. For retrofitting wet quenching plants, the existing wet quenching system can be used. Such a CDQ unit has no excess processing capacity against the coke oven plant.

Driving force for implementation

Environmental reasons, improved stability of the coke quality compared with conventional wet quenching (mainly related to moisture content) and energy efficiency are the driving forces for the implementation of CDQ.

Example plants

By March 2008, the number of CDQ plants (chambers) in operation was: 104 in East Asia, 12 in Central Asia, 5 in South America and 21 in Europe. From Europe, 5 are in Hungary, 3 in Finland, 4 in Poland, 4 in Romania and 5 are in Turkey [290, Nippon Steel Engineering Co. 2008].

Heat recovery coking

This coking system is often also called 'non-recovery coking' because of unrecovered gas and coal chemicals. At the time of writing (2010), however, the term 'heat recovery' is applied, when the waste heat is used and the off-gas is desulphurised as is typical for new constructions. In the heat recovery coking process, essentially all the tar and gases released from the coking process are combusted within the oven and the sole flue. The heat recovery coking process requires a different oven design from that traditional horizontal chamber system. A coke oven gas treatment plant and waste water treatment plant are not needed. Traditional heat recovery plants without any waste gas use and/or cleaning are the 'beehive ovens' which are still in operation in China. The basis for the heat recovery plants is the 'Jewell- Thompson oven' (see Figure 5.14 of the BREF IS), in which several ovens are grouped together to form one battery.

The carbonisation process is started by the heat which exists from the preceding carbonisation cycle. The released coke oven gas is partly burnt in the crown by the addition of ambient air through the oven doors and passed through 'downcomers' into the heating flues situated in the oven sole. By way of a further supply of ambient air, the complete combustion of raw gas is effected here at temperatures of between 1200 and 1400 ºC.

Thus, coking of the input coal takes place by direct heating from the oven crown and by indirect heating from the refractory floor. The whole system operates at sub-atmospheric pressure. With the heat recovery of a modern plant, the hot waste gas is utilised to generate energy and subsequently be subjected to desulphurisation before being emitted into the atmosphere. The cooking time in Jewell-Thompson ovens amounts to approximately 48 hours. After that time, the coke is pushed out and quenched in wet mode. The most essential features by which the heat-recovery technique differs from the conventional coke-making technique are given in Figure 5.15 of the BREF IS and can be summarised as follows:

- flat bed coke making
- operation of ovens under negative pressure
- supply of air directly into the oven chambers
- complete combustion of crude gas in each single oven
- no aqueous effluents
- gypsum as a by-products can be generated.

Applicability

This technique is only applicable as a whole new plant concept depending on the conditions at the operational site. The decision for the construction of a heat recovery plant depends also on the site. It seems to be difficult to achieve an economically profitable energy link when integrating a heat recovery coking plant into an existing steelworks. A heat recovery plant generates no COG that can be used for heating so there must be consumers for the generated steam or electricity on-site.

1.2.6 Techniques to Consider in the Determination of BAT for Blast Furnaces

The first true coke-based blast furnace was introduced in 1735 [152, Ullmann’s 1994]. **The blast furnace remains by far the most important process for the production of hot metal (pig iron). The technique is likely to continue to dominate hot metal (HM) production in the medium term.**

A major parameter for the consumption of energy is the use of reducing agents (e.g. coke, coal, oil), which also determines CO_2 emissions of the blast furnace process to a major extent. Input of reducing agents is influenced by several operating parameters, such as hot blast temperature, rates and quality of sinter and pellets, quality of coke (ash content, sulphur content, CSR value), input of alkaline, slag amount, ilmenite, Pb/Zn and Si. Thus, the average reducing agent demand for different countries within the European Community in 2002 show a wide range from 453 – 514 kg per tonne of hot metal, with an average reducing demand in the EU-15 of 486 kg per tonne of hot metal.

In a special BF-process, where iron which contains waste materials are processed via a sinter strand to produce foundry crude iron in a blast furnace, the consumption of reducing agents are considerably higher than in the usual blast furnace due to a higher input of the influencing factors mentioned above (see Section 2.5.4.4.2).

The blast furnace process is the most energy-consuming process and thus CO_2 emitting unit (in the form of reducing agents) in iron and steel production (see Figure 2.1 and Figure 2.2, BREF IS).

Table 6.16 within the BREF IS gives an example of the energy input/output of a blast furnace with high top pressure using coal injection and top gas pressure recovery in 1986 for electricity generation without considering the energy content of the hot metal suitable for installation of expansion turbines for the recovery of top gas pressure energy.

Process improvements have meant that the specific coal consumption in European steelworks has decreased considerably. **A trend towards direct reducing agent injection will probably further decrease specific coke consumption. Direct reducing agent injection in the blast furnace replaces**

the use of coke, thus saving energy in coke production. Most blast furnace installations inject reducing agents into the furnace at the tuyère level. This partially replaces coke in the top charge. This practice enables the operator to optimise the use of reducing agents. Other advantages are a lowered production of coke, thereby decreasing the specific coke oven emissions per tonne of steel produced. Many plants inject pulverised or granular coal or oil. Some blast furnace operators now inject coke oven gas or natural gas. Two companies have been injecting plastic waste into their furnaces to utilise the high hydrocarbon content for reduction processes for several years [145, UBA Comments 1997] and at least one new facility has been installed in the EU since 2001. Where appropriate, other injectants classified as eco-oils, reclaimed or waste oils, fats, tar, animal fats and emulsions have also received attention [344, Eurofer 2007].

Gas recovery system for top hopper release

The blast furnace burden (coke and ferrous materials) enters the blast furnace at the top (see Section 6.1.2) via a sealed charging system that isolates the furnace gases from the atmosphere. It is necessary to use such a system because the pressure inside the blast furnace is in excess of atmospheric pressure (0.25 – 2.5 bar gauge). The charging system may be a double bell arrangement or, more common in modern blast furnace operations, a bell-less system (such as those supplied by Paul Wurth, see Figure 6.18, BREF IS).

Filling of the top hopper is done at atmospheric pressure. For charging the blast furnace, the pressure of the gas in the top hopper should be matched to the gas inside the blast furnace. There are various means to achieve this pressurisation; the most common is to use semi-clean blast furnace gas drawn from the blast furnace gas system after the removal of the coarse dust and to lead it into the bunker via the primary equalising valve. Minor pressure losses are equalised by means of a secondary valve with nitrogen.

In some installations, the top hoppers are purged and pressurised using nitrogen gas only.

Once the hopper has discharged its contents into the blast furnace, it is isolated from the furnace and the pressure is normally equilibrated with atmospheric pressure by discharging the gas via a silencer to the air. Depending on the size of the blast furnace, there is therefore a potential to release 40 to 80 m^3 of dirty blast furnace gas per charge.

The discharge of blast furnace gas to the atmosphere during pressure equilibration of the top hopper(s) can be prevented by a gas recovery system in which the gases are redirected via the gas recovery valve into the clean gas main after the scrubber. An example is shown in the Figure 6.19 of the BREF IS.

An alternative system for blast furnaces operating at normal pressure is to pressurise the furnace top bunkers with a gas, e.g. nitrogen or steam, which at the time of writing (2010) is being installed at the blast furnaces 5 and 6 of Voestalpine Stahl GmbH, Linz, Austria. The achieved environmental benefits are nearly the same as with the gas-recovery system for top hopper release.

Driving force for implementation

In principle the driving force to apply this technique is a reduction in fugitive dust emissions. **There might also be energy savings** associated with the utilisation of the recovered CO and H_2 in the blast furnace stoves, for example.

Example plants

The bell-less system with primary and secondary equalising systems and without gas recovery systems is applied in almost all Blast Furnaces in Europe. The only known example of the application of gas system recovery is at Blast Furnace A of Voestalpine Stahl GmbH, Linz, Austria.

Use of high quality ores

The idea of this technique is to use preferably sinter or pellets as raw material with a high iron content and low gangue content. Sinter with an iron content of 61 – 63.5 % and pellets with an iron content in the range of 66.6 – 66.8 % are used. Other important factors are moderate ash content of coke and low ash content of coal for injection.

Achieved environmental benefits

The use of high quality ores increases the productivity and the energy efficiency of the iron making process. The consumption of reducing agents is lower, which leads to reduced CO_2 emissions. A yield of 3.4 tonnes/m^3/day and reduction of CO_2 emissions by 15 – 80 kg/t of hot metal can be achieved. Additionally, the slag volume is reduced to about 150 – 200 kg/t hot metal which also lowers the emissions from slag processing.

Applicability

The applicability is strongly limited to the availability of ores with a high iron content.

Driving force for implementation

The improvement in productivity and energy efficiency are the driving forces for the implementation of this technique.

Increase of energy efficiency in blast furnaces

Models can be used for controlling the wear in the blast furnace hearth. There are two separate models in use:

a) A model, which estimates the location of the 1150 °C isotherm based on thermal conductivities and thermocouple measurements in the hearth refractory lining by using the Finite Element Method (FEM).

b) A model, which approximates the height of the ‘dead man’ in the hearth according to the thermal conductivity. Closed-loop operations of cooling water help to provide good furnace management.

c) Smooth continuous operation at a steady state.

Achieved environmental benefits

An increase in the energy efficiency and a reduction of CO_2 emissions and a reduction in maintenance (e.g. refractories) can be achieved by the use of this technique. The consumption of reducing agents are reduced approximately by 5 kg/t hot metal on a long-term basis. This means a reduction of CO_2 emissions by approximately 15 – 20 kg/t hot metal. The BF campaign life can be prolonged by several years.

To c):

Achieving smooth continuous operation help to reduce the emissions and reduce the likelihood of burden slips.

Applicability

Systems to increase the energy efficiency are usually applied in blast furnaces all over Europe.

Driving force for implementation

Benefits are the improvement of process control which leads to energy savings and an improvement in iron quality.

Recovery and use of blast furnace gas

A typical blast furnace produces approximately 1200 – 2000 Nm^3 of BF gas per tonne of hot metal. The BF gas consists of 20 – 28 % carbon monoxide (CO) and 1 – 5 % hydrogen (see Table 6.7 and Table 6.8, BREF IS). The carbon monoxide is formed during the oxidation of carbon in the blast furnace. Much of the CO is further oxidised to CO_2 in the blast furnace. Carbon monoxide and hydrogen represent a potential energy source and measures are taken at all blast furnaces around the world to recover this energy.

Blast furnace top gas is therefore cleaned and buffered in gasholders for subsequent use as a fuel. Given the low energy content of BF gas per Nm^3, it is often enriched with coke oven gas, BOF gas or natural gas prior to use as a fuel.

Achieved environmental benefits

The energy content of BF gas typically varies from 2.7 – 4.0 MJ/Nm^3, depending on its carbon monoxide concentration. This is only 10 % of the energy content of natural gas. **Nevertheless, the large amounts of BF gas generated mean that the energy recovering potential is very high. Total export from the blast furnace is approximately 5 GJ/t hot metal, which equals 30 % of the gross energy consumption of the blast furnace.**

Applicability

Applicable at all new and existing plants.

Driving force for implementation

Benefits are gained from the efficient use of energy and economics.

Example plants

Applied at many new and existing blast furnaces in the world.

Direct injection of reducing agents (e.g. coal, oxy-oil, gas, plastic etc.)

Direct injection of reducing agents means replacing part of the coke with another hydrocarbon source, which is injected in the furnace at the tuyère level (see more information in Section 6.1.3.1). These hydrocarbons may be in the form of heavy oil, oil residues, recovered waste oil, granular or pulverised coal, natural gas or coke oven gas and waste plastics. Coal and oil are the most commonly used of the tuyère injectants. **By reducing the need for coke, overall pollution and energy demand decrease.**

It should be stressed, however, that a certain amount of coke is still necessary in the blast furnace to allow proper blast furnace operation. The coke provides the required carrying capacity to sustain the blast furnace charge and ensures sufficient gas penetration. Tuyère injection of hydrocarbons requires an additional injection of oxygen (at increasing levels as tuyère injection rates increase), in order to achieve the required temperatures within the furnace raceway. Little experience has been gained at very high tuyère injection rates (and thus elevated oxygen levels), and here, safety also becomes a more important issue, among other things.

The net energy savings of coal injection have been calculated at 3.76 GJ/t coal injected. At an injection rate of 180 kg/t hot metal, energy savings amount to 0.68 GJ/t hot metal or 3.6 % of the gross energy consumption of the blast furnace (see Table 6.16, BREF IS). These energy savings are achieved indirectly as a consequence of reduced coke consumption. Higher input rates will enable higher energy savings.

Direct injection of reducing agents is applicable both at new and existing blast furnaces. It should be noted that this highly process-integrated measure is closely related to the operation of the blast furnace itself, the resulting stability, and the hot metal and slag quality.

Energy recovery from top gas pressure

High top pressure blast furnaces provide an ideal opportunity for recovering energy from the large volumes of pressurised top gas which they generate. Energy is recovered by means of an expansion turbine which is installed after the top gas cleaning device.

Achieved environmental benefits

The amount of energy that can be recovered from the top gas pressure depends on the top gas volume, the pressure gradient and the admission temperature. Energy recovery in this way is viable when the BF gas cleaning device and distribution network has a low-pressure drop.

Top gas pressure in modern blast furnaces is approximately 0.25 – 2.5 bar gauge. The pressure of the BF gas collecting main is approximately 0.05 – 0.1 bar. Part of the top gas pressure is 'consumed' by the gas cleaning device.

The electricity generated is reported to be as much as 15 MW in a modern blast furnace with a top gas pressure of 2 – 2.5 bar.

Energy savings are estimated at up to 0.4 GJ/t hot metal for a 15 MW turbine. The savings amount to 2 % of the gross blast furnace energy demand. Application of top gas pressure recovery at blast furnaces is common in furnaces with high top pressure.

Applicability

Top gas pressure recovery can be applied at new plants and in some circumstances at existing plants, albeit with more difficulties and additional costs. Fundamental to the application of this technique is an adequate top pressure that must be in excess of 1.5 bar gauge.

At new plants, the top gas turbine and the BF gas cleaning facility can be adapted to each other in order to achieve a high efficiency of both scrubbing and energy recovery.

Energy savings at the hot stoves

The hot stoves are fired with BF gas (often enriched). Several techniques are available to optimise the energy efficiency of the hot stove and include:

- the use of a computer-aided hot stove operation which prevents unnecessary reserves byadapting the energy supply to the actual demand and which minimises the amount of enriching gas added (in cases where enrichment takes place)
- preheating of the fuel or combustion air in conjunction with insulation of the cold blast line and waste gas flue. Sensible heat from the flue-gas can be used to preheat the fuel media. The feasibility of this depends on the efficiency of the stoves as this determines the waste gas temperature (e.g. at waste gas temperatures below 250 °C, heat recovery may not be a technically or economically attractive option). The heat exchanger preferably consists of a heating oil circuit, for economic reasons. In some cases, imported heat may be used, e.g. sinter cooler heat, if the distances are reasonable. A preheated fuel medium reduces energy consumption. At plants that use enriched blast furnace gas, preheating the fuel could mean that enrichment would not longer be necessary
- use of more suitable burners to improve combustion
- rapid O_2 measurement and subsequent adaptation of combustion conditions.

Achieved environmental benefits

[66, Joksch 1995] reported the following energy savings:

- the use of **computer-aided hot stoves** leads to an efficiency improvement of the hot stove of more than 5 %. **This equals an energy savings of approximately 0.1 GJ/t hot metal**.
- **preheating of the fuel or combustion air can lead to an energy savings of approximately 0.3 GJ/t hot metal as well**. **Significant energy savings are reached by using the combustion gas to preheat the blast furnace gas.** The savings from this technique are about 170 MJ/t steel. The emission levels that can be achieved are: NO_X 20 – 25 g/t hot metal, SO_2 70 – 100 g/t hot metal, CO_2 0.4 – 0.5 g/t hot metal.
- concerning techniques No 3 and 4, an **additional 0.04 GJ/t hot metal may be saved by improved combustion and adaptation of combustion conditions**.

The total energy savings possible by a combination of techniques is of the order of 0.5 GJ/t hot metal.

Applicability

The techniques mentioned above for saving energy at the hot stoves are **applicable both at new and existing plants where design permits and the prerequisites are present.**

1.2.7 Techniques to Consider in the Determination of BAT for Basic Oxygen Steelmaking and Casting

Energy consumption - Basic oxygen furnace (BOF)

In the BOF (converter), fuel is consumed to preheat and dry the converters after relining and repair. **This thermal energy consumption totals to approximately 0.051 GJ/t LS**. **Electricity consumption is**

estimated at 23 kWh/t LS or 0.08 GJ/t LS. This figure includes the production of oxygen and the operation of the converters.

The process gas from the converter contains large amounts of CO and is hot. **When the energy from the BOF gas is recovered (waste heat recovery and/or BOF gas recovery), the BOF becomes a net producer of energy. In a modern plant, energy recovery can be as high as 0.7 GJ/t LS.**

Energy consumption - Continuous casting

Fuel consumption for preheating the ladle which contains liquid steel is estimated at 0.02 GJ/t LS. Electricity consumption of the casting machines is estimated at 0.04 GJ/t LS [65, InfoMil 1997].

Energy recovery from BOF gas

Recovering energy from the BOF gas measure involves making efficient use of both the sensible heat and the chemical energy in the BOF gas. Previously, most of the chemical energy was dissipated by flaring. BOF gas produced during oxygen blowing leaves the BOF through the converter mouth and is subsequently caught by the primary ventilation. This gas has a temperature of approximately 1200 °C and a flow rate of approximately 50 – 100 Nm^3/t steel. The gas contains approximately 70 – 80 % carbon monoxide (CO) when leaving the BOF and has a heating value of approximately 8.8 MJ/Nm^3.

Generally, two systems can be used to recover energy from the BOF gas:

1. Combustion of BOF gas in the converter gas duct and subsequent recovery of the sensible heat in a waste heat boiler to produce steam

This BOF gas can be fully or partially combusted by allowing ambient air into the gas duct of the primary ventilation system. Thus, the sensible heat and the total gas flow in the primary ventilation system increases and more steam can be generated in the waste heat boiler. The amount of air admixed with the BOF gas determines the amount of steam generated.

In a complete steelmaking cycle (approximately 30–40 minutes) oxygen blowing lasts for approximately 15 minutes. Steam generation, which is directly related to oxygen blowing, is therefore discontinuous.

2. Suppression of BOF gas combustion and buffering of the BOF gas in a gasholder for subsequent use

BOF gas combustion in the primary ventilation system can be suppressed by preventing the supply of ambient air from going into the system. This is usually done by lowering a water-cooled retractable skirt over the mouth of the converter. In this way, the carbon monoxide is retained and the BOF gas can be used as an energy source at other locations. The gas is cleaned to meet grid gas requirements and can be buffered in a gasholder. A waste heat boiler may be installed to recover the sensible heat which is present in the non-combusted BOF gas. It should be noted that BOF gas is not collected during the start and the end of blowing on account of its low CO content. During these periods, which last a few minutes, it is flared instead (see Figure 7.11, BREF IS).

There is a trend toward suppressed combustion followed by BOF gas recovery. There are two main reasons for this:

- suppressed combustion reduces the quantity of flue-gas and thus reduces the cost of fans and dust removal. The reduced waste gas flow rate typical of suppressed combustion results in a raw gas with a higher mass concentration. Thus for an identical clean gas dust concentration, a more efficient dust recovery system must be used (see also Section 7.3.1)

- large volumes of steam are obtained from full combustion systems. However, as the steam is produced discontinuously, it cannot always be fully utilised. The use of recovered BOF gas with suppressed combustion is much more flexible. The use of BOF gas in conjunction with blast furnace gas and coke oven gas as a third gas phase furnace product brings substantial advantages if it allows for the replacement of considerable amounts of primary energy resources, such as natural gas. At some plants, the BOF gas is primarily used in upgrading the blast furnace gas. Coke oven gas and natural gas are only admixed in the mixing stations as a second and third priority (cascade control) [66, Joksch 1995].

Energy recovery from a full combustion system with a waste heat boiler is reported to be 80 % of the total outgoing heat. When suppressed combustion is applied, only 10 – 30 % (0.1 – 0.3 GJ/t LS) of the total energy output is recovered in the waste heat boiler [66, Joksch 1995]. Another 50 – 80 % is recovered as chemical energy (CO) in the BOF gas, depending on the air introduction factor. When the gas is flared and thus not recovered, this energy is lost.

In total energy recovery when applying suppressed combustion, BOF gas recovery and a waste heat boiler for the use of sensible heat can be as high as 90 % [1, Arimitsu 1995] [66, Joksch 1995].

When BOF gas is recovered, energy savings amount to 0.35 – 0.7 GJ/t LS, compared to flaring. A leak-free system, which was developed by Nippon Steel Corporation, leads to an energy savings of 0.98 – 1.08 GJ/t LS and an increased molten steel production of 0.4 % compared to flaring.

Applicability

Both waste heat recovery and BOF gas recovery by suppressed combustion can be applied at new and existing plants. In some cases it may not be economically feasible or, with regard to appropriate energy management, not feasible to recover the BOF gas by suppressed combustion. In these cases, the BOF gas may be combusted with the generation of steam. The kind of combustion depends on the local energy management.

Increased energy efficiency in the steel shop by automatisation

Two options for steel shop automatisation are included in this section:

a) the automatic ladle lid system

b) automated BOF tapping practice

Technique a) The automatic ladle lid system

Steel ladles are used for secondary treatments and the transporting of liquid steel from the BOF converters to continuous casting. In normal practice, the ladles are not covered during ladle treatment and transportation, but a lid is commonly used to prevent extra heat losses during continuous casting. After casting and ladle maintenance, the ladles in operation are heated with burners, typically with coke oven gas or natural gas to keep them hot for the next heat.

At Raahe Steel Works, eight to nine ladles are in operation simultaneously. The ladles are equipped with lids which are removed only during the tapping of the BOF and during ladle treatments. No burners are needed to keep the ladles hot after ladle maintenance. BOF converters and secondary metallurgy stations are equipped with lid stands where the lid is automatically placed or removed on/off the ladle depending on the process stage. The system is a 'hinged lid' system, which also enables slag tapping after casting without removing the lid.

Technique b) Automated BOF tapping practice

By utilising the available sub-lance system, steel temperature and a carbon content estimate can be obtained without having to tilt the converter into a horizontal position. Hence, tapping can be commenced within 2 – 3 minutes after the end of blow, depending on the time for post-stirring. In 2004 approximately 75 % of the heats were tapped within three minutes. The tapping sequence, initiated by the operator, consists of the following automated steps:

- steel tapping
- slag coating, and if necessary also slag splashing
- slag tapping.

An infrared camera, which can be used to distinguish between steel and slag, shows when slag enters the tap stream and when to automatically terminate steel tapping.

Achieved environmental benefits

Energy efficiency is improved (improved temperature control) and there is less dust formation.

Technique a) The automatic ladle lid system

Because less heat is lost during ladle cycle time, the average tapping temperature has decreased by 10 °C. Lower tapping temperatures enable an 8 kg/t higher scrap rate at the BOF with no extra fuel added and thus higher productivity. Another possibility is to produce steel with 8 kg/t less hot metal which is equivalent to 15 kg/t reduction in CO_2 emissions. The deviation of tapping temperatures is 4°C lower, which is significant for stable process control. Steel temperatures are more stable during the whole steelmaking process, which reduces interrupted casts at continuous casting. The ladles are practically free of steel and slag sculls. No extra energy is needed at ladle maintenance areas, which allows the use of coke oven gas at other applications in the steelworks. The lids reduce dust emissions and direct heat radiation from steel ladles during transportation. Refractory wear of converters and ladles is slightly improved.

Technique b) Automated BOF tapping practice

This technique shows several major environmental benefits:

- it lowers the aimed tapping temperature for steel by some 15 °C. This allows for an increased scrap ratio, hence a decreased hot metal ratio in the charge. With a 15 °C lower tapping temperature, it is possible to reduce the hot metal ratio by some 9 kg per tonne of crude steel, equivalent to a possible total reduction in CO_2 production at the plant of around 16 kg CO_2 per tonne of crude steel.
- by avoiding tilting the converter into a horizontal position for sampling after the end of blow, the emission of hot gases and dust are reduced.

- with accurate timing of the termination of the steel tap, less steel is left in the converter and tapped together with slag into the slag pot. Less steel in the slag pot results not only in a stabilised process yield, but also in fewer dust emissions when the pots are emptied.
- a higher degree of slag coating leads to a longer lining life and reduces the need for ceramic materials. A rough estimate is that automated tapping, in itself, has led to a 20 % increase in lining life.

The energy efficiency is not only improved by an overall increase in productivity due to shorter times between steel tapping, but also by a reduced tapping temperature, which can be utilised for an increase in scrap recirculation, as well as by an improved steel yield.

Applicability

Technique a)

The automatic ladle lid system is in principle applicable to all steel plants, taking into account the specific characteristics of existing plants. The lids can be very heavy because they are made out of refractory bricks. The capacity of the cranes and the design of the whole building constrict the applicability in existing plants. There are different technical designs for implementing the system into the particular conditions of a steel plant.

Technique b)

Automated BOF tapping practice can be applied at any BOF plant which is equipped with systems for the fast and accurate recording of the temperature and carbon content of the steel at the end of blow, as well as for slag detection during tapping.

Direct tapping from BOF

Normally, expensive facilities like sub-lance or DROP IN sensor-systems are used to tap without waiting for a chemical analysis of the samples taken (direct tapping). Ovako, Koverhar, Finland has developed a practice to achieve direct tapping without such facilities. In practice, the carbon is directly blown down to 0.04 % and simultaneously the bath temperature to a reasonably low target. Before tapping, both the temperature and oxygen activity are measured for further actions. The reblow rate at the Ovako, Koverhar, Finland plant is today approximately 5 %.

Achieved environmental benefits

Through direct tapping, increased energy efficiency is achieved and positive environmental impacts are seen. The advantage of direct tapping practice is mainly to increase energy efficiency. The bath cooling after blowing has reduced by 20 °C. At the same time, the tap-to-tap time is shortened by 20 %. That means a significant increase in productivity. Because of an improved thermal economy, the volume of scrap has increased by 5 % compared to non-direct tapping practices. This means a reduction of CO_2 emission by approximately 15 kg/t.

The lining life is increased by about 10 %. Because of the increased lining life and larger amount of recirculated material (scrap), a reduced environmental impact is also achieved.

Applicability

The practice is principally applicable in BOF plants with certain preconditions. **The realisation of the practice without extra facilities means several years of developmental work.** For succeeded direct tapping, some preconditions are needed, like a suitable hot metal analyser and slag stopping facilities. The availability of a ladle furnace makes the practice easier to realise.

Near net shape strip casting

Near net shape strip casting means the continuous casting of steel to strips with a thickness of less than 15 mm. The casting process is combined with the direct hot rolling, cooling and coiling of the strips without an intermediate reheating furnace used for conventional casting techniques, e.g. continuous casting of slabs or thin slabs. Therefore, strip casting represents a technique for producing flat steel strips of different widths and thicknesses of less than 2 mm.

The casting process can be divided into different techniques. All of them are characterised by moving moulds without the use of casting powder. Twin roll strip casting as a vertical casting technique and direct horizontal strip casting (which used to be called direct strip casting) are the ones with the greatest industrial interest.

Achieved environmental benefits

The achievable benefit for energy savings is essentially based on the fact that reheating is not necessary as well as on the reduced work for hot rolling. In comparison to conventional slab casting, additional energy for reaching the temperature necessary for hot rolling is not needed. Calculations with respect to energy consumption have already been done in the past. The relationship between primary energy consumption and CO_2 emissions for the different casting techniques is given in Figure 7.27 of the BREF IS [141, Ferry, M. 2006] along with the main process steps. A re-evaluation of the energy demand for strip casting is part of a running BMBF (Federal Ministry of Education and Research) project [146, Schäperkötter, M. et al 2009].

Applicability

The strip casting technique is applicable both at new and existing steel plants. The relatively small space needed (approximately 100 m in length) offers the potential to integrate a strip caster when retrofitting.

The casting process can be applied at both types of steel plants, BOF and EAF. Further metallurgical techniques are related to the steel grades, but not to the strip casting process.

The applicability depends also on the produced steel grades (for example: you cannot produce heavy plates with this process) and on the product portfolio (product mix) of the individual steel plant.

1.2.8 Techniques to Consider in the Determination of BAT for Electric Arc Furnace Steelmaking and Casting

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

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

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

The energy consumption of the furnace is the balance of the three aforementioned inputs. In [364, Fuchs, G. 2008] an example is shown for an EAF with a comparably low input of 380 kWh/t electrical energy, 210 kWh/t through fuel combustion and 100 kWh/t through metal oxidation which corresponds to a total of 690 kWh/t of LS. From this input, 370 kWh/t are needed to melt and superheat the scrap to tap temperature, 37 kWh/t to liquefy and superheat the slag, 100 kWh/t are furnace losses and 140 kWh/t are as sensible heat in the off-gas.

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

EAF process optimisation

The EAF process has been steadily improved in order to become optimised and to increase productivity which correlates to the decrease of specific energy consumption. The most important measures/techniques which are briefly described in this section are [312, Dr. Michael Degner et al. 2008]:

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

Increased energy efficiency

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

Applicability

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

Scrap preheating

The utilisation of the sensible heat in the off-gas (approximately 140 kWh/t LS) has been developed in the last 40 years and is today a proven tool in reducing the total energy requirements in the EAF operations. One option is to use the sensible heat for scrap preheating. **The scrap can be preheated to approximately 800 – 1000 °C with discontinuous systems and to 300 – 400 °C with continuous systems prior to the EAF melting process which reduces the total energy consumption by up to 100 kWh/t LS.**

Such preheating is performed either in the scrap charging baskets or in a charging shaft (shaft furnace) added to the EAF or in a specially designed scrap conveying system allowing continuous charging during the melting process. In some cases, even additional fossil energy is added in the preheating process [373, Eurofer 2007].

Achieved environmental benefits

With shaft furnaces, very high scrap preheating temperatures of up to 800 – 1000 °C can be achieved. With the described techniques for scrap preheating 70 – 100 kWh/t LS energy can be saved which is about 10 – 25 % of the overall electricity input. **Calculated on the basis of primary energy, the savings might be higher considering the efficiency of energy supply.** In addition, the two scrap preheating solutions reduce the tap-to-tap time since less electric energy needs to be put into the charge and downtime for batch charging is reduced.

In combination with an advanced off-gas treatment, scrap preheating plays a significant role in the optimisation of EAF steelmaking, not only related to productivity but also to the minimisation of emissions.

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

With the continuous feeding systems, the scrap can be heated up to an average temperature of 300 °C, thus the efficiency of the furnace is increased and energy consumption is reduced. But the continuous feeding has some additional advantages including lower noise emissions. All CO and H_2 are considered to have evolved from the melting process and are burnt to CO_2 and H_2O inside the preheater. The continuity of the process allows for achieving a stable off-gas exit temperature between 800 and 1100 °C, with an oxygen excess of 8 – 10 %, which allows for the complete destruction of PCDD/F. Provided that the off-gases are rapidly cooled below 200 to 250 °C, the risk of PCDD/F formation by de novo synthesis is considerably reduced.

Nevertheless, experiences from at least two continuous charging installations showed a high emissions concentrations for PCDD/F exceeding the value of 0.1 ng I-TEQ/Nm3 significantly [67, TSW GmbH 2005]. **That means that additional measures for reducing PCDD/F to ensure emissions concentrations for PCDD/F below 0.1 ng I-TEQ/Nm^3 may be necessary also for continuous charging techniques from case to case.**

Applicability

The CONSTEEL process is applicable to both new and existing plants. In existing plants, the local conditions related to the space availability and limitations for the conveyor installation and the scrap yard positioning have to be considered which may sometimes prevent the installation of such a technique. Scrap preheating systems do not require specially sized scrap more than the conventional EAF. The scrap yard groundwork is equivalent compared to the buckets-operating furnaces.

Near net shape strip casting

The techniques for continuous net shape strip casting for electric arc steelmaking are similar to those described in Section 7.3.11 for basic oxygen steelmaking.

2 Proposal for the Sector Specific Supplement – Iron and Steel

2.1 Supplement to the Application Form for EE (all units of IS production)

1. Techniques to reduce specific energy consumption

Is a combination of the following techniques applied in order to reduce thermal energy consumption? Please provide further explanations/justifications.		
Technique	**Yes** (*provide brief explanation*):	**No** *(provide brief justification):*
Improved and optimised systems to achieve smooth and stable processing, operating close to the process parameter set points by using: ▪ process control optimisation including computer-based automatic control systems ▪ modern, gravimetric solid fuel feed systems ▪ preheating, to the greatest extent possible, considering the existing process configuration		
Recovering excess heat from processes, especially from their cooling zones		
Optimised steam and heat management		
Applying process integrated reuse of sensible heat as much as possible		

2. Important items to improve the overall energy efficiency of integrated steelworks

Are the following items in place in order to improve energy efficiency? Please provide further explanations/justifications.		
Items	**Yes** (*provide brief explanation*):	**No** *(provide brief justification):*
Optimising energy consumption *(e.g. change in energy supply, optimising tools that consider the whole integrated site)*		
Online monitoring *(e.g. for the most important energy flows and combustion processes at the site)*		
Reporting and analysing tools *(e.g. check the average energy consumption of each process)*		
Specific energy consumption levels *(e.g. for each process, specific energy consumption levels may be defined and compared on a long term basis)*		
Energy audits as defined in the Energy Efficiency BREF		

3. Techniques to optimise process gas utilisation

Are the following process integrated techniques applied in order to improve energy efficiency (i.e. optimised utilisation of process gases such as coke oven gas, blast furnace gas and basic oxygen gas)? Please provide further explanations/justifications.		
Technique	**Yes** (*provide brief explanation*):	**No** (*provide brief justification):*
Use of gas holders for all by-product gases or other adequate systems for short-term storage and pressure holding facilities for maximising the recovery of process gases		
If possible, increasing pressure in the gas grid if there are energy losses in the flares – in order to utilise more process gases with the resulting increase in the utilisation rate		
Gas enrichment with process gases and different caloric values for different consumers (*processes require gases with different calorific values for acceptable level of fuel efficiency)*		
Reheating fire furnaces with process gas in order to maximise the use of process gases and reduce the need to purchase natural gas or electrical power		
Use of a computer-controlled caloric value control system		
Recording and using coke and flue-gas temperatures		
Adequate dimensioning of the capacity of the energy recovery installations for the process gases, in particular with regard to the variability of process gases		

4. Techniques to improve heat recovery

Are the following process integrated measures used to improve energy efficiency in steel manufacturing by improved heat recovery? Please provide further explanations/justifications.		
Technique	**Yes** (*provide brief explanation*):	**No** (*provide brief justification):*
Combined heat and power production with recovery of waste heat by heat exchangers and distribution either to other parts of the steelworks or to a district heating network *(if there are consumers in the vicinity)*		
Installation of steam boilers or adequate systems in large reheating furnaces *(furnaces can cover a part of the steam demand)*		

Are the following process integrated measures used to improve energy efficiency in steel manufacturing by improved heat recovery? Please provide further explanations/justifications.		
Technique	Yes (*provide brief explanation*):	No *(provide brief justification):*
Preheating of the combustion air in furnaces and other burning systems to save fuel, taking into consideration adverse effects *(i.e. an increase of NOx in the off gas)*		
Insulation of steam pipes and hot water pipes		
Recovery of heat from products *(e.g. sinter)*		
Where steel needs to be cooled, the use of both heat pumps and solar panels		
Use of flue-gas boilers in furnaces with high temperatures		
Oxygen evaporation and compressor cooling to exchange energy across standard heat exchangers		
Use of top recovery turbines to convert the kinetic energy of the gas produced in the blast furnace into electric power		

5. Techniques to minimise electrical energy consumption

Is one of the following or a combination of the following techniques used to minimise electrical energy consumption? Please provide further explanations/justifications.		
Technique	Yes (*provide brief explanation*):	No *(provide brief justification):*
Power management systems		
Grinding, pumping, ventilation and conveying equipment and other electricity-based equipment with high energy efficiency		

6. Monitoring

Are relevant parameters necessary to steer the processes measured/assessed from control rooms by means of modern computer-based systems in order to adjust continuously and to optimise the processes online, to ensure stable and smooth processing, thus increase energy efficiency? Please provide further explanations/justifications.

2.2 Supplement to the Application Form for EE (specific units of IS production)

2.2.1 Sinter Plants

7. Techniques to reduce thermal energy consumption

Is one of the following or a combination of the following techniques used to reduce thermal energy consumption? Please provide further explanations/justifications.		
Technique	**Yes** (*provide brief explanation*):	**No** (*provide brief justification):*
Recovering sensible heat from the sinter cooler waste gas		
If feasible, recovering sensible heat from the sintering grate waste gas		
Maximising the recirculation of waste gases to use sensible heat		

2.2.2 Pelletisation Plants

8. Techniques to minimize thermal energy consumption

Is one of the following or a combination of the following techniques used to minimize thermal energy consumption in pelletisation plants? Please provide further explanations/justifications.		
Technique	**Yes** (*provide brief explanation*):	**No** (*provide brief justification):*
Process integrated reuse of sensible heat as far as possible from the different sections of the induration strand		
Using surplus waste heat for internal or external heating networks if there is demand from a third party		

2.2.3 Coke Oven Plants

9. Use of coke oven gas as a fuel/reducing agent and/or for the production of chemicals

Is the extracted coke oven gas (COG) used as a fuel or reducing agent or for the production of chemicals? Please provide further explanations/justifications.

2.2.4 Blast Furnaces

10. Maintenance of a smooth, continuous operation of the blast furnace

Is a smooth, continuous operation of the blast furnace at a steady state maintained to minimise releases and to reduce the likelihood of burden slips? Please provide further explanations/justifications.

11. Use of blast furnace gas as a fuel

Is the extracted blast furnace gas used as a fuel? Please provide further explanations/ justifications.

12. Recovery of energy of top blast furnace gas pressure

Is the energy of top blast furnace gas pressure recovered, where sufficient top gas pressure and low alkali concentrations are present? Please provide further explanations/justifications.

13. Preheat of hot blast stove fuel gases/combustion air

Are the hot blast stove fuel gases or combustion air preheated using the waste gas of the hot blast stove? Please provide further explanations/justifications.

14. Techniques to optimise energy efficiency of the hot stove

Is one of the following or a combination of the following techniques applied to optimise the energy efficiency of the hot stove? Please provide further explanations/justifications.		
Technique	Yes (*provide brief explanation*):	No *(provide brief justification):*
Use of computer aided hot stove operation		
Preheating of the fuel or combustion air in conjunction with insulation of the cold blast line and waste gas flue		
Use of more suitable burners to improve combustion		
Rapid oxygen measurement and subsequent adaptation of combustion conditions		

2.2.5 Basic Oxygen Steelmaking and Casting

15. Use of BOF gas

Is the BOF gas collected, cleaned and buffered for subsequent use as a fuel? Please provide further explanations/justifications.

16. Use of ladle-lid systems

Are ladle-lid systems used to reduce energy consumption? Please provide further explanations/justifications.

17. Use of direct tapping process

Is a direct tapping process used after blowing to optimise the process and reduce energy consumption? Please provide further explanations/justifications.

18. Use of continuous near net shape strip casting

Is continuous near net shape strip casting used to reduce energy consumption (if the quality and the product mix of the produced steel grades justify it)? Please provide further explanations/justifications.

2.2.6 Electric Arc Furnace Steelmaking and Casting

19. Use of continuous near net shape strip casting

Is continuous near net shape strip casting used to reduce energy consumption (if the quality and the product mix of the produced steel grades justify it)? Please provide further explanations/justifications.

20. Use of scrap preheating

Is scrap preheated in order to reduce the total energy requirements in the EAF operations (e.g. use sensible heat for scrap preheating)? Please provide further explanations/justifications.

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