"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638"

Applying Energy Efficient measures for metal and metalworking SMEs and industry (EE-METAL)
GA number 694638
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Database of Best Available Techniques (BATs) applicable in the MMA sector

First version

Public

Work package	WP2
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Prepared by	Marta Podfigurna
Review by	Steering Board
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Abstract	Database of BATs applicable in the MMA sector describes techniques to consider at installation level, in energy using systems, processes and activities and best available technologies including also innovative cross-cutting technologies.

BUILD STATUS:

Version	Date	Author	Reason	Sections
1	30/11/2016	AUiPE	Initial Release	All
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AMENDMENTS IN THIS RELEASE:

Section Title	Section Number	Amendment Summary
Executive Summary	1	Reconsidering the wording *"this deliverable document developed energy efficient technological solutions …"*
Methodology	3	Added references (web-links) with the BREFs' description
BATs DATABASE	Annex	Disclaimer inclusion
Section 1.2.2.2	1.2.2.2	Correction the title of section

DISTRIBUTION:

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1. Executive Summary

This Deliverable document presents energy efficient technological solutions, optimalization of process operations and energy use, use of renewable energies, innovative cross-cutting technologies and recommendations applicable in the metal and metalworking sector (MMA sector).

Described database was developed under WP2 "Development of EE-METAL methodologies and materials" and its goal is to support auditors in development of audits in MMA companies.

The BAT Database exists as two separate tools: database in Word file and database in Excel file. Every tool is divided into three main areas of interests: 1) heat, 2) electricity, 3) heat and electricity.

2. Introduction

The objective of this document is to present the database of Best Available Techniques (BAT) applicable in the metal and metalworking sector (MMA sector).

The database consists of techniques to consider at installation level in energy using systems, processes and activities and best available technologies including also innovative cross-cutting technologies.

Best Available Techniques mean the latest stage of development of processes, of facilities or of methods of operation which indicate the practical suitability of a particular measure for limiting discharges, emissions and waste.

Techniques include both the technology used and the way the installation is designed, built, maintained, operated and decommissioned. Proposed techniques include also organizational aspects such as production scheduling, monitoring and targeting or behaviour changes.

3. Methodology

The database is prepared in order to propose energy efficient technological solutions, optimalization of process operations and energy use, use of renewable energies, innovative cross-cutting technologies.

The process of its development consists of analysis of:

1. the Best Available Techniques reference documents (so-called BREFs) that have been adopted under both the Directive concerning integrated pollution prevention and control (IPPC Directive, 2008/1/EC) and the Industrial Emissions Directive (IED, 2010/75/EU),
2. outcomes of other project (e.g. ECOSMES, EINSTEIN, PolSEFF etc.),
3. CSR reports,
4. information from financial institutions and/or ESCOs,
5. information from equipment suppliers,
6. other available sources.

The Best Available Techniques (BAT) for energy efficiency were gathered and selected from identified sources presented above, taking into consideration, as the main criterion, the highest potential benefits for the MMA sector.

The list of analyzed BREFs that contain Best Available Technologies for energy efficiency in the MMA sector:

1. Best Available Techniques (BAT) Reference Document for Iron and Steel Production (2013) – this BREF covers the processes involved in the production of iron and steel in an integrated works as well as the production of steel in electric arc furnace steelworks *(source: http://eippcb.jrc.ec.europa.eu/reference/BREF/I&S/IS_Published_0312.pdf)*,
2. Best Available Techniques (BAT) Reference Document in the Ferrous Metals Processing Industry (2001) – this BREF includes activities for the processing of semi-finished products (i.e. ingots, slabs, blooms and billets) obtained from ingot casting or continuous casting, like hot rolling, cold rolling, drawing, hot dip metal coating and the related pre- and post-treatment of the shaped steel products *(source:http://eippcb.jrc.ec.europa.eu/reference/BREF/fmp_bref_1201.pdf)*,
3. Best Available Techniques (BAT) Reference Document for the Surface Treatment of Metals and Plastics (2006) - this BREF includes installations for the surface treatment of metals and plastics using an electrolytic or chemical process *(source: http://eippcb.jrc.ec.europa.eu/reference/BREF/stm_bref_0806.pdf)*,
4. Best Available Techniques (BAT) Reference Document for the Non-Ferrous Metals Industries (2014) - this BREF covers the techniques for the production of both primary and secondary non-ferrous metals *(source: http://eippcb.jrc.ec.europa.eu/reference/BREF/NFM/JRC107041_NFM_bref2017.pdf)*,
5. Reference Document on Best Available Techniques (BAT) in the Smitheries and Foundries Industry (2005) - this BREF includes installations for :
   - the processing of ferrous metals as smitheries,
   - ferrous metal foundries and,
   - installations for the smelting, including the alloyage, of non-ferrous metals, including recovered products (refining, foundry casting, etc.),

   (source: http://eippcb.jrc.ec.europa.eu/reference/BREF/sf_bref_0505.pdf)
6. Reference Document on the application of Best Available Techniques to Industrial Cooling Systems (2001) - this BREF addresses the following industrial cooling systems or configurations:
   - once-through cooling systems (with or without cooling towers),
   - open recirculating cooling systems (wet cooling towers),
   - closed circuit cooling systems air-cooled cooling systems,
   - closed circuit wet cooling systems,
   - combined wet/dry (hybrid) cooling systems,
   - open hybrid cooling towers,

   (source: http://eippcb.jrc.ec.europa.eu/reference/BREF/cvs_bref_1201.pdf)
7. Best Available Techniques (BAT) Reference Document for Large Combustion Plants (2016) - this BREF deals with combustion installations with a rated thermal input exceeding 50 MW. Plants with a thermal input lower than 50 MW are, however, discussed where technically relevant because smaller units can potentially be added to a plant to build one larger installation exceeding 50 MW *(source: http://eippcb.jrc.ec.europa.eu/reference/BREF/LCP_FinalDraft_06_2016.pdf)*,

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8. Reference Document on Best Available Techniques (BAT) for Energy Efficiency (2009) - this document addresses energy efficiency improvement in industrial installations by giving generic guidance on how to approach, assess, implement and deal with energy efficiency related issues along with corresponding permit and supervising procedures *(source: http://eippcb.jrc.ec.europa.eu/reference/BREF/ENE_Adopted_02-2009.pdf).*

The structure of the BAT Database consists of six levels and is prepared in similar way to the description of techniques from the Best Available Techniques reference documents (BREFs):

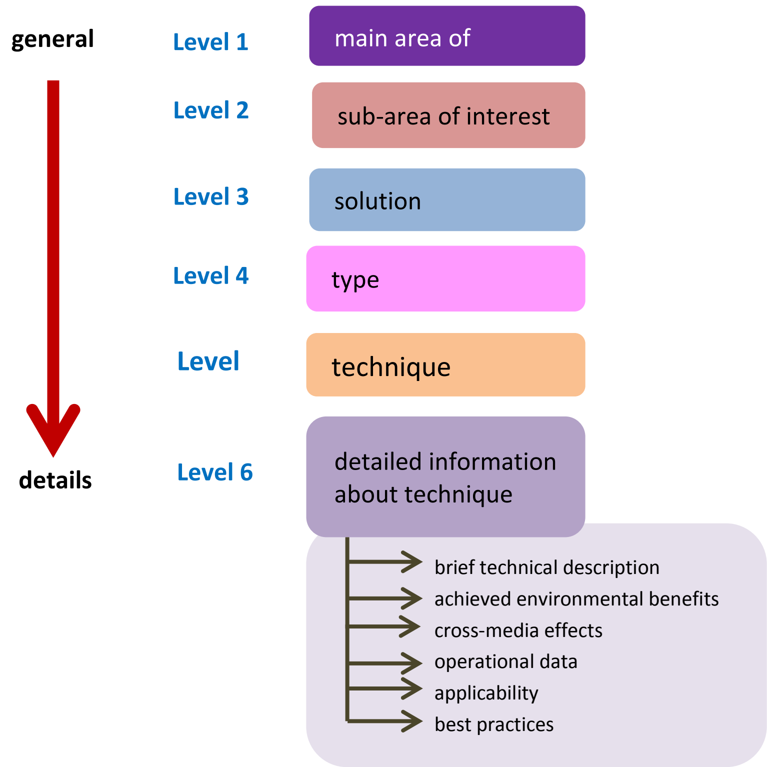

Figure 1. Levels of the BAT Database

The BAT Database is divided into three main areas of interests: 1) heat, 2) electricity, 3) both heat and electricity.

Every main area has its own sub-areas of interest. In heat and heat/electricity area there are: processes, organizational aspects and recovery, in electricity area: the same three as mentioned earlier and lighting as additional one.

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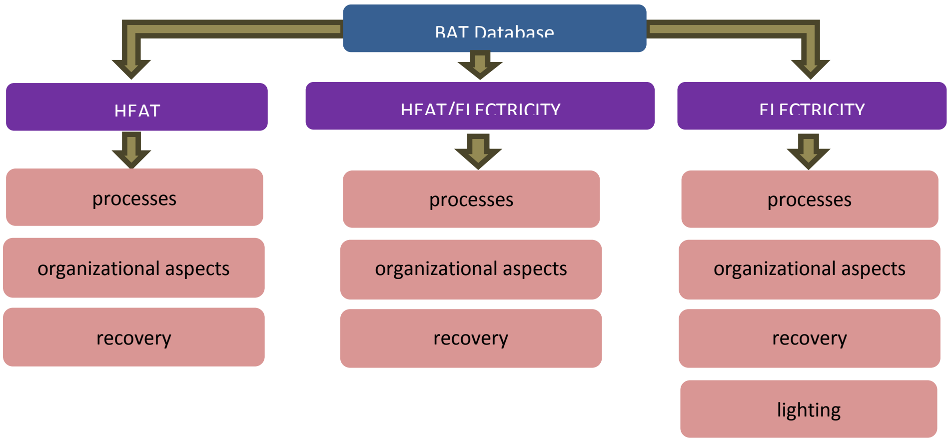

Figure 2. Structure of main and sub-areas in the BAT Database

On the level 3, level 4 and level 5 every user of the BAT Database can find the description of solutions, types and technologies related to areas chosen on previous levels (main area of interest and sub-areas of interest). Level 6 provides the most detailed information about chosen technique. There is such information as:

- brief technical description,
- achieved environmental benefits,
- cross-media effects - potential environmental side effects and disadvantages to other media due to implementing the technique,
- operational data - actual performance data on emission levels, consumption levels and amounts of waste generated,
- applicability - indication of the type of processes in which the technique may or cannot be applied as well as constraints to implementation in certain cases,
- best practices - reference to the company(ies) where the technique has been implemented.

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ANNEX – BATs DATABASE

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Best Available Techniques (BATs) for energy efficiency for the MMA sector

DATABASE

Project title: ***Applying Energy Efficient measures for metal and metalworking SMEs and industry***
Project acronym: *EE-METAL*
Number of grant agreement: *694638*

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PART 1: **HEAT**

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1.1 Organizational aspects

1.1.1 Energy management

Optimisation of energy flows and optimised utilisation of the extracted process gases

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.

Brief technical description

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

- the use of gas holders for all by-product gases or other adequate systems for shortterm storage and pressure holding facilities,
- increasing pressure in the gas grid if there are energy losses in the flares – in order to utilise more process gases with the resulting increase in the utilisation rate,
- gas enrichment with process gases and different calorific values for different consumers,
- heating fire furnaces with process gas,
- use of a computer-controlled calorific 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, annealing temperature, thickness of products, etc.).

Reduce thermal energy consumption

BAT is to reduce thermal energy consumption by 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.

Brief technical description

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

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- 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.

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.

Reduce thermal energy consumption

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

- recovering excess heat from processes, especially from their cooling zones,
- an optimised steam and heat management,
- applying process integrated reuse of sensible heat as much as possible.

Brief technical description

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.

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. CO2 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.

Operational data

In the municipal district heating system, thermal energy is delivered with the help of the closed piping for the heating of the buildings and of other premises and for the production of warm service water. The consumer always receives the heat with the help of heat exchangers. Each of the buildings has similar connections, for example, for the electrical net, for the gas net, for the clean water and the waste water nets.

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 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.

Economics

Selling waste heat can be a remunerative business. The construction of the district heating system is quite advantageous when utilising the technology that has been generally applied. For this reason, the system has been an extremely profitable technique to Raahe Steel Works, Raahe, Finland, and moreover, there are extremely advantageous district heating tariffs in the town of Raahe for the end user. New industry which uses district heating has been developed in the area.

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.

Example plants

At the reference plant Marienhütte in Graz, Austria, about 40 GWh per year are recovered from the EAF (35 tonnes/charge) and fed to the district heating network (status in 2005). District heating is also practiced in Ovako Hofors, SSAB in Luleå, Sweden and at the Ruukki sinter plant in Finland.

Using surplus waste heat

BAT is to use desulphurised and dedusted surplus coke oven gas and dedusted blast furnace gas and basic oxygen gas (mixed or separate) in boilers or in combined heat and power plants to generate steam, electricity and/or heat using surplus waste heat for internal or external heating networks, if there is a demand from a third party.

Achieved environmental benefits

Improved energy efficiency.

Applicability

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.

1.1.2 Combustion

1.1.2.1 Induction furnace

Waste heat utilisation

BAT is to check possibility to use the heat in the furnace cooling system for space-heating, the heating of shower water and for drying raw materials.

Brief technical description

A significant proportion of the electrical energy which is supplied to an induction-melting furnace is converted into waste heat. About 20 to 30% of the total energy input to the plant is dissipated through the cooling system. The furnace cooling circuit not only deals with the electrical losses in the induction coil, but also protects the coil from heat conducted through the furnace lining from the hot metal in the crucible. The heat in the furnace cooling system is used in some installations for space-heating, the heating of shower water and for drying raw materials.

Achieved environmental benefits

Increased energy efficiency.

Cross-media effects

No cross-media effects have been reported.

Operational data

A heat recovery system using the cooling oil of induction furnaces was installed in a Belgian foundry. The foundry operates two induction holding furnaces in duplex with a cupola furnace. The inductors of the electrical furnaces are cooled using thermal oil. The thermal oil gets heated up to 200 – 300^{0}C and looses its heat over an outside oil-air heat-exchanger. Before installation of the heat recovery system, 1 MW of heat was dissipated into the air. An alternative system was installed to use the waste heat for space heating. The heated air is introduced into the core shop. This allows the recuperation of 1/3 of the dissipated heat and replaces the original gas-fired heating system. The implementation was possible at low cost because the oil-air heat-exchanger is installed next to the core shop. Space heating in other parts of the foundry may be considered later, but will require more piping (and will subsequent thus involve further losses).

Applicability

Before heat recovery can be applied, a number of criteria must be met:

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- a worthwhile application for the waste heat must be reasonably nearby and the times at which this recovered heat can be utilised must match the times at which the furnace is operating. However, typically the heat available is fairly low grade. The temperature for the cooling water must not exceed 70 ºC,
- the relatively low temperatures involved mean that heat-exchangers need to be much larger than those which are normally encountered,
- the furnace water must not be returned to the furnaces at a temperature lower than about 30 ºC, otherwise this may give rise to condensation problems,
- maintaining the integrity of the cooling circuits is absolutely essential. The cooling circuit is provided to protect the coil - if it fails in its task the results can be disastrous.

The above aspects, particularly the question of furnace integrity, discourage most furnace operators from even contemplating the utilisation of heat from the cooling circuit.

Economics

A foundry attempting to make use of the heat from the cooling circuit needs to fully evaluate the benefits and then compare them with the cost of the additional equipment and the safety of the furnace and operators.

Driving force for implementation

Increasing energy efficiency at the foundry.

Example plants

Space heating using hot air:

- Proferro, Oudenaarde,
- Metso Paper Jyväskylä Foundry.

Waste heat utilisation

Space heating and hot water supply: A similar system to the one discussed above may be used to blow hot air into the foundry hall for space heating. Alternatively, a water-water heat-exchange is used to heat a water circuit for radiators or for hot water supply.

Brief technical description

A significant proportion of the electrical energy which is supplied to an induction-melting furnace is converted into waste heat. About 20 to 30% of the total energy input to the plant is dissipated through the cooling system. The furnace cooling circuit not only deals with the electrical losses in the induction coil, but also protects the coil from heat conducted through the furnace lining from the hot metal in the crucible. The heat in the furnace cooling system is used in some installations for space-heating, the heating of shower water and for drying raw materials.

Achieved environmental benefits

Increased energy efficiency.

Cross-media effects

No cross-media effects have been reported.

Operational data

A heat recovery system using the cooling oil of induction furnaces was installed in a Belgian foundry. The foundry operates two induction holding furnaces in duplex with a cupola furnace.

Applicability

Before heat recovery can be applied, a number of criteria must be met:

- a worthwhile application for the waste heat must be reasonably nearby and the times which this recovered heat can be utilised must match the times at which the furnace is operating. However, typically the heat available is fairly low grade. The temperature for the cooling water must not exceed 70 ºC,
- the relatively low temperatures involved mean that heat-exchangers need to be much larger than those which are normally encountered,
- the furnace water must not be returned to the furnaces at a temperature lower than about 30 ºC, otherwise this may give rise to condensation problems,
- maintaining the integrity of the cooling circuits is absolutely essential. The cooling circuit is provided to protect the coil - if it fails in its task the results can be disastrous.

The above aspects, particularly the question of furnace integrity, discourage most furnace operators from even contemplating the utilisation of heat from the cooling circuit.

Economics

A foundry attempting to make use of the heat from the cooling circuit needs to fully evaluate the benefits and then compare them with the cost of the additional equipment and the safety of the furnace and operators.

Driving force for implementation

Increasing energy efficiency at the foundry.

Example plants

Space heating using hot air:

- Proferro, Oudenaarde,
- Metso Paper Jyväskylä Foundry.

1.1.2.2 Cupola furnace

Waste heat utilisation

The need to cool cupola off-gases before they enter the bag filter leads to the possibility of attaching to a secondary user and applying waste heat utilisation. The secondary user may be e.g.:

- a steam boiler,
- a thermal oil circuit,
- a heating circuit,
- a hot water circuit.

Achieved environmental benefits

Recovery of waste heat, which otherwise would be lost to the outside, allowing a reduction in fuel (or other sources of energy) consumption.

Cross-media effects

No cross-media effects apply.

Applicability

This technique applies to new installations and should be taken into account when designing the process. For existing plants, the technique can be applied during major refurbishment of the plant, however, small add-on units can generally be accomodated in existing plants.

Economics

The stated examples were installed as part of a major rebuilding of the considered installation. It is therefore not possible to extract specific cost data.

Driving force for implementation

Increasing energy efficiency of industrial processes.

Example plants

The two example plants located in Germany.

1.1.2.3 Ladles

Reduce energy loss/improve preheating practice of ladles

Brief technical description

Energy is wasted if the molten metal transfer system allows an excessive loss of metal temperature between furnace tapping and mould pouring. Losses can be prevented by using good practice measures. These imply the following:

- the utilisation of clean ladles, preheated to bright red heat,
- the utilisation of distribution and pouring ladles, which are as large as is practicable and are fitted with heat-retaining covers,
- keeping the covers on ladles which are standing empty or putting ladles upside down when not in use,
- minimising the need to transfer metal from one ladle to another,
- always conveying the metal as quickly as possible, while still complying with safety requirements.

Achieved environmental benefits

To reduce energy losses.

Cross-media effects

No cross-media effects occur.

Applicability

Since this technique involves measures related to good practice, it is applicable to all new and existing foundries.

Economics

No economic data can be given.

Driving force for implementation

Energy efficient foundry management.

Example plants

These measures are used to a varying extent in European foundries.

1.2 Processes

1.2.1 Combustion

1.2.1.1 Basic Oxygen Steelmaking and Casting

Collection, cleaning and buffering 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.

Reduction of 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.

Optimisation of the process and reduction of energy consumption by using a direct tapping process after blowing

Brief technical description

Direct tapping normally requires expensive facilities like sub-lance or DROP IN sensorsystems 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.

Reduction of energy consumption by using continuous near net shape strip casting

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.

Brief technical 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.

1.2.1.2 Blast Furnaces

Recovering the energy of top blast furnace gas pressure

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

Achieved environmental benefits

Improved energy efficiency.

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.

Recovering the energy of top blast furnace gas pressure

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.

Brief technical 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.

Achieved environmental benefits

Improved energy efficiency.

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.

1.2.1.3 Coke Oven Plants

Preheating the hot blast stove fuel gases or combustion air

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.

Brief technical 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.

1.2.1.4 Electric Arc Furnace Steelmaking

Reduction of energy consumption by using continuous near net shape strip casting

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.

Brief technical 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.

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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.

1.2.1.5 Pelletisation Plants

Reduction/minimisation thermal energy consumption in pelletisation plants

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

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

Brief technical 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'.

Achieved environmental benefits

Improved energy efficiency.

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.

1.2.1.6 Sinter Plants

Reduction of thermal energy consumption within sinter plants

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

1. recovering sensible heat from the sinter cooler waste gas,
2. recovering sensible heat, if feasible, from the sintering grate waste gas,
3. maximising the recirculation of waste gases to use sensible heat.

Brief technical 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. The sensible heat is transferred directly back to the sinter bed by the hot recirculated 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.

Achieved environmental benefits

Improved energy efficiency.

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.

1.2.2 Processes

1.2.2.1 Alkali and alkaline Earth Metals

Gas collection and abatement

According to the techniques to consider that are presented for air abatement, BAT for this sector is considered as follows.

- Bag filters are suitable for cleaning the suction air from raw material storage and handling devices. The associated level of residual particulate matter concentration for a bag filter is less than 5 mg/Nm3. It should be noted that a bag filter could achieve very low levels of dust, which is dependent on the used filter medium. If special cases (e.g. health and safety conditions) require very low dust emissions, this can be achieved by using the appropriate membrane filter bags.
- An EP or fabric filter may clean the off-gas from a calciner, where the associated dust emission levels are in the range between 20 - 30 mg/Nm3 for an EP and 5 mg/Nm3 for a bag filter.
- The cell room air ("stife") needs to be cleaned in order to minimise the environmental input of Chlorine and HCl. Multi stage venturi scrubbers with subsequently a packed tower using caustic soda is suitable to remove chlorine. The associated level of chlorine is less than 1 mg/Nm^3.
- The off-gas from the chlorination furnaces is cleaned in multi-stage scrubbers connected with a wet EP and an afterburner in order to reduce dioxin and chlorinated hydrocarbon emissions to air. The total efficiency of the combination for abatement techniques should be 99.9%. To achieve lower dioxin-concentrations in the off-gas, an additional injection of activated carbon may be considered. The effluent from the scrubber and the wet EP needs to be treated in order to minimise the dioxin and chlorinated hydrocarbon emissions to water.

Brief technical description

Emission levels to air associated with the use of BAT:

Pollutant: Dust
Emissions associated with the use of BAT: < 5 mg/Nm³
Techniques that can be used to reach these levels: Fabric filter
Comments: Fabric filters are normally used for dedusting off-gases

Pollutant: Dust
Emissions associated with the use of BAT: < 20 - 30 mg/Nm³
Techniques that can be used to reach these levels: EP
Comments: Cleaning the off-gas from a dolomite calciner used in the production of magnesium metal

Pollutant: Heavy metals
Techniques that can be used: Fabric filter
Comments: High performance fabric filters (e.g. membrane fabric filters) can achieve low levels of heavy metals. The concentration of heavy metals is linked to the concentration of dust and the proportion of the metals as part of the dust.

Pollutant: Cl
Emissions associated with the use of BAT: < 1 mg/Nm3
Techniques that can be used to reach these levels: Multi stage venturi scrubbers with subsequently a packed tower using caustic soda
Comments: For cleaning the cell-room air

Pollutant: Dioxins and hydrocarbons from the chlorination in the Mg
Emissions associated with the use of BAT: Total destruction efficiency > 99.9%
Techniques that can be used to reach these levels: Multi-stage scrubbers connected with a wet EP and an afterburner
Comments: Dioxin emissions are < 10 µg/t TEQ for the $MgCl_2$ brine dehydration process instead of 53 µg/t TEQ for the process which needs a chlorination step. The $MgCl_2$ brine dehydration process is therefore regarded as BAT for new plants.

Note. Collected emissions only.

Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period.

For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.

Achieved environmental benefits

Recovery of the heat energy.

Cross-media effects

Significant reduction of chlorinated-hydrocarbons and dioxins.

Operational data

Bag filter and wet scrubbers, also multi-stage scrubbers are normally used for the off-gas cleaning. The ventilation air from a cell-room where sodium metal is produced can be extracted by using a two-stage venturi-scrubber and a packed tower using caustic soda to remove chlorine.

The off-gas from the chlorination furnace in a magnesium production is cleaned in a series of wet scrubbers and wet electrostatic precipitators before being finally subjected to incineration in an afterburner. The chlorine gas formed by the magnesium electrolysis is cleaned in a bag filter in order to remove entrained salts before recycled back to the chlorination stage.

Driving force for implementation

Processes to produce Alkali and alkaline Earth Metals.

Example plants

Non Ferrous Metals Industries.

Best practices

TREATMENT OF OFF-GASES CONTAINING DIOXINS AND CHLORINATED HYDROCARBONS

Description

Off-gases from the chlorination furnaces in the magnesium plant contain Cl_2 and HCl, and also dioxins and chlorinated hydrocarbons (CHC's). The off-gases are treated in a series of wet scrubbers to remove the Cl_2 and HCl, and then wet electrostatic precipitators to remove aerosols from the gas, before finally being subjected to incineration. SO_2 gas is added to the off-gases between scrubbing stages to convert Cl_2 to HCl and thereby enhance the efficiency of the scrubbing. Water from the off-gas treatment is transferred to a water treatment plant.

The incineration plant: - The off-gases after scrubbing still contain unacceptable amounts of dioxins and CHC's. They are therefore subjected to a final incineration treatment, where volatile organic compounds including dioxins and CHC's are destroyed.

The incineration plant has 5 vertical chambers filled with ceramic stoneware for heat exchange, being switched by flow control valves to achieve effective heat recuperation. In-coming gas is led through chambers in "inlet" model and heated to reaction temperature before entering the horizontal combustion chamber on top of the chambers. In the combustion chamber the CO content of the gas (approx. 1-2%) is burned together with fuel gas supplied through three gas burners to keep the temperature in the combustion chamber above 800 ^oC.

The treated gas is then led through chambers in "outlet" mode to recover its heat content for heating in-coming gas after switching of chambers. Treated gas is then vented to the stack.

Destruction efficiencies achieved:
Chlorinated hydrocarbons 99.9% (total efficiency)
Dioxins 99.9% (total efficiency)
CO 100%

Outlet concentrations:
Chlorinated hydrocarbons 0.01 mg/Nm^3
Dioxins 0.8 ng/Nm^3

Chlorinated hydrocarbons as sum of hexa- and penta-chlorobenzene and octachlorostyrene.
Dioxins as sum of PCDDs and PCDFs expressed as TCDD equivalents.

Achieved environmental benefits

Significant reduction of chlorinated-hydrocarbons and dioxins. Recovery of the heat energy that is generated in the combustion chamber of the incineration plant.

Cross-media effects

In the scrubbers the dioxins and chlorinated hydrocarbons are transferred from the air to the water side, therefore an additional water-treatment is needed.

Operational data: Status of development

Volumetric capacity: 70000 Nm^3/h
Combustion chamber temperature: Above 800 ºC
Residence time in combustion chamber: Minimum 2 sec.
Energy consumption (external): Fuel gas 30000 GJ/a

Applicability

To all new and existing plants.

1.2.2.2 Recover heat from source either to hot water

Brief technical description

Although the opportunities for energy saving by heat transfer from flue gases from the galvanizing kettles are limited due to low volumes and relatively low temperatures (450ºC), it is good practice to recover heat from this source either to hot water used elsewhere in the plant or to air for drying.

Achieved environmental benefits

Energy savings.

Example plants

Plants using Ferrous Metals Processing Industry.

1.2.2.3 Carbon and Graphite electrodes

Other process stages

The processes used are strongly influenced by the product and its specification. These factors are therefore site specific. The blending and forming, baking (production of anodes), impregnation, graphitisation, product shaping and fume collection and abatement systems described as applied techniques are therefore techniques to consider in the determination of BAT. Essentially the process technologies discussed in this chapter, combined with suitable abatement will meet the demands of stringent environmental protection. The following are the most important techniques to consider:

- Enclosed and extracted grinding and blending of raw materials, fabric filters for abatement.
- Use of furnaces with adequate extraction of process gases. Furnaces operated on planned basis to allow cooling and heating periods to maximise heat recovery from the gases.
- Destruction of cyanides, tars and hydrocarbons in an afterburner if they have not been removed by other abatement.

- Use of low NOx burners or oxy-fuel firing. Control of the firing of furnaces to optimise the energy use and reduce PAH and NOx emissions.
- Adequate maintenance of the furnaces to maintain the sealing of off-gas and air ducts.
- Monitoring of the off-gas collection system to identify blockages or potential explosive mixtures caused by condensing hydrocarbons.
- Use of wet or semi-dry scrubbing to remove sulphur dioxide if necessary.
- Use of coke bed filters or dry scrubbers plus fabric filters.
- Electrostatic precipitators to remove tars hydrocarbons and PAHs emitted from pitch storage, blending, impregnation, forming and baking stages. Use of afterburners to reduce their levels further if necessary.
- Use of bio filters to remove odorous components if necessary (special carbon production).
- Use of sealed or indirect cooling systems.

Achieved environmental benefits

Optimise the energy usage.

Best practices

USAGE OF REGENRATIVE AFTERBURNER

Description

A regenerative afterburner has been used in a number of applications. The process depends on an alternating cycling of gases through a series of support zones where heating, cooling and cleaning cycles take place. The combustible fraction is heated in the heating zone and passes to a common residence chamber where combustion is completed, the hot gases then pass into a cooling section which is heated to become the next heating zone. The zones are change using a manifold system to allow cleaning.

Achieved environmental benefits

The energy content of the contaminants (hydrocarbon and PAH) is used to heat the support materials and auto-thermal operation is therefore possible.

Cross-media effects

Auto-thermal operation.

Operational data: Status of development

Not available but < 0.1 ng/Nm^3 dioxins have been reported for an installation serving a blast furnace.

Applicability

Applicable to a variety of processes. The basic principle is good but the changeover to the cleaning phase may cause the emission of un-combusted material if the design is poor. It is considered to be emerging for high molecular weight, condensable hydrocarbons.

Economics

Not available but several installations are operating viably.

1.2.2.4 Cold Rolling Mill

Combustion air preheating by regenerative or recuperative burners

Brief technical description

Higher NO_x concentrations may arise in the case of annealing furnaces operating with combustion air preheating. No data was submitted on NO_x concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication.

Limiting the preheating temperature may be seen as a NO_x reduction measure. However, the advantages of reduced energy consumption and reductions in SO_2, CO_2 and CO have to be weighed against the disadvantage of possible increased emissions of NO_x.

Achieved environmental benefits

Increase of energy efficiency.

Example plants

Plants using Ferrous Metals Processing Industry.

1.2.2.5 Galvanizing of Sheet

Heat Treatment (Zinc and Zinc Alloy Coating)

Brief technical description

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

Achieved environmental benefits

Increase of energy efficiency.

Driving force for implementation

For very high quality standards and for improving the adherence of the following metallic coating.

Example plants

Plants using Ferrous Metals Processing Industry

The reduction of emissions and energy consumption of heat treatment furnaces

Brief technical description

Low-NOx burners with associated emission levels of 250 - 400 mg/Nm³ for NO_x (3% O_2) without air preheating and 100 - 200 mg/Nm³ for CO.

Achieved environmental benefits

Reduction of emissions and energy consumption of heat treatment furnaces.

Example plants

Plants using Ferrous Metals Processing Industry.

Combustion air preheating by regenerative or recuperative burners

The best available techniques for the reduction of emissions and energy consumption of heat treatment furnaces.

Brief technical description

No data were submitted on NO_x concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication. Limiting the preheating temperature may be seen as a NO_x reduction measure. However, the advantages of reduced energy consumption and reductions in SO_2, CO_2 and CO have to be weighed against the disadvantage of possible increased emissions of NO_x.

Achieved environmental benefits

Reduction of emissions and energy consumption of heat treatment furnaces.

Example plants

Plants using Ferrous Metals Processing Industry.

Metods to reduce emissions and energy consumption

In installations where galvannealing is done, there are a few metods to reduce emissions and energy consumption.

Brief technical description

Low-NO_x burners with associated emission levels of 250 - 400 mg/Nm³ for NO_x (3% O_2) without air preheating.

Regenerative or recuperative burner systems.

No data were submitted on NO_x concentrations in connection with air preheating, but the figures given for reheating furnaces may serve as an indication. Limiting the preheating temperature may be seen as a NO_x reduction measure. However, the advantages of reduced energy consumption and reductions in SO_2, CO_2 and CO have to be weighed against the disadvantage of possible increased emissions of NO_x.

Achieved environmental benefits

Reduction of emissions and energy consumption of heat treatment furnaces.

Example plants

Plants using Ferrous Metals Processing Industry.

1.2.2.6 Hot Dipping

Enclosed Galvanizing Pot

Brief technical description

Enclosures in combination with scrubbers or fabric filters.

Achieved environmental benefits

Reduction of fugitive air emissions (reported 95 – 98% capture of dust and other emissions).

- Reduction of squirts.
- Energy savings due to reduced surface heat loss from the galvanizing bath.

Cross-media effects

Energy consumption (electrical energy is used for extraction fans, filter cleaning and possibly filter heating), but compared to other suction systems weaker suction is required (meaning less energy is needed). Wet scrubbers: generate waste water, requiring treatment, less recycling potential than for dry filter dust.

Applicability

New and existing plants. Loading in longitudinal direction of bath.

Economics

At Verzinkerei Rhein-Main, investment costs of DM 1634167 and operating costs of DM 309000 were incurred in 1985 for enclosure in combination with a fabric filter. The operating costs include DM 259000 for service of capital.

Example plants

Verzinkerei Rhein-Main GmbH, Groß-Rohrheim, Germany.

Heat Recovery from Galvanising Kettle Heating

Brief technical description

The method most commonly used for heat recovery from combustion gas is transfer to air or water. Heat exchangers typically fabricated from banks of stainless steel tubes are used to recover heat from flue gas to air. The flue products are normally on the tube side. Flue products may be introduced at 500 to 700^{o}C when the furnace is operating at full production rate. The heat exchanger may be placed directly in the furnace flue duct but, in the absence of forced extraction of flue gases, only a small flue gas pressure drop can be tolerated. This limits the rate of heat transfer.

Shell and tube heat exchangers can be used to transfer heat from flue products to water or steam, with flue gas on the shell side. Another common type of exchanger is a bank of finned tubes placed in the flue duct. In this case water is on the tube side.

Gases may be drawn through the heat exchanger using a fan downstream of the exchanger in order to increase the overall coefficient. This is a common arrangement for gas-to-water heat exchange. Both heat exchanger and fan are located in a branch parallel to the main flue duct, thus avoiding any back-pressure effect on the furnace. The fan consumes a small amount of power.

In a few cases flue gases are contacted directly with the outer surface of a pre-treatment tank, transferring heat by radiation and convection.

Heat exchangers for oil fuels and for surface heated baths require special design due to the presence of SO_2 and ash in the flue gases.

Achieved environmental benefits

Reduced fuel consumption, energy savings.

Applicability

New and existing plants. In principle, can be applied to any installation subject to economic analysis, which depends on fuel price, thermal rating of furnace and demand for waste heat.

Not normally interesting on two burner systems (small kettles) because there is not enough heat available to be useful. Heat recovery systems are very frequently installed on four and six burner systems.

Economics

Energy reductions in the range 15 – 45 kWh/t black steel.

Driving force for implementation

Fuel cost.

Example plants

Plants using Ferrous Metals Processing Industry.

1.2.2.7 Hot Rolling Mill

Reduction of heat loss in intermediate products

Brief technical description

Minimizing the storage time and by insulating the slabs/blooms (heat conservation box or thermal covers) depending on production layout.

Achieved environmental benefits

Lower energy consumption.

Driving force for implementation

To minimize the energy requirements.

Example plants

Plants using Ferrous Metals Processing Industry.

Change of logistic and intermediate storage

Brief technical description

Change of logistic and intermediate storage to allow for a maximum rate of hot charging, direct charging or direct rolling (the maximum rate depends on production schemes and product quality).

Achieved environmental benefits

Lower energy consumption.

Driving force for implementation

To minimize the energy requirements.

Example plants

Plants using Ferrous Metals Processing Industry.

Reheating and heat treatment furnaces

BAT for reheating and heat treatment furnaces

Brief technical description

Avoiding excess air and heat loss during charging by operational measures (minimum door opening necessary for charging) or structural means (installation of multi-segmented doors for tighter closure).

Careful choice of fuel (in some cases, e.g. coke oven gas, desulphurisation maybe necessary) and implementation of furnace automation and control to optimise the firing conditions in the furnace.

Recovery of heat in the waste gas:

- by feedstock preheating,
- by regenerative or recuperative burner systems,
- by waste heat boiler or evaporative skid cooling (where there is a need for steam).

Limiting the air preheating temperature. With increasing air preheating temperature, a significant rise in NO_x concentrations is inevitable. Thus, limiting the preheating temperature may be seen as a NO_x reduction measure. However, the advantages of reduced energy consumption and reductions in SO_2, CO_2 and CO have to be weighed against the disadvantage of potentially increased emissions of NO_x.

Achieved environmental benefits

Reduction of direct energy consumption. Optimum energy efficiency. Energy savings of 40-50% can be achieved by regenerative burners, with reported NO_x reductions potentials of up to 50%. Energy savings associated with recuperators or recuperative burners are about 25%, with reported achievable NO_x reductions of about 30% (50% in combination with low-NO_x burners).

Driving force for implementation

To optimise the firing conditions in the furnace.

Example plants

Plants using Ferrous Metals Processing Industry.

1.2.2.8 *Nickel and Cobalt*

Refining and transformation processes

The refining and transformation processes such as:

- leaching, chemical refining and solvent extraction,
- electro-winning,
- production of metal powders ingots and other products

should be taken into account when determining BAT, when used with effective gas and liquid collection and treatment techniques.

Brief technical description

The use of sealed reactors where possible for the leaching and solvent extraction stages allow gases and vapours to be contained and re-used. These techniques are considered to be BAT.

There are occasions when sealing is not possible for example covered settlement baths. Fume collection from semi-sealed equipment is a very important component of BAT as the mass of fugitive emissions can be greater than abated emissions.

The correct use of furnace sealing and fume collection techniques is also considered to be BAT and is associated with the use of proper prevention and maintenance techniques.

Achieved environmental benefits

Reduction of energy use.

Operational data

The refining processes described in applied techniques are applied to a wide range of raw materials of varying quantity and composition. The techniques have been developed by the Companies in this sector to take account of this variation. The choice of pyro-metallurgical or hydrometallurgical technique is driven by the raw materials used, the impurities present and the product made. In particular the morphology of the final product can be crucial for example when powders are produced for battery manufacture or when metal coatings are applied to a variety of substrates such as foams.

The basic refining processes outlined above therefore constitute the techniques to consider for the recovery processes. The application of the reactor sealing, abatement, control and management techniques are techniques to consider.

Applicability

Refining and transformation processes.

1.3 Recovery

Heat exchangers

BAT is to maintain the efficiency of heat exchangers by both: monitoring the efficiency periodically, and preventing or removing fouling.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Brief technical description

Direct heat recovery is carried out by heat exchangers. A heat exchanger is a device in which energy is transferred from one fluid or gas to another across a solid surface. They are used to either heat up or cool down processes or systems. Heat transfer happens by both convection and conduction.

Heat exchangers are designed for specific energy optimised applications. The subsequent operation of heat exchangers under different or variable operating conditions is only possible within certain limits. This will result in changes to the transferred energy, the heat transfer coefficient (U-value) and the pressure drop of the medium.

The heat transfer coefficient and hence transferred power are influenced by the thermal conductivity as well as the surface condition and thickness of the heat transfer material. Suitable mechanical design and choice of materials can increase the efficiency of the heat exchanger.

Costs and mechanical stresses also play a major role in the choice of material and structural design.

The power transferred through the heat exchanger is heavily dependent on t he heat exchanger surface. The heat exchanger surface area may be increased using ribs (e.g. ribbed tube heat exchangers, lamella heat exchangers). This is particularly useful in attaining low heat transfer coefficients (e.g. gas heat exchangers).

The accumulation of dirt on the heat exchanger surface will diminish the heat transfer. Dirt levels may be reduced by using appropriate materials (very smooth surfaces), structured shapes (e.g. spiral heat exchangers) or changing the operating conditions (e.g. high fluid speeds). Furthermore, heat exchangers may be cleaned or fitted with automatic cleaning systems (dynamic or scrapped surface).

Higher flowrates will increase the heat transfer coefficient. However, increased flowrates will also result in higher pressure drops. High levels of flow turbulence improve heat transfer but result in an increased pressure drop. Turbulence may be generated by using s tamped heat exchanger plates or by fitting diverters.

The transferred power is also dependent on the physical state of the fluid (e.g. temperature and pressure). If air is used as the primary medium, it may be humidified prior to entering the heat exchanger. This improves the heat transfer.

Achieved environmental benefits

Energy savings are made by using secondary energy flows.

Cross-media effects

No data submitted.

Operational data

Condition monitoring of heat exchanger tubes may be carried out using eddy current inspection. This is often simulated through computational fluid dynamics (CFD). Infrared photography may also be used on the exterior of heat exchanges, to reveal significant temperature variations or hot spots.

Fouling can be a serious problem. Often, cooling waters from rivers, estuaries or a sea is used, and biological debris can enter and build layers. Another problem is scale, which is chemical deposit layers, such as calcium carbonate or magnesium carbonate. The process being cooled can also deposit scale, such as silica scale in alumina refineries.

- plate heat exchangers need to be cleaned periodically, by disassembling, cleaning and re-assembly,
- tube heat exchangers can be cleaned by acid cleaning, bullet cleaning or hydrodrillling (the last two may be proprietary techniques),

- specific techniques are selected on a case-by-case basis.

Applicability

Heat recovery systems are widely used with good results in many industrial sectors and systems. It is being applied for an increasing number of cases, and many of these can be found outside of the installation. Heat recovery is not applicable where there is no demand that matches the production curve.

Economics

Payback time may be as short as six months or as long as 50 years or more. In the Austrian pulp and paper industry, the payback time of the complex and different systems was between one and about three years.

The cost-benefits and payback (amortisation) periods can be calculated, e.g. as shown in the ECM REF. In some cases, particularly where the heat is used outside the installation, it may be possible to use funding from policy initiatives.

Driving force for implementation

Reduction of energy costs, reduction of emissions and the often rapid return of investments.

Improved process operation, e.g. reduction of surface contamination (in scrapped surface systems), improvement of existing equipment/flows, reduction in system pressure drop (which increases the potential maximum plant throughput).

Savings in effluent charges.

Example plants

Acid cleaning: Eurallumina, Portovecompany, Italy.

Monitoring and maintenance of heat exchangers

BAT is to maintain the efficiency of heat exchangers by both: monitoring the efficiency periodically, and preventing or removing fouling.

Brief technical description

Condition monitoring of heat exchanger tubes may be carried out using eddy current inspection. This is often simulated through computational fluid dynamics (CFD). Infrared photography may also be used on the exterior of heat exchanges, to reveal significant temperature variations or hot spots.

Fouling can be a serious problem. Often, cooling waters from rivers, estuaries or a sea is used, and biological debris can enter and build layers. Another problem is scale, which is chemical deposit layers, such as calcium carbonate or magnesium carbonate.The process being cooled can also deposit scale, such as silica scale in alumina refineries.

Achieved environmental benefits

Improved heat exchange for heat recovery.

Cross-media effects

Use of chemicals for removing scale.

Operational data

- plate heat exchangers need to be cleaned periodically, by disassembling, cleaning and re-assembly,
- tube heat exchangers can be cleaned by acid cleaning, bullet cleaning or hydrodrillling (the last two may be proprietary techniques),
- the operation and cooling of cooling systems.

Applicability

Applicable to all heat exchanges. Specific techniques are selected on a case-by-case basis.

Economics

Maintaning the heat exchangers to their design specifications optimises payback.

Driving force for implementation

Maintaining production capacity.

Heat pumps

BAT is to maintain the efficiency of heat exchangers by both: monitoring the efficiency periodically, and preventing or removing fouling.

Brief technical description

The main purpose for heat pumps is to transform energy from a lower temperature level (low exergy) to a higher level. Heat pumps can transfer heat (not generate heat) from man-made heat sources such as industrial processes, or from natural or artificial heat sources in the surroundings, such as the air, ground or w ater, for use in domestic, commercial or industrial applications. However, the most common use of heat pumps is in cooling systems, refrigerators, etc. Heat is then transferred in the opposite direction, from the application that is cooled, to the surroundings. Sometimes the excess heat from cooling is used to meet asimultaneous heat demand elsewhere. Heat pumps are used in co- and trigeneration, these are systems that provide both cooling and heating simultaneously, and with varying seasonal demands

In order to transport heat from a heat source to a location where heat is required, external energy is needed to drive the heat pump. The drive can be any type, such as an electric motor, a combustion engine, a turbine or a heat source for adsorption heat pumps.

Types of heat pumps:

- Compression heat pumps (closed cycle),
- Absorption heat pumps,
- Mechanical vapour recompression (MVR).

Achieved environmental benefits

Heat pumps enable the recovery of low grade heat, with primary energy consumption lower than the energy output (depending on the COP, and if the requirements for an good seasonal overall efficiency are fulfilled). This enables the use of low grade heat in useful applications, such as heating inside in the installation, or in the adjacent community. This results in reducing the use of primary energy and related gas emissions, such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x) in the specific applications.

The efficiency of any heat pump system is strongly dependent on the required temperature lift from source to sink.

Cross-media effects

Use of refrigerant with environmental impacts (greenhouse gas effect in particular) from leaks or decommissioning compression or absorption heat pumps.

Applicability

Compressor systems: typically used working fluids limit the output temperature to 120 °C.

Absorption systems: a water/lithium bromide working fluid pair can achieve an output of 100 °C and a temperature lift of 65 °C. New generation systems have higher output temperatures (up to 260 °C) and higher temperature lifts.

Current MVR systems work with heat source temperatures of 70 - 80 °C and delivery heat of 110 - 150 °C, and in some cases, up to 200 °C. The most common vapour compressed is steam although other process vapours are also used, notably in the petrochemical industry.

The situation in an industry with combined heat and power production is more complicated. For example, with backpressure turbines, the lost work from the turbines must also be considered.

Heat pumps are used in cooling equipment and systems (where the heat removed is often dispersed). However, this demonstrates the technologies are robust and well developed. The technology is capable of a much wider application for heat recovery.

- space heating,
- heating and cooling of process flows,
- water heating for washing, sanitation and cleaning,
- steam production,
- drying/dehumidification,
- evaporation,
- distillation,
- concentration (dehydration).

They are also used in co- and trigeneration systems.

The most common waste heat streams in industry are cooling fluid, effluent, condensate, moisture, and condenser heat from refrigeration plants. Because of the fluctuation in waste heat supply, it may be necessary to use large (insulated) storage tanks to ensure stable operation of the heat pump.

Adsorption heat pumps are applicable for cooling systems in sites where there is a large amount of waste heat.

Most MVR installations are in unit operations such as distillation, evaporation, and drying, but steam production to a steam distribution network is also common.

Relatively few heat pumps are installed in industry for heat recovery and usually realised in the course of planning new facilities and plants, or significant upgrades.

Heat pumps are more cost-effective when fuel costs are high. Systems tend to be more complex than fossil fuel fired systems, although the technology is robust.

Economics

The economy depends strongly on the local situation. The amortisation period in industry is 2 years at best. This can be explained on the one hand by the low energy costs, which minimise savings through the use of heat pumps and on the other hand by the high investment costs involved.

The profitability for an MVR installation, besides fuel and electricity prices, depends on installation costs. The installation cost for an installation at Nymölla in Sweden, was about EUR 4.5 million. The Swedish Energy Agency contributed a grant of nearly EUR 1.0 million. At the time of installation, the annual savings amounted to about EUR 1.0 million per year.

Driving force for implementation

- savings of operational energy costs,
- an installation could provide the means to increase production without investing in a new boiler if the boiler capacity is a limiting factor.

Example plants

- Dåvamyren, Umeå, Sweden: compressor driven heat pump in waste to energy plant,
- Renova Göteborg, Sweden: absorption driven heat pump,
- Borlänge, Halmstad and Tekniska Verken, Linköping, Sweden, W-t-E plants, and biofuel burners, Sweden: MVR heat pumps,
- MVR has been adapted to small scale installations, where the compressor can be run by a simple electric motor.

PART 2: **ELECTRICITY**

2.1 Lighting

BAT is to optimise artificial lighting systems by:

- planning space and activities in order to optimise the use of natural light,
- selection of fixtures and lamps according to specific requirements for the intended use,
- trainings for building occupants about utilisation of lighting equipment in the most efficient manner,
- usage of lighting management control systems including occupancy sensors, timers, etc.

Brief technical description

Artificial lighting accounts for a significant part of all electrical energy consumed worldwide. In offices, from 20 to 50 per cent of the total energy consumed is due to lighting. Most importantly, for some buildings over 90 per cent of lighting energy consumed can be an unnecessary expense through over-illumination. Thus, lighting represents a critical component of energy use today, especially in large office buildings and for ot her large scale uses where there are many alternatives for energy utilisation in lighting.

There are several techniques available to minimise energy requirements in any building:

a) identification of lighting requirements for each area

This is the basic concept of deciding how much lighting is required for a given task. Lighting types are classified by their intended use as general, localised, or task lighting, depending largely on the distribution of the light produced by the fixture. Clearly, much less light is required for illuminating a walkway compared to that needed for a computer workstation.

Generally speaking, the energy expended is proportional to the design illumination level. For example, a lighting level of 800 lux might be chosen for a work environment encompassing meeting and conference rooms, whereas a level of 400 lux could be selected for building corridors:

- general lighting is intended for the general illumination of an area. Indoors, this would be a basic lamp on a table or floor, or a fixture on the ceiling. Outdoors, general lighting for a parking area may be as low as 10 - 20 lux since pedestrians and motorists already accustomed to the dark will need little light for crossing the area,
- task lighting is mainly functional and is usually the most concentrated, for purposes such as reading or inspection of materials. For example, reading poor quality pr int products may require task lighting levels up to 1500 lux, and some inspection tasks or surgical procedures require even higher levels.

b) analysis of lighting quality and design

- the integration of space planning with interior design (including choice of interior surfaces and room geometries) to optimise the use of natural light. Not only will greater reliance on natural light reduce energy consumption, but will favourably impact on human health and performance,
- planning activities to optimise the use of natural light,
- consideration of the spectral content required for any activities needing artificial light,
- selection of fixtures and lamp types that reflect best available techniques for energy conservation.

Types of electric lighting include:

- incandescent light bulbs: an electrical current passes through a thin filament, heating it and causing it to become excited, releasing light in the process. The enclosing glass bulb prevents the oxygen in air from destroying the hot filament. An advantage of incandescent bulbs is that they can be produced for a wide range of voltages, from just a few volts up to several hundred. Because of their relatively poor luminous efficacy, incandescent light bulbs are gradually being replaced in many applications by fluorescent lights, high intensity discharge lamps, light-emitting diodes (LEDs), and other devices.

- arc lamps or gas discharge lamps: an arc lamp is the general term for a class of lamps that produce light by an electric arc (or voltaic arc). The lamp consists of two electrodes typically made of tungsten which are separated by a gas. Typically, such lamps use a noble gas (argon, neon, krypton or xenon) or a mixture of these gases. Most lamps contain additional materials, such as mercury, sodium, and/or metal halides. The common fluorescent lamp is actually a low pressure mercury arc lamp where the inside of the bulb is coated with a light emitting phosphor. High intensity discharge lamps operate at a higher current than the fluorescent lamps, and come in many varieties depending on the material used. Lightning could be thought of as a type of natural arc lamp, or at least a flash lamp. The type of lamp is often named by the gas contained in the bulb including neon, argon, xenon, krypton, sodium, metal halide, and mercury. The most common arc or gas discharge lamps are:
  - fluorescent lamps
  - metal halide lamps
  - high pressure sodium lamps
  - low pressure sodium lamps.

The electric arc in an arc or gas discharge lamp consists of gas which is initially ionised by a voltage and is therefore electrically conductive. To start an arc lamp, usually a very high voltage is n eeded to 'ignite' or 'strike' the arc. This r equires an electrical circuit sometimes called an 'igniter', which is part of a larger circuit called the 'ballast'. The ballast supplies a suitable voltage and current to the lamp as its electrical characteristics change with temperature and time. The ballast is typically designed to maintain safe operating conditions and a constant light output over the life of the lamp. The temperature of the arc can reach several thousand degrees Celsius. An arc or gas discharge lamp offers a long life and a high light efficiency, but is more complicated to manufacture, and requires electronics to provide the correct current flow through the gas

- sulphur lamps: the sulphur lamp is a highly efficient full spectrum electrodeless lighting system whose light is generated by sulphur plasma that has been excited by microwave radiation. With the exception of fluorescent lamps, the warm-up time of the sulphur lamp is notably shorter than for other gas discharge lamps, even at low ambient temperatures. It reaches 80 % of its final luminous flux within twenty seconds (video), and the lamp can be restarted approximately five minutes after a power cut
- light emitting diodes, including organic light emitting diodes (OLEDs): a light emitting diode (LED) is a semiconductor diode that emits incoherent narrow spectrum light. One of the key advantages of LED-based lighting is its high efficiency, as measured by its light output per unit of power input. If the emitting layer material of an LED is an organic compound, it is known as an organic light emitting diode (OLED). Compared with regular LEDs, OLEDs are lighter, and polymer LEDs can have the added benefit of being flexible. Commercial application of both types has begun, but applications at an industrial level are still limited.

Different types of lights have vastly differing efficiencies.

The most efficient source of electric light is the low pressure sodium lamp. It produces an almost monochromatic orange light, which severely distorts colour perception. For this reason, it is generally reserved for outdoor public lighting usages. Low pressure sodium lights generate light pollution that can be easily filtered, contrary to broadband or continuous spectra.

Data on options, such as types of lighting, are available via the Green Light Programme. This is a voluntary prevention initiative encouraging non-residential electricity consumers (public and private), referred to as ' Partners', to commit to the European Commission to install energy efficient lighting technologies in their facilities when (1) it is profitable, and (2) lighting quality is maintained or improved.

c) management of lighting

- emphasise the use of lighting management control systems including occupancy sensors, timers, etc. aiming at reducing lighting consumption,
- training of building occupants to utilise lighting equipment in the most efficient manner,
- maintenance of lighting systems to minimise energy wastage.

Achieved environmental benefits

Energy savings.

Cross-media effects

Certain types of lamps, e .g. mercury vapour, fluorescent, contain toxic chemicals such as mercury or lead. At the end of their useful life, lamps must be recycled or disposed of correctly.

Operational data

It is valuable to provide the correct light intensity and colour spectrum for each task or environment. If this is not the case, energy could not only be wasted but over-illumination could lead to adverse health and psychological effects such as headache frequency, stress, and increased blood pressure. In addition, glare or excess light can decrease worker efficiency.

Artificial nightlighting has been associated with irregular menstrual cycles.

To assess ef fectiveness, baseline and post-installation models can be constructed using the methods associated with measurement and verification (M&V) options A, B, C and D:

M&V Option A:

Focuses on physical assessment of equipment changes to ensure the installation is to specification. Key performance factors (e.g. lighting wattage) are determined with spot or short term measurements and operational factors (e.g. lighting operating hours) are stipulated based on the analysis of historical data or spot/short term measurements. Performance factors and proper operation are measured or checked yearly.

Engineering calculations using spot or short term measurements, computer simulations, and/or historical data.

Cost dependent on number of measurement points. Approx. 1-5% of project construction cost

M&V Option B: Savings are determined after project completion by short term or continuous measurements taken throughout the term of the contract at device or system level. Both performance and operations factors are monitored.

Engineering calculations using metered data.

Cost dependent on number and type of systems measured and the term of analysis/metering. Typically 3-10% of project construction cost.

M&V Option C: After project completion, savings are determined at whole building or facility level using the current year and historical utility meter or sub-meter data.

Analysis of utility meter (or sub-meter) data using techniques from simple comparison to multivariate (hourly or monthly) regression analysis.

Cost dependent on number and complexity of parameters in analysis. Typically 1-10% of project construction cost.

M&V Option D: Savings are determined through simulation of facility components and/or the whole facility.

Calibrated energy simulation/modelling; calibrated with hourly or monthly utility billing data and/or end-use metering.

Cost dependent on number and complexity of systems evaluated. Typically 3–10% of project construction cost.

Applicability

All cases. Cost benefit on lifetime basis.

Techniques such as the identification of illumination requirements for each given use area, planning activities to optimise the use of natural light, selection of fixture and lamp types according to specific requirements for the intended use, and management of lighting are applicable to all IPPC installations. Other measurements such as the integration of space planning to optimise the use of natural light are only applicable to new or upgraded installations.

Where this can be achieved by normal operational or maintenance rearrangements, consider in all cases. If structural changes, e.g. building work, is required, new or upgraded installations.

Economics

The Green Light investments use proven technology, products and services which can reduce lighting energy use from between 30 and 50%, earning rates of return of between 20 and 50%.

Payback can be calculated using techniques in the ECM REF.

Driving force for implementation

- health and safety at work,
- energy savings.

Example plants

Widely used.

2.2 Organizational aspects

2.2.1 Cooling system

Design phase of a cooling system

It is BAT in the design phase of a cooling system:

- to reduce resistance to water and airflow,

- to apply high efficiency/low energy equipment,
- to reduce the amount of energy demanding equipment,
- to apply optimised cooling water treatment in once-through systems and towers to keep surfaces clean and avoid scaling, fouling and corrosion.

Brief technical description

If dry air cooling systems are the preferred option, measures are primarily related to reduction of direct energy consumption and noise emissions and the optimization of size with respect to the required cooling surface.

Following the BAT "approach", the design of the cooling system and the choice of materials to be used are an important preventive step. Both can affect the operation as the required amount of direct energy consumption.

For each individual case a combination of the above-mentioned factors should lead to the lowest attainable energy consumption to operate a cooling system.

The right choice of material and design will reduce the required power consumption of cooling systems. The following practices are applied and can be mentioned, as options one should be aware of:

1. proper lay-out of the cooling system, such as smooth surfaces and as few changes of flow direction as possible, will avoid turbulence and reduce resistance to the flow of the coolant;
2. in mechanical cooling towers, choice of type and position of fans and possibility of airflow adjustment are options for reduced energy use;
3. choice of the right fill or packing (in light of the operating conditions) to secure maximum heat exchange at all times;
4. choice of drift eliminators with minimum resistance to airflow.

Achieved environmental benefits

Reduction of energy consumption.

Operational data

The following factors are taken into account:

- type of operation (e.g. once-through or recirculating),
- design of cooler and layout of cooling system (direct/indirect),
- pressure level (condenser),
- composition and corrosiveness of the cooling water,
- composition and corrosiveness of the medium to be cooled,
- required longevity and costs.

A range of materials is available and, in order of increasing resistance, most commonly used are carbon steel, coated (galvanised) steel, aluminium/brass, copper/nickel, adequate types of stainless steel and titanium. Within these groups a further sub-classification on the quality is used. Especially resistance to corrosion, mechanical erosion and biological pollution is greatly determined by the quality of the water combined with possible conditioning agents.

Example plants

Plants using cooling system.

2.2.2 Energy management

Benchmarking the installation

It is BAT to continuously optimise the use of inputs (raw materials and utilities) against benchmarks. A system to action the data will include:

- identifying a person or persons responsible for evaluating and taking action on the data,
- action being taken to inform those responsible for plant performance, including alerting operators, rapidly and effectively, to variations from normal performance,
- other investigations to ascertain why performance has varied or is out of line with external benchmarks.

Brief technical description

Benchmarking is the systematic recording of inputs (raw materials, energy and water) and outputs (emissions to air, water and as waste), and the regular comparisons of these with previous data for the installation, with its sector, national or regional benchmarks.

Appropriate benchmarking requires comparable data – a "like for like" comparison. For surface treatment activities this would be best achieved on a surface area treated basis or other consumption or throughout basis. For instance, kg of zinc used per 10000 m^2 of surface, kg zinc discharged per 10000 m^2 of surface, kWh per 10000 m^2 of surface.

Variables can make such data difficult to acquire accurately: for instance, workpieces have irregular shapes and varying thicknesses so estimations of surface area can vary in accuracy, and thickness of deposited coatings can vary widely. However, these difficulties do not prevent the gathering of data to be used.

It is BAT to establish benchmarks (or reference values) that enable the installation's performance to be monitored on an ongoing basis and also against external benchmarks. Record and monitor usage of all utility inputs by type: electricity, gas, LPG and other fuels, and water, irrespective of source and cost per unit. The detail and period of recording, whether hourly, by shift, by week, by square metre throughput or other measure etc. will be according to the size of the process and the relative importance of the measure.

Achieved environmental benefits

Assists individual installations to assess their environmental performance with other installations. Assists in identifying techniques used by the best performing installations.

Cross-media effects

None.

Operational data

Provides benchmarks and assessment of operational environmental performance for installations and techniques.

Applicability

Data must be available for several installations with homogeneity of inputs and outputs before an individual installation can be benchmarked. The breadth of data and installations needs to be sufficiently wide to be challenging; for example, benchmarks water usage at 50 litres per m^2 from TWG) and the French regulatory maximum is 8 litres per m^2 per rinsing operation which equates to 40 litres per m^2 for a 5-process line. Weighting factors need to be determined. Knowledge of DEA and its

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application with linear programming is required. This approach may be useful for a group of companies or a trade association. The technique does not readily take account of cross-media effects.

Economics

Optimisation of the plant environmental performance will usually achieve economic optimisation.

Driving force for implementation

Benchmarking is also commensurate with good economic performance. Benchmarking and optimising environmental performance (such as raw material, water and power inputs, as well as material losses) will achieve economic optimisation at the same time.

Example plants

Surface treatment of metals plants.

Minimising of electrical energy consumption

BAT is to minimise electrical energy consumption by using one or a combination of the following techniques:

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

Achieved environmental benefits

Improved 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.

Minimising the effects of reworking

It is BAT to minimise the environmental impacts of reworking by management systems that require regular re-evaluation of process specifications and quality control jointly by the customer and the operator. This can be done by:

- ensuring specifications are:
  - o correct and up to date
  - o compatible with legislation
  - o applicable
  - o attainable
  - o measurable appropriately to achieve customer's performance requirements
- both customer and operator discussing any changes proposed in each other's processes and systems prior to implementation,
- training operators in the use of the system,
- ensuring customers are aware of the limitations of the process and the attributes of the surface treatment achieved.

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Brief technical description

Workpieces or substrate surface treated incorrectly, to the wrong or inappropriate specification, or a specification incorrectly applied can lead to significant amounts of metal stripping and rectification (in barrel and jig work). Workpieces and/or substrate may also have to be scrapped, predominantly large scale coils and printed circuit boards, although some jig and barrel processed workpieces may be damaged irrecoverably.

Reduction in reworking and scrap can be achieved in a variety of ways, such as using formal quality management systems, QMS. As with environmental management tools, to achieve success within the installation, it is good practice to ensure these systems are formally recorded and disseminated to the workforce. While many such systems are externally accredited (and this may be a customer requirement) it may not be essential.

However, it is usual to have the system externally audited, to provide unbiased input to validate and update the system, as well as giving customer confidence. These systems usually include statistical process control (SPC).

Attention to the appropriate process specification and its quality control is also an important factor. In surface treatment activities a 'right first time approach' is normally anticipated and is often part of a formal system. To achieve this, it is common practice to ensure the correct process is applied in the correct manner to achieve the desired effect. This requires a proper understanding of the properties given by the surface treatment and the subsequent operations to be performed on the workpiece or substrate such as pressing, forming, bending, crimping, drilling, welding, soldering, etc. Other techniques that form part of achieving the correct specification are discussed in EMS and in production management systems, such as ISO 9000.

To match the treatment to the required objective, environmental and/or quality management systems (as appropriate) can make sufficient provision for dialogue and agreement between the operator and the customer about the correct process specification, engineering design drawings and the quality control measurement points for the workpieces and/or substrates. The following are examples of areas that can be addressed:

- surface treatments can alter the dimensions of a workpiece by the thickness of layer added (e.g. changing the size of threaded components), the characteristics of the substrate (e.g. hydrogen embrittlement with acid zinc plating) or be inappropriate for subsequent manipulation (e.g. some finishes may be brittle and may flake when a treated workpiece is subsequently bent or crimped),
- in electrolytic processes where the applied material is current-carrying, the deposits build preferentially at edges and corners of the workpiece and/or substrate, where the charge density is greatest. The method of measurement and the points to be measured for quality control of the finish may be agreed taking account of the differences of thickness at different parts of the workpiece or substrate to be finished. Some measurement methods require flat surfaces and to meet performance requirements attention may need to be given the coating thickness being significantly thinner in flat areas than at the edges (a ratio of centre thickness to edge thickness of approximately 1:3 or 1:4). Also, while specifications may be met in the flat, measured areas, edge build-up can result in flaking if the edges are subsequently manipulated, such as by crimping,
- performance specifications (such as to achieve a specified level of corrosion resistance) are preferable to total reliance on prescriptive specifications. The more usual and readily applied thickness measurements are best used in conjunction with performance specifications, when thicknesses at agreed points that meet the specified performance can be established alterations to the manufacturing process prior to surface treatment. For example, change in pressing oils

(to a type which may become pressed into the substrate micro-structure and does not respond to normal degreasing processes), type of substrate, pressing workpieces in place of machining, hardening prior to surface treatment, etc.,

- alterations to end use specification,
- barrel treatment instead of jig (possibly because of cost constraints),
- major organisations or industry sectors requiring large amounts of surface treatment may write their own specifications (such as automotive or aerospace organisations).Smaller organisations often use these publicly available specifications. To meet specifications, take care to ensure the latest versions are referred to, and the specifications are suitable for other products, their subsequent processing and end use,
- some customers may request the highest quality specifications available, such as military and aerospace specifications involving cadmium for other products. However, military and aerospace applications are exempt from marketing and use legislation applying to cadmium.

There are many ways in which processes can be improved for stability and consistency over time and many techniques have this advantage as well as improving environmental performance. Examples are the use of insoluble anodes with external make-up, process solution agitation and control of concentration of process chemicals.

Achieved environmental benefits

Avoiding reworking minimises losses in raw material, energy and water inputs, as well as minimising waste water treatment and the generation of sludge and liquid acid wastes.

Cross-media effects

There are no negative cross-media effects.

Operational data

If specification or processing is incorrect, a significant proportion of production capacity may be affected.

Applicability

Applicable to all installations. However, note that the IPPC Directive applies to the installation and its management systems. It does not apply to the supply chain and products.

Economics

There is significant economic justification for ensuring the specification is correct and is met, thus preventing reworking. Avoiding reworking is a positive action towards sustainable manufacturing and increases process throughput efficiency, as well as increasing customer confidence. There are cost savings in raw materials, hazardous waste disposal, energy and water, as well as labour. For sub-contract installations, the cost of stripping and reworking is usually borne by the sub-contractor.

Conversely, there are costs associated with introducing and maintaining process management systems and SPC.

Driving force for implementation

Business economics and sustainability. Customer requirements for quality management systems.

Example plants

Surface treatment of metals plants.

Process line optimisation and control

It is BAT to optimise individual activities and process lines by calculating the theoretical inputs and outputs for selected improvement options and comparing with those actually achieved.

Information from benchmarking, industry data and other sources can be used. Calculations can be performed manually, although this is easier with software.

For automatic lines, it is BAT to use real time process control and optimisation.

Brief technical description

Calculating the theoretical inputs and outputs required for selected options is useful to benchmark the installation's environmental and economical performance. While this can be carried out manually, it is tedious and time consuming. Software modelling tools can be used to help optimise performance of process lines by making recalculations easier and quicker. They can be written for processes by external contractors or in-house, and may be general or bespoke for a specific installation.

One software tool is based on an Excel spreadsheet and has a series of parameters for rack and barrel zinc electroplating. The calculations used in the spreadsheet are the same as, or similar to other similar information, including standard financial calculations.

As an example, the difference in typical zinc and passivation barrel line and one optimised using various BAT techniquesis:

- Typical line: 11500 m^3 water usage per year
- Optimised line: 2951 m^3 water usage per year, a saving of 74%

The input data for the 'industry average'(benchmark) plant can be adjusted to an actual plant for benchmarking, or used to examine the effects of various options, such as adding rinsing stages, evaporators, or changing processes, etc.

While the software is set for zinc plating, all the variables, such as chemical make-up type, and all input and output costs can be varied, so the software can be used for other processes, either complete lines such as for copper plating, or to judge the effects of changing one activity.

Achieved environmental benefits

Enables a process line to be optimised theoretically for consumption of energy, as well as minimising emissions to air.

Cross-media effects

Enables optimisation of inputs (raw materials and utilities) and emissions to water at the same time.

Operational data

Can use existing data and can be used to benchmark performance as well as plan improvements.

Applicability

For this example, the 'front-end'(visible page in the software) shows zinc electroplating, but the same calculations can readily be adapted by the user to other surface treatment activities, by entering simple, appropriate data in the model. It can therefore be used for all multistage process lines, or individual sub-processes.

While financial data is shown in GBP this is purely symbolic, all financial data can be entered as if in other currencies for calculation.

The programme does not optimise the whole installation.

Other manual or software packages can be used or built, sometimes for a specific plant.

Economics

The software referred to is free of charge. Trialling options using software can assist with process management and investment decisions before commitment.

Driving force for implementation

Environmental optimisation can optimise the plant's process and economic performance.

Example plants

Surface treatment of metals plants.

Best practices

DATA ENVELOPE ANALYSIS (DEA)

Description

Data envelope analysis (DEA) is a method of analysis that has been developed to compare the efficiency of organisational units when it is difficult to make the inputs or outputs comparable with unambiguous quantities. It can be applied in situations in which there are observations from many relatively homogeneous production units. In this context, homogeneity refers to the inputs and outputs that the units produce. They do not need to be organised in the same way or use the same types of production technology.

An example of DEA applied to surface treatment is given in Data variables from a survey of 15 electroplating companies were analysed in four groups:

- quantity of workpiece/substrate outputs
- labour and capital invested in equipment
- energy and water consumption
- emissions.

The DEA results were calculated using a varying combination of input factors. The efficiency score (productive efficiency) was calculated for inputs in capital and man-hours, water and energy with various outputs to the environment. The only output quantifier was the annual revenue earned by treatment. The data was modelled using linear programming methods with weighting factors.

2.2.3 Pumping systems

Avoid oversizing when selecting pumps and replace oversized pumps

BAT is to optimise pumping systems by avoiding oversized when selecting pumps and replacing oversized pumps.

Brief technical description

The pump is the heart of the pumping system. Its choice is driven by the need of the process which could be, first of all, a static head and a flowrate. The choice also depends on the system, the liquid, the characteristic of the atmosphere, etc.

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In order to obtain an efficient pumping system, the choice of the pump has to be done so as to have a n operating point as close as possible to the best efficiency point. It is estimated that 75% of pumping systems are oversized, many by more than 20%.

Oversized pumps represent the largest single source of wasted pump energy. When choosing a pump, oversizing is neither cost nor energy efficient as:

- the capital cost is high
- the energy cost is high because more flow is pumped at a higher pressure than required.

Energy is wasted from excessive throttling, large by passed flows, or operation of unnecessary pumps. Where oversized pumps are identified, their replacement must be evaluated in relation to other possible methods to reduce capacity, such as trimming or changing impellers and/or using variable speed controls. Trimming centrifugal pump impellers is the lowest cost method to correct oversized pumps. The head can be reduced 10 to 50 per cent by trimming or changing the pump impeller diameter within the vendor's recommended size limits for the pump casing.

The energy requirements of the overall system can be reduced by the use of a booster pump to provide the high pressure flow to a selected user and allow the remainder of the system to operate a lower pressure and reduced power.

The European Procurement Lines for water pumps provides a simple methodology for selecting a highly efficient pump with a high efficiency for the requested duty point. This methodology can be downloaded from:

http://re.jrc.ec.europa.eu/energyefficiency/motorchallenge/pdf/EU_pumpguide_final.pdf

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Oversizing is the largest single source of pump energy wastage.

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

For new pumps: all cases

For existing pumps: lifetime cost benefit

The applicability of particular measures and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Control and regulation system

BAT is to optimise pumping systems.

Brief technical description

A pump application might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. A control and regulation system is important in a pumping system so as to optimise the duty working conditions for the head pressure and the flow. It provides:

- process control
- better system reliability
- energy savings.

For any pump with large flow or pressure variations, when normal flows or pressures are less than 75% of their maximum, energy is probably being wasted from excessive throttling, large bypassed flows (either from a control system or deadhead protection orifices), or operation of unnecessary pumps.

The following control technique may be used:

- controlling a centrifugal pump by throttling the pump discharge (using a valve) wastes energy. Throttle control is, however, generally less energy wasteful than two other widely used alternatives: no control and bypass control. Throttles can, therefore, represent a means to save pump energy, although this is not the optimum choice.

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

All cases.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

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Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Design of pipework system

BAT is to optimise pumping systems.

Brief technical description

The pipework system determines the choice of the pump performance. Indeed, its characteristics have to be combined with those of the pumps to obtain the required performance of t he pumping installation.

The energy consumption directly connected to the piping system is the consequence of the friction loss on the liquid being moved, in pipes, valves, and other equipment in the system.

This loss is proportional to the square of the flowrate. Friction loss can be minimised by means such as:

- avoiding the use of too many valves,
- avoiding the use of too many bends (especially tight bends) in the piping system,
- ensuring the pipework diameter is not too small.

Achieved environmental benefits

Save energy.

Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

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Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

The applicability of particular measures and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Match the correct choice of pump to the correct motor for the duty

BAT is to optimise pumping systems.

Brief technical description

Note that it is important to match the right pump for the task to the correct size of motor for the pumping requirements (pumping duty).

Achieved environmental benefits

Save energy

Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

For new pumps: all cases.

For existing pumps: lifetime cost benefit.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Regular maintenance

BAT is to optimise pumping systems.

Brief technical description

Excessive pump maintenance can indicate:

- pumps are cavitating,
- badly worn pumps,
- pumps that are not suitable for the operation.

Pumps throttled at a constant head and flow indicate excess capacity. The pressure drop across a control valve represents wasted energy, which is proportional to the pressure drop and flow.

Where unplanned maintenance becomes excessive, check for:

- cavitation
- wear
- wrong type of pump

A noisy pump generally indicates cavitation from heavy throttling or excess flow. Noisy control valves or bypass valves usually mean a high pressure drop with a correspondingly high energy loss.

Pump performance and efficiency deteriorates over time. Pump capacity and efficiency are reduced as internal leakage increases due to excessive clearances between worn pump components: backplate; impeller; throat bushings; rings; sleeve bearings. A monitoring test can detect this condition and help size a smaller impeller, either new, or by machining the initial one, to achieve a huge reduction in energy. Internal clearances should be restored if performance changes significantly.

Applying coatings to the pump, will reduce friction losses.

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

All cases. Repair or replace as necessary.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Shut down unnecessary pumps

BAT is to optimise pumping systems.

Brief technical description

A pump application might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. A control and regulation system is important in a pumping system so as to optimise the duty working conditions for the head pressure and the flow. It provides:

- process control
- better system reliability
- energy savings.

For any pump with large flow or pressure variations, when normal flows or pressures are less than 75% of their maximum, energy is probably being wasted from excessive throttling, large bypassed flows (either from a control system or deadhead protection orifices), or operation of unnecessary pumps.

The following control technique may be used:

• shut down unnecessary pumps. This obvious but frequently overlooked measure can be carried out after a significant reduction in the plant's use of water or other pumped fluid (hence the need to assess the whole system)

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

All cases.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Use of multiple pumps (staged cut in)

BAT is to optimise pumping systems.

Brief technical description

A pump application might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. A control and regulation system is important in a pumping system so as to optimise the duty working conditions for the head pressure and the flow. It provides:

- process control
- better system reliability
- energy savings.

For any pump with large flow or pressure variations, when normal flows or pressures are less than 75% of their maximum, energy is probably being wasted from excessive throttling, large bypassed flows (either from a control system or deadhead protection orifices), or operation of unnecessary pumps.

The following control technique may be used:

• multiple pumps offer an alternative to variable speed, by pass, or throttle control. The savings result because one or more pumps can be shut down when the flow of the system is low, while the other pumps operate at high efficiency. Multiple small pumps should be considered when the pumping load is less than half the maximum single capacity. In multiple pum ping systems, energy is commonly lost from bypassing excess capacity, running unne cessary pum ps, maintaining excess pressure, or having a large flow increment between pumps

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

When the pumping flow is less than half the maximum single capacity.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

Variable speed drives (VSDs)

BAT is to optimise pumping systems by using variable speed drivers (VSDc).

Brief technical description

A pump application might need to cover several duty points, of which the largest flow and/or head will determine the rated duty for the pump. A control and regulation system is important in a pumping system so as to optimise the duty working conditions for the head pressure and the flow. It provides:

- process control
- better system reliability
- energy savings.

For any pump with large flow or pressure variations, when normal flows or pressures are less than 75% of their maximum, energy is probably being wasted from excessive throttling, large bypassed flows (either from a control system or deadhead protection orifices), or operation of unnecessary pumps.

The following control technique may be used:

- variable speed drives (on the electric motor) yield the maximum savings in matching pump output to varying system requirements, but they do have a higher investment cost compared to the other methods of capacity control. They are not applicable in all situations, e.g. where loads are constant.

Achieved environmental benefits

Save energy. Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Electric motors driving a variable load operating at less than 50% of capacity more than 20% of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Applicability

The applicability of particular measures and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

2.3 Processes

2.3.1 Compressed air systems (CAS)

System design, installation or refurbishment

1. BAT is to optimise compressed air systems (CAS) by:
   - overall system design, including multi-pressure systems,
   - upgrading of compressor,
   - reduction of frictional pressure losses (for example by increasing pipe diameter),
   - usage of sophisticated control systems,
   - storage of compressed air near highly-fluctuating uses,
   - optimisation of certain end use devices,
   - reduction of air leaks,
   - more frequent filter replacement,
   - optimisation of working pressure.

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

New or significant upgrade.

2. BAT is to optimise compressed air systems (CAS) by improving cooling, drying and filtering.

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

This does not include more frequent filter replacement.

3. BAT is to optimise compressed air systems (CAS) by improvement of drives (high efficiency motors).

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

Most cost effective in small (<10 kW) systems.

4. BAT is to optimise compressed air systems (CAS) by improvement of drives (speed control).

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

Applicable to variable load systems. In multi-machine installations, only one machine should be fitted with a variable speed drive.

5. BAT is to optimise compressed air systems (CAS) by recover waste heat for use in other functions.

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

Note that the gain is in terms of energy, not of electricity consumption, since electricity is converted to useful heat.

6. BAT is to optimise compressed air systems (CAS) by usage of external cool air as intake.

Achieved environmental benefits

Improve energy efficiency.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

Where access exists.

2.3.2 Cooling system

Application of cooling water treatment

Optimization of the application of oxidizing biocides in once-through systems is based on timing and frequency of biocide dosing. It is considered BAT to reduce the input of biocides by targeted dosing in combination with monitoring of the behavior of macrofouling species (e.g. valve movement of mussels) and using the residence time of the cooling water in the system.

For systems where different cooling streams are mixed in the outlet, pulse-alternating chlorination is BAT and can reduce even further free oxidant concentrations in the discharge.

In general, discontinuous treatment of once-through systems is sufficient to prevent fouling.

Depending on species and water temperature (above 10-12°C) continuous treatment at low levels may be necessary.

For seawater, BAT-levels of free residual oxidant (FRO) in the discharge, associated with these practices, vary with applied dosage regime (continuous and discontinuous) and dosage concentration level and with the cooling system configuration. They range from ≤ 0.1 [mg/l] to 0.5 [mg/l], with a value of 0.2 [mg/l] as 24h-average.

An important element in introducing a BAT-based approach to water treatment, in particular for recirculating systems using non-oxidizing biocides, is the making of informed decisions about what water treatment regime is applied, and how it should be controlled and monitored.

Selection of an appropriate treatment regime is a complex exercise, which must take into account a number of local and site-specific factors, and relate these to the characteristics of the treatment additives themselves, and the quantities and combinations in which they are used.

In order to assist the process of BAT decision making on cooling water additives at a local level, the BREF seeks to provide the local authorities responsible for issuing an IPPC permit with an outline for an assessment.

The Biocidal Products Directive 98/8/EC regulates the placing of biocidal products on the European market and considers as a specific category the biocides used in cooling systems. The information exchange shows that in some Member States specific assessment regimes are in place for the application of cooling water additives.

The discussion as part of the information exchange on industrial cooling systems resulted in two proposed concepts for cooling water additives, which can be used as a complementary tool by the permitting authorities:

1. A screening assessment tool based on the existing concepts, which allows a simple relative comparison of cooling water additives in terms of their potential aquatic impact.
2. A site specific assessment of the expected impact of biocides discharged in the receiving water, following the outcome of the Biocidal Products Directive and using the methodology to establish Environmental Quality Standards (EQSs) of the future Water Framework Directive as key elements.

The Benchmarking Assessment can be seen as a method to compare the environmental impact of several alternative cooling water additives while the Local Assessment for Biocides provides a yard stick for the determination of a BAT compatible approach for biocides in particular (PEC/PNEC <1). The use of local assessment methodologies as a tool in controlling industrial emissions is already common practice.

Brief technical description

Cooling water is treated to promote an efficient transfer of heat and to protect the cooling system so as to overcome a number of adverse effects on the performance of the cooling equipment. In other words, cooling water treatment aims to reduce total energy consumption.

The adverse effects are strongly related to the chemistry of the water taken in for cooling and the way the cooling system is operated (e.g. cycles of concentration). Salt water will have different demands from fresh water and industrial emissions of polluted substances upstream may be a challenge. Also, cooling water can become contaminated by leakage of process fluids from heat exchangers or, in the case of wet open cooling towers, by the air passing through the tower introducing dust, micro-organisms and exchange of vapour.

Cooling water additives are used for once-through systems, open wet cooling systems, closed circuit wet cooling and wet/dry systems. Where water is used as an intermediate coolant in the coil of dry systems, very low amounts of additives may be used to condition the water in the closed loop.

Environmentally, additives are important: they leave the cooling system at some stage, being discharged to surface water or, to a much lesser extent, into air. Generally, the chemistry and the application of the chemicals applied are known, but the choice of non-oxidizing biocides is mainly based on "trial and error". The environmental effects of the chemicals used can be assessed by means of modelling (risk/hazard) or by measurement. As they are used to improve an efficient heat exchange, their application is also related to the adverse effects that arise from a lower exchange efficiency. The industrial process to be cooled can be affected when heat transfer is inefficient, causing an increase in the use of energy (i.e. similar to an increase in air emissions) or a higher demand on raw materials to compensate for the loss of production.

Energy consumption of the cooling system can increase due to a higher demand on pumps and fans to compensate for loss of heat exchange efficiency.

Problems arising from water quality that are commonly encountered are:

- Corrosion of cooling water equipment, which may lead to leakage of heat exchangers and spills of process fluids into the environment or loss of vacuum in condensers;

- Scaling, predominantly by precipitation of calcium carbonates, sulphates and phosphates, Zn and Mg;
- (Bio-)Fouling of conduits and heat exchangers (also fill of wet cooling towers) by micro-, macro-organisms and suspended solids which can lead to blockage of the heat exchanger tubes by large particulate (shells) or to emissions to air from cooling towers.

Cooling water problems are often interrelated. Scaling can lead to both corrosion and biofouling. Spots of corrosion lead to changed waterflow patterns and create turbulence areas, where biofouling is enhanced. Biofouling may enhance further corrosion of the underlying surface.

Achieved environmental benefits

Reduction of direct energy consumption.

Operational data

The following groups of chemicals are used to condition the water:

- Corrosion inhibitors: formerly metals were mainly used, but there is a trend towards azoles, phosphonates, polyphosphates and polymers. This means that toxicity decreases while the persistency increases. Recently some better biodegradable polymers have been developed.
- hardness stabilisers or scale inhibitors: formulas exist mainly of polyphosphates, phosphonates and certain polymers. Recent developments in this application are also towards better biodegradable compounds.
- Dispersion chemicals: mostly copolymers, often in combination with surfactants. The main environmental effect is poor biodegradability.
- Oxidising biocides: chlorine (or a combination of chlorine and bromine) and monochloramine are mainly used. Chlorine (bromine) is a strong oxidiser (acutely toxic), which means that the half-life is short, but the side effects of chlorinating are the forming of halogenated by-products. Other oxidising biocides are ozone, UV, hydrogen peroxide or peracetic acid. The use of ozone and UV needs pre-treatment of the make-up water and needs special materials. The environmental effects are expected to be less harmful then halogenated biocides, but the application needs special care, is expensive and not applicable in all situations.
- Non-oxidising biocides: isothiazolones, DBNPA, glutaraldehyde and quaternary ammonium compounds etc. These compounds are in general acutely toxic and often not readily biodegradable, although there are some which hydrolyse or are degraded by other mechanisms. The environmental effects are significant.

The application of cooling water conditioning is a highly complex and local issue, where selection is based on a combination of the following elements:

- design and material of heat exchanger equipment;
- temperature and chemistry of the cooling water;
- organisms in the surface water that can be entrained;
- sensitivity of the receiving aquatic ecosystem to emitted additive and its associated by-produkts

For proper performance of any of the treatments, control of the cooling water pH and alkalinity within a specified range is usually required. Good pH and alkalinity control has become more important where more pH-sensitive treatment programmes are used or where higher cycles of concentration are applied in open recirculating cooling towers to minimise blowdown and reduce the water requirement. It is increasingly common practice in industry to have maintenance programmes developed and carried out by the additive supplier, but the responsibility for systems operation remains with the owner of the cooling system.

Example plants

Plants using cooling system.

Cooling and evaporation

Usage of closed refrigerated cooling system, for new or replacement cooling systems.

Brief technical description

Evaporation is widely used to remove excessive energy from vats by evaporating water from the process solution and maintaining the process temperature at the desired level. It can be optimised by using an air agitation, an evaporation system or evaporator, and may be used with cascade rinsing systems to conserve materials, minimise discharges, and can assist with closing loops for materials.

Achieved environmental benefits

Evaporation combines process cooling with drag-out recovery and usually forms part of any closed loop or zero discharge systems.

Cross-media effects

May require higher process bath temperatures with increased energy use and/or for drag-out recovery. May require energy input into the evaporator to evaporate sufficient water. Condensed water may be re-used.

Operational data

Normally run as an integrated system with countercurrent rinsing to maximise drag-out recovery and minimise process solution losses and therefore waste treatment. With sufficient countercurrent rinsing stages and/or additional heating in the evaporator, loops can be closed for certain materials.

For electrolytic processes, evaporators have less power input and costs are lower if the processing temperature is as high as necessary to remove any electrolytic energy input by natural evaporation from the solution surface.

Applicability

Can be used with solutions running at ambient temperatures.

Economics

Each kWh removed by evaporation is equivalent to 1.4 litres of water which can be balanced by drag-out recovery containing process chemicals and reduced rinse-water.

Driving force for implementation

If direct evaporation is used, then no capital investment is required.

Example plants

Surface treatment of metals plants.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Efficiency improvement of cooling systems

Upgrading existing heat transfer technology.

Brief technical description

Often a change of cooling technology for different reasons is not suitable. However, also a modification of the existing technology could lead to better efficiency, better performance, less emissions and lower operating costs. Development of air moving systems and heat transfer surfaces, as well as the application of more durable construction materials, are main reasons for replacement scenarios.

As there is usually no change in process temperatures (same technology) the main focus in this scenario is to reduce operating resources and environmental impacts as well as to achieve an extension of equipment's life. Equipment's life extension of more than 10 years can be realised by the use of new durable materials. It is very likely that any equipment installed 15 or 20 years ago, can now be replaced by modern equipment with higher operating efficiency and better environmental and economic performance.

A typical example for improvement of once-through cooling systems is the application of the more efficient plate and frame heat exchangers. For evaporative cooling systems for example, major developments have taken place to improve the performance of fill packs and of air moving systems, resulting in a more compact design with higher energy efficiencies. For air-cooled systems, new technology to shape fins in various ways has achieved similar results.

Often it is not necessary to replace the whole cooling system. The performance of existing cooling systems can also be improved by upgrading. Major components or accessories of the system are replaced or repaired, while the existing installation remains in situ. Upgrading can increase system efficiency and reduce the environmental impact.

Achieved environmental benefits

Reduction of direct energy consumption.

Operational data

Examples of upgrading are new and more efficient fill packs of cooling towers and the application of sound-attenuation.

Upgrading the operational strategy is another example of efficiency improvement. The on and of cycling of fans can be changed into modulating control with frequency converters. This can result in significant savings of electrical energy, which, depending on conditions, can be 70% and more.

Example plants

Plants using cooling system.

Evaporation

Prevention of over-cooling by optimising the process solution composition and working temperature range, monitor temperature of processes and control within these optimised process ranges.

Brief technical description

Evaporation is widely used to remove excessive energy from vats by evaporating water from the process solution and maintaining the process temperature at the desired level. It can be optimised by using an air agitation, an evaporation system or evaporator, and may be used with cascade rinsing systems to conserve materials, minimise discharges, and can assist with closing loops for materials.

Achieved environmental benefits

Evaporation combines process cooling with drag-out recovery and usually forms part of any closed loop or zero discharge systems.

Cross-media effects

May require higher process bath temperatures with increased energy use and/or for drag-out recovery. May require energy input into the evaporator to evaporate sufficient water. Condensed water may be re-used.

Operational data

Normally run as an integrated system with countercurrent rinsing to maximise drag-out recovery and minimise process solution losses and therefore waste treatment. With sufficient countercurrent rinsing stages and/or additional heating in the evaporator, loops can be closed for certain materials.

For electrolytic processes, evaporators have less power input and costs are lower if the processing temperature is as high as necessary to remove any electrolytic energy input by natural evaporation from the solution surface

Applicability

Can be used with solutions running at ambient temperatures.

Economics

Each kWh removed by evaporation is equivalent to 1.4 litres of water which can be balanced by drag-out recovery containing process chemicals and reduced rinse-water.

Driving force for implementation

If direct evaporation is used, then no capital investment is required.

Example plants

Surface treatment of metals plants, specifically use evaporators.

Evaporation using surplus internal energy

BAT is to remove excess energy from process solutions by evaporation

- there is a need to reduce the solution volume for make-up chemicals,
- evaporation can be combined with cascade and/or reduced water rinsing systems to minimize water and materials discharges from the process.

Brief technical description

Evaporation is atmospheric and achieved here by using the surplus heat energy in the process generated because of the poor electrical efficiency of the solution. The amount of energy necessary for evaporating corresponds roughly to the energy which is released in the process tank as heat energy thus the system is energetically self-sufficient. The rate of evaporation can be increased by using air agitation, or an evaporator. In this case, the process solution is pumped through the evaporator where it meets an air stream blown through the evaporator to the atmosphere. The evaporator chamber is usually filled with packing material to increase the water evaporation surface.

Evaporation from the process can be due to:

- an elevated processing temperature, such as >80°C for electroless nickel and >55°C for electrolytic nickel and phosphating at >90 °C,
- cooling of the process solution by evaporation to maintain a constant processing temperature, such as in cyanide zinc barrel plating at <25 °C, bright chromium at 40 °C and hard chromium at 60 °C.

The evaporation of 1 litre of water requires approximately 1.4 kWh.The evaporation losses in operating parameters can be calculated as follows:

Jig plating

- surface area of plating solution 6 m2
- water evaporation at 60 ° 5.5 litres/m2h
- water evaporation 33 litres/h.

Barrel plating

- plating energy/barrel 2.5 kWh
- plating energy total 25 kWh
- water evaporation equivalent 35 litres/h.

Equivalent quantities of rinse-water with diluted process solution can be added back into the process tank. The recovery rate is directly related to the concentration of process chemicals in rinse-water, and this again depends on the chosen rinse technique.

Achieved environmental benefits

Higher recovery of drag-out. Can be part of closing the loop for specific process steps.

Cross-media effects

Reduction in the need for cooling systems.

Possible aggressive fume formation at higher operating temperatures in some processes.

Extraction of the vapours from the process is part of the evaporation. The extracted air may need scrubbing. Scrubbing liquors may be treated in a typical waste water treatment plant. Decomposition products are concentrated, so additional solution maintenance is required

Operational data

Evaporation is most readily used with process solutions working at elevated temperatures, in particular chromium electrolytes. In connection with multistage rinsing technology (in practice up to five rinsing stages), the procedure can be operated almost waste water free. Sufficient evaporation can occur at an ambient temperature. In hexavalent chromium plating, chromic acid dragged out from the process bath into the rinses is virtually completely recovered to the solution. Minimum chromium acid losses are to be expected through the exhaust air and with the regeneration of the electrolytes.

Evaporation can be increased by using air agitation and/or an evaporator to increase the surface area

Applicability

All process solutions, particularly those with poor electrical efficiency where the process solution heats and is often cooled by evaporation. Hexavalent chromium electrolytes are particularly suitable for this technique. May also be used with chemical solutions with a high heat of reaction. Regional weather patterns may also affect applicability.

Economics

Requires little or no capital installation.

Example plants

Surface treatment of metals plants.

Increasing drag-out recovery rate and closing the loop

BAT is to install an evaporator system in preference to a cooling system where the energy balance calculation shows a lower energy requirement for forced evaporation than for additional cooling and the solution chemistry is stable.

Brief technical description

Where the quantity of water needed for appropriate rinsing (to achieve process control and product quality) exceeds evaporation losses, and recovery rates>90 % are expected, the amount of water in the drag-out recovery system has to be decreased. This is achieved by a combination of techniques.

In some cases, drag-out can be recovered until the loop can be closed for process chemicals by applying a suitable combination of techniques. Closing the loop refers to one process chemistry within a process line, not to entire lines or installations.

Closed loop is not zero discharge: there may be small discharges from the treatment processes applied to the process solution and process water circuits (such as from ion exchange regeneration). It may not be possible to keep the loop closed during maintenance periods.

Wastes and exhaust gases/vapours will also be produced. There are also likely to be discharges from other parts of the process line, such as rising after degreasing or etching.

Increasing drag-out recovery can best be considered with other processes and activities, such as recycling and re-using water and an overall approach derived for the installation.

Increasing drag-out recovery and closing the loop require techniques to:

- reduce drag-out,
- reduce rinse-water (such as by cascade rinsing and/or sprays) with drag-out recovery
- concentrate the returning drag-out or receiving solutions, such as by ion exchange, membrane techniques, or evaporation. The water removed during concentration (such as from evaporation) can often be recycled back into the rinse.

Examples of techniques for this purpose are, for example:

- addition of an eco rinse tank,
- evaporation using surplus internal energy,
- evaporation using additional energy (and in some cases, low pressure),
- electrodialysis,
- reverse osmosis.

It is BAT to conserve process materials by returning the rinse-water from the first rinse to the process solution. This can be achieved by a combination of the techniques such as: cascade rinsing, ion exchange, membrane techniques, evaporation.

Closed loop is not zero discharge: there may be small discharges from the treatment processes applied to the process solution and process water circuits (such as from ion exchange regeneration). It may not be possible to keep the loop closed during maintenance periods.

Wastes and exhaust gases/vapours will also be produced. There may also be discharges from other parts of the process line.

Closing the loop achieves a high raw material utilisation rate and in particular can:

- reduce the use (and therefore cost) of raw materials and water,
- as a point-source treatment technique, achieve low emission limit values,
- reduce the need for end-of-pipe waste water treatment (e.g. removing nickel from contact with effluent containing cyanide),
- reduce overall energy usage when used in conjunction with evaporation to replace cooling systems,
- reduce the use of chemicals for treating the recovered materials that would otherwise be discharged in the waste water,
- reduce the loss of conservative materials such as PFOS where used.

Achieved environmental benefits

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- reduce the need for end-of-pipe waste water treatment (e.g. removing nickel from contact with effluent containing cyanide),
- reduce overall energy usage when used in conjunction with evaporation to replace cooling systems,
- reduce the use of chemicals for treating the recovered materials that would otherwise be discharged in the waste water,
- reduce the loss of conservative materials such as PFOS where used.

Cross-media effects

Energy is used for concentration techniques, although this is less for processes that gain heat from the electrochemical reactions, such as hexavalent Cr(VI). Energy is also used for pumping and pressure filtration techniques.

Operational data

It is good practice to consider increased drag-out recovery with other options for the whole installation. These can include combining compatible streams from different processes for purification/recovery.

Applicability

Increasing drag-out recovery is widely practised. Some techniques require additional energy, which means cost, which may be offset by savings in cooling energy and drag-out recovery. The chemical content of the rinse-water to be processed also affects the appropriate choice.

Closing the loop has been successfully achieved on some substrates for:

- precious metals,
- cadmium,
- barrel nickel plating,
- copper, nickel and hexavalent chromium for decorative rack plating,

- hexavalent decorative chromium,
- hexavalent hard chromium,
- etching copper from PCBs.

The type of system installed will depend on the existing infrastructure, and plant as well as the process type.

Economics

Capital and running costs of the techniques may be offset by increased recovery of process chemicals, which can be >95%. Also, these techniques can reduce running costs and/or investment in a waste water treatment plant. Extra steps cause a loss in process line capacity (an increase in the number of cycles).

Planning calculations can be assisted by software tools.

Driving force for implementation

Reduced costs.

Example plants

Surface treatment of metals plants.

Modulation of air and water flow

Low direct energy consumption by the cooling system is achieved by reducing resistance to water and/or air in the cooling system, by applying low energy equipment. Where the process to be cooled demands variable operation, modulation of air and water flow has been successfully applied and can be considered BAT.

Achieved environmental benefits

Reduction of direct energy consumption.

Operational data

Identify required cooling range.

Example plants

Plants using cooling system.

Optimization of internal/external heat reuse

Reduction of the level of heat discharge by optimization of internal/external heat reuse.

Brief technical description

A preventive approach should start with the industrial process requiring heat dissipation and aim to reduce the need for heat discharge in the first place. In fact, discharge of heat is wasting energy and as such not BAT. Reuse of heat within the process should always be a first step in the evaluation of cooling needs. Process-integrated energy measures are outside the scope of this document, but reference is made to other BAT Reference Documents drafted in the framework of IPPC describing options for energy measures.

In a greenfield situation, assessment of the required heat capacity can only be BAT if it is the outcome of maximum use of the internal and external available and applicable options for reuse of excess heat.

In an existing installation, optimizing internal and external reuse and reducing the amount and level of heat to be discharged must also precede any change to the potential capacity of the applied cooling system. Increasing the efficiency of an existing cooling system by improving systems operation must be evaluated against an increase of efficiency by technological measures through retrofit or technological change. In general and for large existing cooling systems, the improvement of the systems operation is considered to be more cost effective than the application of new or improved technology and can therefore be regarded as BAT.

Achieved environmental benefits

Reduction of the level of heat discharge.

Example plants

Plants using cooling system.

Reduction of water consumption and reduction of heat emissions to water

Recirculation of cooling water, using an open or closed recirculating wet system.

Brief technical description

The reduction of water consumption and the reduction of heat emissions to water are closely linked and the same technological options apply.

The amount of water needed for cooling is linked to the amount of heat to be dissipated. The higher the level of reuse of cooling water, the lower the amounts of cooling water needed.

Recirculation of cooling water, using an open or closed recirculating wet system, is BAT where the availability of water is low or unreliable.

In recirculating systems an increase of the number of cycles can be BAT, but demands on cooling water treatment may be a limiting factor.

It is BAT to apply drift eliminators to reduce drift to less than 0.01% of the total recirculating flow.

Achieved environmental benefits

Reduction of direct energy consumption.

Example plants

Plants using cooling system.

Use of a once-through systems

To achieve a high overall energy efficiency when handling large amounts of low level heat (10-25°C) it is BAT to cool by open once-through systems. In a greenfield situation this may justify selection of a (coastal) site with reliable large amounts of cooling water available and with surface water with sufficient capacity to receive large amounts of discharged cooling water.

Brief technical description

The site-imposed limits apply particularly to new installations, where a cooling system must still be selected. If the required heat discharge capacity is known it may influence the selection of an appropriate site. For temperature-sensitive processes it is BAT to select the site with the required availability of cooling water.

In terms of the overall energy efficiency of an installation, the use of a once-through systems is BAT, in particular for processes requiring large cooling capacities (e.g. > 10 MWth). In the case of rivers and/or estuaries once-through can be acceptable if also:

- extension of heat plume in the surface water leaves passage for fish migration;
- cooling water intake is designed aiming at reduced fish entrainment;
- heat load does not interfere with other users of receiving surface water.

For power stations, if once-through is not possible, natural draught wet cooling towers are most energy-efficient than other cooling configurations, but application can be restricted because of the visual impact of their overall height.

Achieved environmental benefits

Reduction of direct energy consumption.

Operational data

Select site for once-through option for large cooling capacity.

Example plants

Plants using cooling system.

2.3.3 Design, operating and control

Use of a once-through systems

On-line monitoring of the current and voltage of electrolytic processes.

Brief technical description

Process control techniques that are designed to measure and maintain optimum parameters such as temperature, pressure, gas components and other critical process parameters etc are considered to be BAT.

The use of feed weighing and metering systems, the use of microprocessors to control material feed-rate, critical process and combustion conditions and gas additions allow process operation to be optimised. Several parameters can be measured to allow this and alarms provided for critical parameters, which include on-line monitoring of the current and voltage of electrolytic processes.

Operators, engineers and others should be continuously trained and assessed in the use of operating instructions, the use of the modern control techniques and the significance of alarms and the actions to be taken when alarms are given.

Optimisation of levels of supervision to take advantage of the above and to maintain operator responsibility.

Achieved environmental benefits

Energy saving.

Example plants

Non Ferrous Metals Industries.

2.3.4 Drying, separation and concentration processes

Drying using air knives

It is BAT to prevent the loss of metals and other raw materials together.

Brief technical description

Air knives can be used to remove excess oil and grease from parts. They are low pressure, high volume systems where air is emitted through precision slits, giving a laminar air curtain, through which components can be passed, either manually or on a conveyor belt. The air heats up due to compression and movement in the system, and this warms oils and greases, assisting their removal. Both the laminar air movement and the temperature also facilitate drying of components.

There is a growing use of localised air drying by means of precision nozzles or 'air knives' that is more energy efficient than hot air tank drying.

Achieved environmental benefits

Energy saving.

Example plants

Surface treatment of metals plants.

2.3.5 Electric motor driven sub-systems

Lubrication, adjustments, tuning

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   - prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   - electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20% of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Lubrication, adjustments, tuning.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 1-5%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

All cases.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

As a result, an EEM has a higher efficiency but also a lower slip frequency (which results in more rpm) and a higher starting current from the power supply than a motor of standard efficiency. The following examples show cases where using an EEM is not the optimum solution:

- when a HVAC system is working under full load conditions, the replacement of an EEM increases the speed of the ventilators (because of the lower slip) and subsequently increases the torque load. Using an EEM in his case brings about higher energy consumption than by using a motor of standard efficiency. The design should aim not to increase the final rpm,
- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings,
- if the application has to start and stop frequently, the savings may be lost because of the higher starting current of the EEM,
- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20% higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

• payback period can be as short as 1 year or less with AC drives

• high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM)

where:

- costHEM = cost of the new high efficiency motor
- costold = cost of rewinding the old motor
- costelectricity = cost of electricity
- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control,
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date),
2. Heinz food processing factory (UK) a new energy centre will be 14% more efficient due to combustion air fans controlled by AC drives. The energy centre has four boilers and has replaced the existing boiler plant.

Motor repair (EEMR) or replacement with an EEM

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   - prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   - electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20% of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Motors above 5 kW can fail and are often repaired several times during their lifetime.

Laboratory testing studies confirm that poor motor repair practices reduce motor efficiency of typically between 0.5 and 1%, and sometimes up to 4% or even more for old motors.

To choose between repair and replacement, electricity cost/kWh, motor power, average load factors and the number of operating hours per year will all have to be taken into account. Proper attention must be given to the repair process and to the repair company, which should be recognised by the original manufacturer (an energy efficient motor repairer, EEMR).

Typically, replacement of a failed motor through the purchase of a new EEM can be a good option in motors with a large number of operating hours. For example, in a facility with 4000 hours per year of operation, an electricity cost of EUR 0.06/kWh, for motors of between 20 and 130 kW, replacement with an EEM will have a payback time of less than 3 years.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 0,5-2%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

At time of repair.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application

designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

As a result, an EEM has a higher efficiency but also a lower slip frequency (which results in more rpm) and a higher starting current from the power supply than a motor of standard efficiency. The following examples show cases where using an EEM is not the optimum solution:

- when a HVAC system is working under full load conditions, the replacement of an EEM increases the speed of the ventilators (because of the lower slip) and subsequently increases the torque load. Using an EEM in his case brings about higher energy consumption than by using a motor of standard efficiency. The design should aim not to increase the final rpm,
- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings,
- if the application has to start and stop frequently, the savings may be lost because of the higher starting current of the EEM,
- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20% higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

• payback period can be as short as 1 year or less with AC drives
• high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM)

where:

- costHEM = cost of the new high efficiency motor
- costold = cost of rewinding the old motor
- costelectricity = cost of electricity
- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control,
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date),
2. Heinz food processing factory (UK) a new energy centre will be 14 % more efficient due to combustion air fans controlled by AC drives. The energy centre has four boilers and has replaced the existing boiler plant.

Optimisation of electric motors

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s) is part of (e.g. cooling system),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Electric motors are widely used in industry. Replacement by electrically efficient motors (EEMs) and variable speed drives (VSDs) is one of the easiest measures when considering energy efficiency. However, this should be done in the context of considering the whole system the motor sits in, otherwise there are risks of:

- losing the potential benefits of optimising the use and size of the systems, and subsequently optimising the motor drive requirements,
- losing energy if a VSD is applied in the wrong context.

Achieved environmental benefits

Improve energy efficiency.

Applicability

The key systems using electric motors are:

- compressed air,
- pumping,
- heating, ventilation and air conditioning,
- cooling.

Power quality control

BAT is to optimise electric motors in the following order:

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2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Public electrical power is supplied via high voltage grids where the voltage and current vary in sine wave cycles at 50 Hz (in Europe) in three phases at 120 ° intervals. The voltage is high to minimise current losses in transmission. Depending on the equipment used, the voltage is stepped down on entering the site, or close to specific equipment, usually to 440 V for industrial use, and 240 V for offices, etc.

Various factors affect the delivery and the use of energy, including the resistance in the delivery systems, and the effects some equipment and uses have on the supply. Stable voltages and undistorted waveforms are highly desirable in power systems.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 0,5-3%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

Lifetime cost benefit.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

As a result, an EEM has a higher efficiency but also a lower slip frequency (which results in more rpm) and a higher starting current from the power supply than a motor of standard efficiency. The following examples show cases where using an EEM is not the optimum solution:

- when a HVAC system is working under full load conditions, the replacement of an EEM increases the speed of the ventilators (because of the lower slip) and subsequently increases the torque load. Using an EEM in his case brings about higher energy consumption than by using a motor of standard efficiency. The design should aim not to increase the final rpm,
- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings,
- if the application has to start and stop frequently, the savings may be lost because of the higher starting current of the EEM,
- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

• payback period can be as short as 1 year or less with AC drives
• high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM)

where:

- costHEM = cost of the new high efficiency motor
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- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control,

- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date),
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Proper motor sizing

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3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Electrical motors are very often oversized for the real load they have to run. Motors rarely operate at their full-load point. In the European Union, field tests indicate that, on a verage, motors operate at around 60% of their rated load.

The maximum efficiency is obtained for the motors of between 60 to 100% full load. The induction motor efficiency typically peaks near 75 % full load and is relatively flat down to the 50% load point. Under 40% full load, an electrical motor does not work at optimised conditions and the efficiency falls very quickly. Motors in the larger size ranges can operate with reasonably high efficiencies at loads down to 30% of rated load.

Proper sizing:

- improves energy efficiency, by allowing motors to operate at peak efficiency
- may reduce line losses due to low power factors
- may slightly reduce the operating speed, and thus power consumption, of fans and pumps.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 1-3%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

Lifetime cost benefit.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application

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For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

As a result, an EEM has a higher efficiency but also a lower slip frequency (which results in more rpm) and a higher starting current from the power supply than a motor of standard efficiency. The following examples show cases where using an EEM is not the optimum solution:

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- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings,
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- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

• payback period can be as short as 1 year or less with AC drives
• high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM)

where:

- costHEM = cost of the new high efficiency motor
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- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control,
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date)
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Rewinding

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s) is part of (e.g. cooling system),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Rewinding a motor is idely carried out in industry. It is cheaper and may be quicker than buying a new motor. However, rewinding a motor can permanently reduce its efficiency by more than 1 %. Proper attention must be given to the repair process and to the repair company, which should be recognised by t he original manufacturer (an energy e fficient motor repairer, EEMR). The extra cost of a new motor can be quickly compensated by its better energy efficiency, so rewinding may not be economic when considering the life-time cost.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

At time of repair.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

As a result, an EEM has a higher efficiency but also a lower slip frequency (which results in more rpm) and a higher starting current from the power supply than a motor of standard efficiency. The following examples show cases where using an EEM is not the optimum solution:

- when a HVAC system is working under full load conditions, the replacement of an EEM increases the speed of the ventilators (because of the lower slip) and subsequently increases the torque load. Using an EEM in his case brings about higher energy consumption than by using a motor of standard efficiency. The design should aim not to increase the final rpm
- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings,
- if the application has to start and stop frequently, the savings may be lost because of the higher starting current of the EEM
- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

- payback period can be as short as 1 year or less with AC drives
- high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM)

where:

- costHEM = cost of the new high efficiency motor
- costold = cost of rewinding the old motor
- costelectricity = cost of electricity
- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date)

2. Heinz food processing factory (UK) a new energy centre will be 14% more efficient due to combustion air fans controlled by AC drives. The energy centre has four boilers and has replaced the existing boiler plant.

Transmission losses

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s) is part of (e.g. cooling system),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Transmission equipment including shafts, belts, chains, and gears should be properly installed and maintained. The transmission system from the motor to the load is a source of losses. These losses can vary significantly, from 0 to 45 %. When possible, use synchronous belts in place of V-belts. Cogged V-belts are more efficient than conventional V-belts. Helical gears are much more efficient than worm gears. Direct coupling has to be the best possible option (where technically feasible), and V-belts avoided.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 2-10%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

Lifetime cost benefit.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application

designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

For instance, EEMs include more material (copper and steel) than motors of a lower efficiency.

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- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

- payback period can be as short as 1 year or less with AC drives
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Using energy efficient motors (EEM)

BAT is to optimise electric motors in the following order:

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2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Energy efficient m otors (EEMs) and high efficiency motors (H EMs) offer greater energy efficiency. The additional initial purchase cost may be 20 - 30 % or higher for motors of greater than 20 kW, and may be 50 - 100 % higher for motors under 15 kW, depending on the energy savings category (and therefore the amount of additional steel and copper use) etc. However, energy savings of 2 - 8 % can be achieved for motors of 1 - 15 kW.

As the reduced losses result in a lower temperature rise in the motor, the lifetime of the motor winding insulation, and of the bearings, increases. Therefore, in many cases:

- reliability increases
- downtime and maintenance costs are reduced
- tolerance to thermal stresses increases
- ability to handle overload conditions improves
- resistance t o abnormal operating c onditions under and overvoltage, phase unbalance, poorer voltage and current wave shapes (e.g. harmonics), etc. – improves
- power factor improves
- noise is reduced.

A European-wide agreement between the European Committee of Manufacturers of Electrical Machines and Power lectronics (CEMEP) and the uropean Commission ensures that the efficiency levels of most electric motors manufactured in Europe are clearly displayed. The European motor classification scheme is applicable to motors < 100 k W and basically establishes three efficiency classes, giving motor manufacturers an incentive to introduce higher efficiency models:

- EFF1 (high efficiency motors)
- EFF2 (standard efficiency motors)
- EFF3 (poor efficiency motors).

These efficiency levels apply to 2 and 4 pole three phase AC squirrel cage induction motors, rated for 400 V, 50 Hz, with S1 duty class, with an output of 1.1 to 90 kW, which account for the largest sales volume on the market.

The Eco Design (EuP) Directive is likely to eliminate motors in class EFF 3 and EFF 2 by 2011. The International Electrotechnical Comission (IEC) is, at the time of writing, working on the introduction of a new international classification scheme, where the EFF2 and EFF# motors are together at the bottom, and above EFF1 there will be a new premium class.

An a ppropriate motor choice can be greatly aided through the use of adequate computer software, such as Motor Master Plus29 and EuroDEEM30 proposed by the EU-SAVE PROMOT project.

Appropriate motor solutions may be selected by using the EuroDEEM database31, which collates the efficiency of more than 3500 types of motors from 24 manufacturers.

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 2-8%. Although the valuesare typical, the applicability of the measures will depend on the specific characteristics of the installation.

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

Lifetime cost benefit.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application designs from parts replacement in existing applications. Thea ssessment conclusions will identify the measures which are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

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- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%

- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

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- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

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Best practices

ELECTRIC MOTOR AND PUMP

<u>Description</u>

An electric motor is used to operate a pump that provides cooling water for a cooling system. The combination of motor and pump is regarded here as one sub-system.

The output value of this sub-system is the hydraulic power in the form of cooling water flow and pressure. Due to the low efficiency of the pump, the output value is limited to 45 kW.

The old pump is replaced by a new one, thereby increasing the pump efficiency from 50 to 80%. The efficiency of the new sub-system is much higher than the previous one. The hydraulic power has increased from 45 to 67 kW. The increase in energy efficiency can be shown as:

EEF = efficiency/reference efficiency = 75/47 = 1.60 (i.e. 60 % improvement in energy efficiency)

NEW ELECTRIC MOTOR AND NEW PUMP WITH CONSTANT OUTPUT VALUE

<u>Description</u>

The cooling system worked satisfactorily even at a hydraulic power of 45 kW. The benefit of an increase of the hydraulic power by 50 % to 67 k W is not clear, and the pumping losses may now have been transferred to a control valve and the piping system. This was not the intended aim of replacing the components by more energy efficient alternatives.

A comprehensive study of the cooling system may have shown that a hydraulic power of 45 kW was sufficient, and in this case, the shaft power can be estimated at 45/0.8 = 56 kW. The electric power needed to drive the motor would then be about 56/0.937 = 60 kW.

In this case, the power input was 40 kW lower than before. The efficiency remains at 75%, but the power consumption from System 1 (old motor and, presumably, old pump) is reduced by 40%, and from System 2 (new motor, new pump) reduced by 33%.

The assessment could have investigated whether it was possible to reduce the size of both the motor and the pump without harmful effects on the cooling, or to reduce the required hydraulic power to, e.g. 20 k W. This may have reduced the capital shown an energy efficiency improvement.

Variable speed drives

BAT is to optimise electric motors in the following order:

1. optimise the entire system the motor(s) is part of (e.g. cooling system),
2. then optimise the motor(s) in the system according to the newly-determined load requirements,
3. when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according to criteria such as:
   i. prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs,
   ii. electric motors driving a variable load operating at less than 50% of capacity more replacement with EEMs than 20 % of their operating time, and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

The adjustment of the motor speed through the use of variable speed drives (VSDs) can lead to significant energy sav ings associated to better process control, less wear in the echanical equipment and less acoustical noise. When loads vary, VSDs can reduce electrical energy consumption particularly in centrifugal pumps, compressors and fan applications typically in the range of 4 -50%. Materials processing applications like centrifugal machines, mills and machine tools, as well as materials handling applications such as winders, conveyors and elevators, can also benefit both in terms of energy consumption and overall performance through the use of VSDs.

The use of VSDs can also lead to other benefits including:

- extending the useful operating range of the driven equipment
- isolating motors from the line, which can reduce motor stress and inefficiency
- accurately synchronising multiple motors
- improving the speed and reliability of response to changing operating conditions.

VSDs are not applicable for all applications, in particular where the load is constant (e.g. fluid bed air input fans, oxidation air compressors, etc.), as the VSD will lose 3 - 4% of the energy input (rectifying and adjusting the current phase).

Achieved environmental benefits

Potentially significant energy savings measures which might be applicable to a motor driven sub-system are 4-50%. Although the values are typical, the applicability of the measures will depend on the specific characteristics of the installation.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Operational data

Harmonics caused by speed controllers, etc. cause losses in motors and transformers. An EEM takes more natural resources (copper and steel) for its production.

Applicability

Use of VSDs may be limited by security and safety requirements.

According to load. Note in multi-machine systems with variable load systems (e.g. CAS) it may be optimal to use only one VSD motor.

Electric motor drives exist in practically all industrial plants, where electricity is available.

The applicability of particular measures, and the extent to which they might save money, depend upon the size and specific nature of the installation. An assessment of the needs of the entire installation and of the system within it can determine which measures are both applicable and profitable. This should be done by a qualified drive system service provider or by qualified in-house engineering staff. In particular, this is important for VSDs and EEMs, where there is a risk of using more energy, rather than savings. It is necessary to treat new drive application

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- when a HVAC system is working under full load conditions, the replacement of an EEM increases the speed of the ventilators (because of the lower slip) and subsequently increases the torque load. Using an EEM in his case brings about higher energy consumption than by using a motor of standard efficiency. The design should aim not to increase the final rpm
- if the application runs less than 1000 - 2000 hours per year (intermittent drives), the EEM may not produce a significant effect on energy savings (see Economics)
- if the application has to start and stop frequently, the savings may be lost because of the higher starting current of the EEM
- if the application runs mainly with a partial load (e.g. pumps) but for long running times, the savings by using EEM are negligible and a VSD will increase the energy savings.

Economics

The price of an EEM motor is about 20 % higher than that of a convetional one. Over its lifetime, approximate costs associated with operating a motor are:

- Energy 96%
- Maintenance 1,5%
- Investment 2,5%

When buying or repairing a motor, it is really important to consider the energy consumption and to minimise it as follows:

- payback period can be as short as 1 year or less with AC drives
- high efficiency motors need a longer payback on energy savings.

Calculating the payback for this energy efficient technique, e .g. buying a higher efficiency motor compared to rewinding a failed standard motor:

Payback (in years) = (Cost HEM - Cost old)/[H x kW x Cost electricitye x (1/N rewinded - 1/ N HEM) where:

- costHEM = cost of the new high efficiency motor
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- costelectricity = cost of electricity
- kW = average power drawn by motor when running.

Driving force for implementation

- AC drives are often installed in order to improve the machine control
- other factors are important in the selection of motors: e.g. safety, quality and reliability, reactive power, maintenance interval.

Example plants

1. LKAB (Sweden) this mining company consumes 1700 gigawatt hours of electricity a year, 90 per cent of which is used to power 15 000 motors. By switching to high efficiency motors, LKAB cuts its annual energy bill by several hundred thousand dollars (no date),
2. Heinz food processing factory (UK) a new energy centre will be 14 % more efficient due to combustion air fans controlled by AC drives. The energy centre has four boilers and has replaced the existing boiler plant.

2.3.6 Electrical power supply

DC supply

It is BAT to reduce electricity consumption by:

- reduction the voltage drop between conductors and connectors by minimising the distance between the rectifiers and anodes (and conductor rolls in coil coating). The installation of the rectifiers in direct proximity of the anodes is not always realisable or may subject the rectifiers to sever corrosion and/or maintenance. Alternatively, bus bars with larger cross-sectional area can be used,
- keeping the bus bars short, with sufficient cross-sectional area, and keep cool, using water cooling where air cooling is insufficient,
- regularly maintaining rectifiers and contacts (bus bars) in the electrical system,
- installing modern electronically-controlled rectifiers with a better conversion factor than older types,
- increasing of conductivity of process solutions through additives and by maintenance of solutions.

Brief technical description

Energy savings can be attained through:

- reduction of voltage drop in conductors and connectors
- regular maintenance of rectifiers and contacts (bus bars) in the electrical supply system
- installation of modern rectifiers having a better conversion factor than older types, when run at maximum power
- increasing conductivity of process solutions through additives, e. g. sulphuric acid in acid copper baths, and by maintenance of solutions, such as lowering the iron and the trivalent chromium content in hard chromium baths

- modified wave forms (e.g. pulse, reverse) which may improve metal deposits. This is widely used in PCB plating

Achieved environmental benefits

In total, an energy saving in DC supply of 10 – 20% may be expected.

Cross-media effects

Higher concentrations in solutions means higher drag-out of materials.

Economics

Lower power consumption and therefore lower costs.

Driving force for implementation

Cost savings associated with saving 10 – 20% of DC supply.

Example plants

Surface treatment of metals plants.

Energy efficient equipment

It is BAT to reduce electricity consumption by install modern electronically-controlled rectifiers with a better conversion factor than older types.

Brief technical description

It is good practice to install energy efficient equipment, such as energy efficient motors.

Achieved environmental benefits

Power saving.

Reduction in energy consumption on the line.

Cross-media effects

None.

Applicability

Depending on the size of the unit and energy consumption, the use of energy efficient motors is good practice for large applications. They can be specified for new installations, for the replacement for defective motors or for cost savings.

Can be used in new plant or as replacement parts.

Economics

For large scale applications.

The initial investment is medium: EUR 0.015 – 0.8/t installed. Operating costs are low EUR 0.001 to 0.15/t.

Driving force for implementation

Cost saving. Process efficiency.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Example plants

Surface treatment of metals plants. Many continuous electroplating lines.

Energy efficient motors - power factor correction

BAT is to increase the power factor according to the requirements of the local electricity distributor.

Brief technical description

Many electrical devices have inductive loads. These all require both active electrical power and reactive electrical power. The active electrical power is converted into useful mechanical power, while the reactive electrical power is used to maintain the device's magnetic fields. This reactive electrical power is transferred periodically in both directions between the generator and the load (at the same frequency as the supply). Capacitor banks and buried cables also take reactive energy.

Vector addition of the real (active) electrical power and the reactive electrical power gives the apparent power. Power generation utilities and network operators must make this apparent power a vailable and transmit it. This means that generators, transformers, power lines, switchgear, et c. must be sized for greater power ratings than if the load only drew active electrical power.

Power supply utilities (both on-site and off-site) are faced with extra expenditure for equipment and additional power losses. External suppliers, therefore, make additional charges for reactive power if this exceeds a certain threshold. Usually, a certain target power factor of cos of between 1.0 and 0.9 (lagging) is specified, at which point the reactive energy requirement is significantly reduced.

(Electrical) power factor = Real power/Apparent power

For example, using the power triangle, if:

real power = 100 kW and apparent power = 142 kVAr, then the power factor = 100/142 = 0.70

This indicates that only 70 % of the current provided by the electrical utility is being used to produce useful work.

If the power factor is corrected, for example by installing a capacitor at the load, this totally or partially e liminates the reactive power draw at the power supply company. Power factor correction is at its most effective when it is physically near to the load and uses state-of-the-art technology.

The power factor can change over time so needs to be checked periodically (depending on site and usage, and these checks can be anything from 3 to 10 years apart), as the type of equipment and the supplies listed (above) change over time. Also, as capacitors used to correct the power factor deteriorate with time, these also require periodic testing (most easily carried out by checking if the capacitors are getting warm in operation).

Other measure to take is:

- to minimise operation of idling or lightly loaded motors
- to avoid operation of equipment above its rated voltage
- to replace standard motors as they burn out with energy efficient motors
- even with energy efficient motors, however, the power factor is significantly affected by variations in load. A motor must be operated near of a high power factor design.

Achieved environmental benefits

Energy savings to both the supply side and the consumer.

Across the EU as a whole, it has been estimated that if a power correction factor for industry was applied, then 31 TWh power could be saved, although part of this potential has been exploited. This is calculated on the basis that the EU-25's total electricity consumption industry and service sector in 2002 was 1788 TWh, from which industry used 65%).

In an installation, it is estimated that if an operator with a power correction factor of 0.73 corrected the factor to 0.95, they would save 0.6% of their power usage (0.73 is the estimated figure for industry and services).

Cross-media effects

None reported.

Operational data

An uncorrected power supply will cause power losses in an installation's distribution system.

Voltage drops may occur as power losses increase. Excessive drops can cause overheating and premature failure of motors and other inductive equipment.

Applicability

At time of replacement.

Economics

External suppliers may make additional charges for excessive reactive electrical power if the correction factor in the installation is less than 0.95.

The cost of power correction is low. Some new equipment (e.g. high efficiency motors) addresses power correction.

Driving force for implementation

- power savings both inside the installation and in the external supply grid (where used)
- increase in internal electrical supply system capacity
- improved equipment reliability and reduced downtimes.

Example plants

Widely applied.

Harmonics

BAT is to check the power supply for harmonics and apply filters if required.

Brief technical description

Certain electrical equipment with non-linear loads causes harmonics in the supply (the addition of the distortions in the sine wave). Examples of non-linear loads are rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched mode power supplies, computers, etc.

Filters can be applied to reduce or eliminate harmonics. The EU has set limits on harmonics as a method of improving the power factor, and there are standards such as EN 61000-3-2 and EN 61000-3-12, requiring switched power supplies to have harmonics filters.

Achieved environmental benefits

Power savings.

Cross-media effects

None reported.

Operational data

Harmonics can cause:

- nuisance tripping of circuit breakers
- malfunctioning of UPS systems and generator systems
- metering problems
- computer malfunctions
- overvoltage problems.

Harmonics cannot be detected by standard ammeters, only by using 'true RMS' meters.

Applicability

All sites should check for equipment causing harmonics.

Economics

Losses due to equipment malfunction.

Driving force for implementation

- improved reliability of equipment
- reduced losses in downtimes
- with harmonics, reduced current in earths
- the safety issues of design grounding being exceeded if harmonics are present.

Example plants

Widely applied.

High voltage and large current demands

It is BAT to reduce electricity consumption by:

- minimising reactive energy losses for all three phase supplies by testing at annual intervals to ensure that cos l between the voltage and the current peaks lies permanently above 0.95,
- keeping the bus bars short, with sufficient cross-sectional area, and keep cool, using water cooling where air cooling is insufficient,
- usage of individual anode feeding by bus bar with controls to optimise current setting.

Brief technical description

Incoming supply should be managed to match phases, minimise reactive energy losses on step down from high voltage and supply large current demand, etc.

On a large site, the energy is supplied at 150 kV and is rectified to 0.033 kV for use in the galvanic cells. Typical rectifying operations involve the following steps:

- step 1: two high tension transformers drop the voltage from 150 kV to 15 kV
- step 2: 15 feeding cells drop the voltage for the rectifiers from 15 kV to 525 V
- step 3: 60 rectifiers (one per anode, four per galvanic cell) drop the voltage from 525 V to 33 V. Rectification is through thyristor bridges, transformers and diode bridges
- step 4: supply to 15 galvanic cells. The length of the copper bus bars is short and water cooled to minimise the resistance losses. This is achieved through:

- a very short distance between the rectifiers and the conductor rolls and anodes
- the connection of the conductor rolls and anodes through one (the same) side of the cells
- the individual anode feeding allows an optimal current setting

- step 5: compensation for the reactive energy.

Any AC electrical equipment such as transformers, motors etc., absorbs a total energy called the apparent energy. This is made up of active energy (in the form of work or heat) and reactive energy which is unproductive. The reactive energy increases if the current is out of phase in relation to the voltage, and is the difference between the voltage and the current wave peaks.

The power factor (cos l) of an electrical device is the ratio of the active power P (kW) over the apparent power S (kVA) and is the cosine of the angle between the peaks of the sine curves of voltage and current. The closer cos l is to unity (1), the more efficient the use of power; the lower cos l value, the less effectively the energy is used. When cos l lies permanently above 0.95, the reactive energy losses at 15 kV and 150 kV levels are limited.

Achieved environmental benefits

Minimises energy losses.

Applicability

All installations using a three-phase supply. Power correction and reduction of reactive energy requires skilled review of power demands and correction.

All installations using electrolytic processes can ensure reduction of resistance losses in power supplies.

Economics

Energy losses as unwanted heating, reactive energy, etc. increase power consumption and cause higher costs.

Driving force for implementation

Cost saving.

Example plants

Surface treatment of metals plants.

Optimising process electrical efficiency

It is BAT to reduce electricity consumption by use modified wave forms (e.g. pulse, reverse) to improve metal deposits, where the technology exists.

Brief technical description

Addition of conducting chemical compounds to the electrolyte to increase the electrical conductivity.

Achieved environmental benefits

Reduces electrical power consumption. Environmental benefit is high compared with cost.

Applicability

To new and existing lines. This requires technical support, either in-house or from the supplier.

Economics

For coil plating, the initial investment is EUR 0.001 to maintenance costs of EUR 0.001 to 0.15/t installed.

Driving force for implementation

Process efficiency and cost.

Example plants

Many continuous electroplating plants, surface treatment of metals plants.

Optimising supply

BAT is to optimise the power supply efficiency.

Brief technical description

Resistive losses occur in cabling. Equipment with a large power usage should, therefore, be supplied from a high voltage supply as close as possible, e .g. the corresponding transformer should be as close as possible.

Cables to equipment should be oversized to prevent unnecessary resistance and losses as heat. The power supply can be optimised by using high efficiency equipment such as transformers. Ensure power cables have the correct dimensions for the power demand.

Achieved environmental benefits

Improve energy efficiency.

Cross-media effects

No data submitted.

Operational data

- all large equipment using power should be planned to be adjacent to supply transformers,
- cabling should be checked on all sites and oversized where necessary.

Applicability

- improved reliability of equipment,
- reduced losses in downtimes,
- consider the costs on an operating lifetime basis.

When the equipment is not in use, e.g. at shutdown or when locating or relocating equipment.

Economics

Savings in equipment downtime and power consumption.

Driving force for implementation

Cost.

Example plants

Widely used.

Transformers

BAT is to optimise the power supply efficiency by:

- keeping online transformer(s) operating at a load above 40 - 50 % of the rated power,
- usage high efficiency/low loss transformers,
- placing equipment with a high current demand as close as possible to the power source (e.g. transformers).

Achieved environmental benefits

Less consumption of secondary energy resources.

Operational data

Normally in transformer substations there is a surplus of electrical power supply installed, and therefore the average load factor is generally low. Historically, utilities managers maintain this surplus to ensure a continuing power supply in the case of failure of one or more of the transformers.

Applicability

- for existing plants: when the present load factor is below 40%, and there is more than one transformer,
- on replacement, use a low loss transformer and with a loading of 40 - 75%.

At time of replacement, or where there is a lifetime cost benefit.
When locating or relocating equipment

Economics

In the case of the installation of low loss transformers with respect to 'normal series' transformers, or in substitution of low efficiency transformers operating at present, payback times are normally short, considering that transformers operate for a high number of hours/year.

Driving force for implementation

Energy and money savings are the driving force for implementation.

Example plants

For the refurbishment of a transformer room, foreseeing the installation of four new transformers whose electric power is 200, 315, 500 and 1250 kVA, a payback time of 1.1 years has been estimated.

2.3.7 Processes

2.3.7.1 Anodising

Cold sealing

It is BAT to prevent the loss of metals and other raw materials together.

Brief technical description

Sealing methods at lower temperatures have been developed. So-called mid-temperature sealing processes are also available operating at about 60 °C. These are not based on the hydrothermal conversion of aluminium oxide for closing the pores, but by the use of nickel salts, such as the fluoride or silicate. In the past, in the European market, there was some concern about long term-properties such as light fastness and corrosion resistance. However, such processes have now been proven and accredited for outside use.

There are also processes working at 25 - 35 °C. Advantages with cold processes are lower energy consumption and shorter process times.

Achieved environmental benefits

Hot sealing may also require ventilation and have very high energy consumption. However, this can be reduced by covering the tanks or with proper insulation. There is lower energy consumption with cold sealing.

Example plants

Surface treatment of metals plants.

2.3.7.2 Degreasing

Substitution and choices for degreasing

Solvent degreasing can be replaced by other techniques in all cases in this sector as subsequent treatments are water-based and there are no incompatibility issues. There may be local reasons at an installation level for using solvent-based systems, such as where:

- a water-based system can damage the surface being treated,
- there a specific customer has a specific quality requirement.

Brief technical description

Solvent degreasing is usually by means of chlorinated hydrocarbons (CHC), alcohols, terpenes, ketones, mineral spirits or hydrocarbons.

CHCs are used because of their good cleaning efficiency and universal applicability, as well as their quick drying and incombustibility, but their use is restricted by environmental and health legislation. All solvents affect the central nervous system and exposure should be controlled.

There are two types of process:

- cold cleaning: The workpieces and/or substrates are immersed in the solvent or cleaned in a stream of solvent. In some cases, the solvent is pumped round taking the liquid from near the top of a holding tank, leaving dirt to settle at the bottom. The tank is cleaned periodically
- vapour phase: The solvent is vaporised in a purpose-built bath and the cold component suspended in the vapour. The vapour condenses on the component dissolving grease and drained off with the dirt and grease, leaving the component clean and dry. The most common solvents are CHCs. As the vapours are heavier than air they are contained in the bath. Hydrocarbon solvent may be used.

The choice of solvents will depend on a number of factors including the substrate to be cleaned, the type of oil or grease to be removed, the previous manufacturing process and the requirements of the subsequent surface treatments. Chlorinated ethanes and ethylenes attack aluminium and should not be brought into contact with substrate, tanks, containers, valves, etc. made of aluminium. Dichloroethylenes in contact with copper should be avoided under all circumstances as explosive acetylides may be formed.

Chlorinated solvents have no flashpoints. Ketones and mineral spirits may be used, but are flammable. Higher hydrocarbons with a narrow distillation range give the highest flashpoints commensurate with solvent drying from the workpieces and/or substrate.

Achieved environmental benefits

Low heat consumption.

Cross-media effects

Because of the classification of certain CHCs as potentially carcinogenic materials, their water-endangering potential and problems with emissions to the air and their use is strongly regulated. Alternative solvents are inflammable.

Operational data

Good cleaning efficiency, quick drying.

Applicability

Almost universally applicable.

Driving force for implementation

Used for high specification work, e.g. some aerospace or military applications.

Used where water-based treatments can damage the surface being treated.

Example plants

Have been widely used. Surface treatment of metals plants.

Weak emulsion degreasing

BAT is to reduce the use of chemicals and energy in aqueous degreasing systems by using long-life systems with solution regeneration and/or continuous maintenance, off-line or on-line

Brief technical description

This is a variation of chemical aqueous degreasing, using a more easily maintained solution.

Surface-active agents used in weak emulsion degreasing solutions are developed chemically so they do not form a stable emulsion with the removed oils and greases. The degreasing tanks are drained to a holding tank (usually for a group of degreasing tanks) for the removal of floating oils and sediments. Weak emulsion cleaning solution separates by itself, so that simple mechanical systems (skimmers) can be used for the removal of the oil. By the continuous removal of contamination via the holding tank and feedback of the cleaned degreasing solutions in the bath, a high service lifetime is achieved.

Weak emulsion degreasing systems offers thereby a compromise between the two requirements for degreasing systems:

- a smaller (but still sufficiently high) oil-absorbing capacity than strongly emulsifying egreasing baths;
- they can be substantially more easily regenerated and re-used.

The type of systems to be used can be derived from these characteristics.

Achieved environmental benefits

Minimisation of chemical and power consumption in cleaning.

Cross-media effects

Small additional power consumption required for pumping and oil recovery.

Operational data

The advantage of a weak emulsion system is that the solution is constantly being refreshed by having the oil removed.

Weak emulsion degreasing can leave grease/oil films on the panels of barrels - especially from the first bath. This film can be carried through all the vats in the plant. The grease/oil films from cleaners with weak emulsions can block ion-exchanger resins and membranes for membrane processes if these are used for recirculating rinses in the plant. These effects do not exist with stable emulsions.

Applicability

Numerous cases are known in practice, where the conversion to a weak emulsion degreasing systems has given satisfactory cleaning.

Workpieces with strongly adhering pollution or with very viscous oils or grease on the surface cannot be cleaned by weak emulsion systems.

Strongly emulsifying systems have better degreasing capabilities, but are more difficult to regenerate. It is advisable to determine applicability on a case by case basis.

Economics

The investment in this type of plant may be high particularly if taken in conjunction with the maintenance options. A complex investment is only likely to be cost-effective if the process line and the amounts of oil and grease involved are large.

Driving force for implementation

Improved down-stream process control.

Example plants

Surface treatment of metals plants.

2.3.7.3 Electrolytic

Optimisation of the anode-cathode gap. Continuous coil – large scale steel coil

Optimise the anode-cathode gap for electrolytic processes.

Brief technical description

A mechanism of adjusting the gap as a function of the processed strip to be processed (width-thickness-flatness).

Achieved environmental benefits

Optimisation of the energy consumption, reduction of the contacts between anode and strip surface, increasing quality and cutting strip rejections.

Cross-media effects

None.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Applicability

To new lines.

Economics

The initial investment is EUR 0.001 to 0.15/t installed with operating and maintenance costs of EUR 0.001 to 0.15/t.

Driving force for implementation

Process efficiency, reduced energy consumption.

Example plants

Many continuous electroplating plants.

2.3.7.4 Electroplating

Decorative chromium plating

Plating systems such as for hexavalent chromium are a significant investment and include specific equipment such as anodes, as well as the solutions. The solution cannot simply be changed for different customer batches. However, to minimise the amounts of hexavalent chromium, it is possible to use a cold chromium technique and where there is more than one decorative hexavalent chromium process line in the same installation, the option exists to run one or more one lines for hexavalent specifications and one or more lines with trivalent chromium.

When changing to trivalent or other solutions, it is BAT to check for complexing agents.

Brief technical description

A new technique using 'cold chromium' has been put into production in 2000 in an Italian plant.

The temperature of the processing bath with Cr(VI) is kept at about 18–19°C by a refrigeration system (instead of 25–30°C). At this temperature, the concentration of Cr(VI) the process solution may be reduced by about 50%. The quality of plating is the same.

Achieved environmental benefits

Minimisation of hexavalent chromium released.
Minimisation of evaporation of process solution evaporation.
Less energy used in the process.
Reduction of exposure to workers.
Reduction of water consumption.
Less waste water treatment required and less sludge produced.

Cross-media effects

Additional energy required for refrigeration. It is not clear how this compares with the energy savings in the process.

Operational data

Less concentrated solutions require a longer time for processing.
Better quality because of better throwing power.
No white edges.

Applicability

The technique may only be suitable for application in a new plant.

Example plants

Surface treatment of metals plants.

Different electrode yields

In electroplating, where the anode efficiency is higher than the cathode efficiency and the metal concentration is constantly increasing, it is BAT to control the metal concentration according to the electrochemistry by:

- external dissolution of the metal, with electroplating using inert anodes. Currently, the main application is for alkaline cyanide-free zinc plating,
- replacing some of the soluble anodes by membrane anodes with separate extra current circuit and control. Membrane anodes are breakable, and it may not be possible to use this technique in sub-contract plating, where the shapes and sizes of parts to be plated vary continuously (and may make contact with and break membranes),
- using of insoluble anodes where the technique is proven.

Brief technical description

The simple concept of electrolytic metal deposition is that the concentration of the metal ions in the solution remains constant because the metal anode dissolves at the same rate as deposition. However, in reality, there are frequently different electrode efficiencies at the anode and cathode. A higher anodic yield leads to an increase of the metal ion concentration. This can be found with certain electrolytes, such as nickel and zinc solutions. There are options for dealing with this problem, which may be used alone or together. Problems are discussed under Applicability, below:

- where solution electrochemistry allows, use insoluble anodes with external dissolution of the metal and controlled solution strength,
- replace some of the soluble anodes by membrane anodes with an extra current circuit,
- special insoluble anodes that allow the concentration of the solution to balanced,
- run workpieces or substrates requiring higher thickness coatings,
- 'plating out' on steel sheet,
- removing anodes.

Achieved environmental benefits

Minimisation of energy usage and waste of process metal in drag-over.
Reduction of plating over the required specification thickness.
Reduction in environmental effects from reworking due to problems with over-plating.

Cross-media effects

Additional equipment is required where external dissolution tanks are used, or membrane circuits and/or separately controlled additional circuits.

Operational data

All techniques may improve process control. Use of external make-up tanks or process additions requires increased process quality control and maintenance.

Applicability

Many electrolytic processes, including zinc, can utilise insoluble electrodes and use external make-up tanks, or separate solution additions. An inert anode system with external make up requires additional investment but addresses the problem consistently over time.

Running workpieces or substrates requiring higher thickness coatings and 'plating out' on steel sheet, only works with soluble anodes. 'Current efficiency' may then become too high. The right balance of specifications for workpieces (i.e. combination of thicker and thinner coating thickness requirements) may not coincide with the need to remove excess dissolved metal, especially for jobbing shops.

Removing anodes: the anodic current density must be considered. This can lead to anode passivation and/or increased electrolytic decomposition of process solution constituents. The reduced current density reduces throughput and takes more time to reduce the process solution metal concentration.

Plating out does not recover anode metal. However, electrolytic selective plating using low current densities can be used to remove unwanted contaminating metals, for example from nickel baths with soluble Ni anodes.

In practice, nickel processes cannot utilise insoluble electrodes.

Membrane anodes are breakable, and it may not be possible to use this technique in sub-contract plating, where the shapes and sizes of parts to be plated vary continuously (and may make contact with and break membranes). Membrane anodes are also limited by current density.

Economics

Investment in an inert anode system with external make-up or using membrane anodes with a separate circuit is usually self-financing through materials saving and improved process quality.

Other options are cheaper in the short term, but lack long-term consistency and savings, and if relied on regularly, may give more quality problems (and hence cost) than they resolve.

Driving force for implementation

Process economics.

Process uniformity over time and reduction in reworking.

Example plants

Surface treatment of metals plants.

Trivalent chromium chloride-based electroplating process

For decorative uses, it is BAT to replace hexavalent chromium either by plating with trivalent chromium. Where increased corrosion resistance is required, this can be achieved by trivalent chromium solution with increased nickel layer underneath and/or organic passivation for Cr(III) chloride based solutions.

Brief technical description

Bright trivalent chromium electroplating electrolytes are based on chromium III compounds, such as sulphate or chloride, together with proprietary chemicals. The electrolyte contains only about 20 g/l of the trivalent chromium, compared with about 200 g/l of chromic acid in the hexavalent chromium process.

Currently, trivalent chromium can only be used for decorative finishes, and cannot replace hexavalent chromium for hard chrome plating.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

The use of trivalent chromium eliminates the carcinogenic and other hazards associated with hexavalent chromium in the workplace. Fume extraction and scrubbing, or fume suppressant are not required for hexavalent chromium. However, additives are required to prevent the formation of free chlorine and AOX.

The lower electrolyte concentration has a lower viscosity than the hexavalent electrolyte. This results in better draining of plated parts, and subsequently less drag-out, less loss of electrolyte, less effluent treatment required and less chromium-containing waste being produced.

Achieved environmental benefits

The plating bath runs at a concentration of 20 g/l instead of 200 to 450g/l for hexavalent chromium. Reduced solution viscosity means less chromium dragged-out, and a reduction of chromium released: Cr(VI) is not released. Solutions can be chloride- or sulphate-based.

In three case studies, the following were found:

- reduced or no hexavalent chromium compounds to store, handle or were in use
- in conjunction with electrolytic removal of chromium (as hydroxide), waste water treatment sludge reduced from 20 tonnes per year to 2 tonnes per year in one case, and there was thirty times less sludge in another
- about 30% reduced power consumption
- no chemicals required for metals reduction
- no surfactants required to prevent mist formation
- the plating baths can be recovered using porous pots, membrane electrolysis or ion exchange
- air pollution treatment requirements reduced.

Lower health and environmental problems for Cr(III) to 0.05 mg/m^3 for Cr(VI).

Cross-media effects

Problems have been reported in waste water treatment plant caused by complexing agents used in Cr (III) solutions. However, these have not been confirmed on site visits or in the case studies.

Operational data

The colour of the Cr(VI) deposit is described as blue-bright, the chloride trivalent deposit varyingly as grey-bright, yellow-bright or dark-bright. These historic problems with colour differences to deposits from hexavalent chromium and variations during processing compared with hexavalent chromium have largely been overcome by new solutions. These colour problems, and poor solution reliability and life, have long been overcome: it is crucial to use carbon filtration and ion exchange, or proprietary solution treatment processes, as well as minimising carry-over from previous processes.

Trivalent chromium solutions containing chloride can theoretically produce chlorine at the anode and hence AOX in the solutions, which could be dragged-out. In practice this has been controlled for 20 years by the addition of proprietary chemicals.

Requires training of staff and increased process control, which is similar to that required for bright nickel, which is used for the preceding layers.

Thicknesses can be measured by the same equipment (e.g. Couloscope, X-ray diffraction).

Higher current efficiency means higher loading of racks and 15% increase in throughput has been reported.

Lower current density requires lighter, less expensive racks and wiring.

Reject rate reduced from 5 - 10 % to 0.5 % due to Cr(III)'s better throwing power, higher current capacity and less susceptibility to ripples in supply, reducing rough deposits (i.e. burning in high current density areas) and reduced 'whitewashing' from plating interruption.

Applicability

It cannot replace hard chromium plating.

It cannot replace certain corrosion resistance applications, such as where the CASS requirement is greater than 16 h. Trivalent chromium does not passivate unplated surfaces. Lower corrosion resistance has been reported, which is likely to be due to areas of no or low nickel thickness.

Where hollow or recessed components (such as tubes) are plated, care is needed to prevent corrosion post-plating. This includes rapid and thorough rinsing of the acid bath, and possibly followed by passivation in a proprietary organic solution (validation from industry practitioners internationally) or a light Cr(VI) passivation (this mitigates some of the advantages of a Cr(VI)-free system).

The colour is a slightly yellow hue when compared directly to parts plated by hexavalent chromium. Cases have been reported of this being a problem to specific customers.

Colour and corrosion resistance has been accepted in major retail uses, such as cookers, on components subject to high temperatures and abrasive cleaners with strong caustic and acid components.

This has successfully been used with no loss of customer confidence

Economics

One-off costs include disposal of old hexavalent chromium solution, replacing lead vat lining with PVDF and replacing lead/antimony anodes with carbon. An ion exchange system is required for controlling metal contamination, and the resin requires changing at approximately three year intervals. The base chemicals are more expensive.

These are more than offset by:

- a 30 % saving in energy,
- a reduction in solid waste produced and disposed,
- reduced effluent treatment costs (no Cr(VI) to reduce),
- reduced air monitoring,
- reduced staff medical monitoring,
- reduced reject rate,
- a significantly reduced risk of employee ill health.

One case study reports an overall gross profit improvement of USD 182 per shift of 670 m2 from a jig plating line (1995 costs).

Driving force for implementation

Reduced risk to employee health. Reduces health and safety requirements, as well as expenditure on aerosol suppression, air extraction, monitoring for hexavalent chromium in the workplace atmosphere, as well as medical monitoring of staff. Cost-effective overall.

Example plants

Surface treatment of metals plants.

Best practices

SUBSTITUTION BY TRIVALENT CHROMIUM PLATING FOR HEXAVALENT CHROMIUM IN HARD CHROMIUM APPLICATIONS USING MODIFIED PULSE CURRENT

Description

The process uses a simplified trivalent chromium electroplating solution based on chromium sulphate. The current waveform is proprietary (patents pending) and includes pulse-reverse current.

Chromium has been deposited at up to 250µm successfully and could be deposited to any thickness. Hardness, rate of deposition and post-finishing for thick coatings are the same as for chromium from hexavalent solutions. Colour for thin layers is the same (chrome-blue) as from hexavalent chromium. The process retains the advantages of Cr III solutions, such as lower concentrations, higher current efficiency and tolerance to sulphate and chloride dragged-in from any previous nickel plating stages. Lack of organic additives will reduce or eliminate solution maintenance with activated carbon.

Achieved environmental benefits

Replaces hexavalent chromium solutions, with reduced waste gas and waste water treatments.

Solution concentrations are the same as existing Cr(III) chemistry and up to ten times lower than Cr(VI) solutions.

Higher current efficiency, therefore less power consumption.

No chloride electrolyte, so no production of chlorine.

Requires no organic additives to suppress chlorine formation, or such as PFOS to suppress mist formation or to improve throw, etc.

A further stage of development will confirm if it can be operated as a closed loop system.

Operational data: Status of development

The process has been patented and is at pre-production verification in three key projects:

- comparative testing (against Cr(VI) plated components) of 11" (28cm) rotors for pumps handling abrasive slurries (such as in mining, oil exploration and cement handling). Completion in Spring 2004
- rollers in large-scale steel rolling mill. Completion in Summer 2004
- compliance with military specifications through an approved Commercial Technology for Maintenance Activity (CTMA) project involving the US Department of Defence and military maintenance depots with the National Centre for Manufacturing Sciences (Michigan, US; CTMA promotes new techniques which reduce health, safety and environmental risks in military applications). Completion in 2005.

Applicability

Intended applicability is full replacement of Cr(VI) electroplating for hard chromium treatments.

Economics

Likely future operating costs: The system is chromium sulphate based, which is currently slightly more expensive than existing CrIII chemistry (increased usage may reduce market price). However, no organic additives are used, reducing cost and maintenance. Electricity costs are likely to be half of present costs. Reduced effluent treatment chemicals, and possible reduction in waste produced.

Likely future capital costs: Power supply: up to double the cost of a traditional DC supply.

Reduced requirements for waste gas and waste water treatment equipment.

Driving force for implementation

The development of alternatives to using hexavalent chromium electroplating solutions is driven by health and safety in the workplace and environmental toxicity (chromium metal plated on a surface has no adverse health effects).

SUBSTITUTION BY CHROMIUM (III) CONVERSION COATINGS FOR CHROMIUM (VI) CONVERSION LAYERS

Description

Hexavalent chromium chemicals, such as chromic acid, are frequently used in surface finishing. The main applications are:

- decorative chromium plating
- hard chromium plating
- chromic acid anodising
- chromate conversion coatings.

Hexavalent chromium has been classified as carcinogenic by inhalation, and regulations apply to its use in processes. It is a priority substance for the US EPA to minimise use and release, as well as restrictions on the use of hexavalent chromium products. Chromium trioxide is being reviewed by the EU and is likely to be raised in status from toxic to very toxic. This may trigger the lower threshold requirements of the Seveso II Directive where over five tonnes are used.

In addition, only chromate films containing hexavalent chromium may release Cr(VI) during the handling and the usage of the finished product. There are no contact problems with metallic chromium on finished workpieces from any process (hexavalent or a trivalent.

Any zinc-plated part is usually post-treated with a suitable chromate conversion process as well as many substrates (such as die-castings). The colour of the finishes of existing hexavalent chromium conversion processes and the level of their corrosion protection is directly in relation to their thickness and to their hexavalent chromium content.

Because of these environmental and health and safety concerns, European directives limit the amount of hexavalent chromium left in the product in the automotive, electrical and electronic industries. This is the driving force for innovative hexavalent chromium-free technologies. Various EU R&D projects are nearing conclusions on Cr(VI) management.

Achieved environmental benefits

Reduction of Cr(VI) in waste water discharges.

Cross-media effects

Higher process temperature and energy use. May require additional organic (lacquer) layer. The complexing agents may have adverse effects in waste water treatment plant.

Operational data: Status of development

In a research project, supported by the Ministry of Science and Research, SurTech GmbH developed a procedure for the production of 300 nm thick chromium (III) layers on electroplated iron (called Chromitierung). The conversion layer is completely free of hexavalent chrome and has a greenish appearance. This green colour (caused by interference bands) disappears after adding an organic layer. The thickness of the "Chromitierung" layer is reached by a high chrome concentration in the solution, an increased operating temperature of 60 °C and the employment of suitable complex ligands. By using dark pigments into the conversion layer of the "Chromitierung" it can be given a black colour comparable to the black Cr(VI) chromate finishing. Workpieces electroplated with nickel or cobalt can also be treated with chromium (III) layers.

In salt spray tests the corrosion protection of both systems is approximately equal.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Driving force for implementation

The development of alternatives to using hexavalent chromium electroplating solutions is driven by health and safety in the workplace and environmental toxicity (chromium metal plated on a surface has no adverse health effects).

In addition to occupational health issues associated with the use of Cr(VI), the use of Cr(VI) as a passivation (conversion) layer is under pressure because of its restriction in new vehicles by the ELV Directive and its banning in electrical and electronics applications by the RoHS directive

Zinc electroplating - Acid zinc

It is BAT to substitute zinc cyanide solutions by using acid zinc for optimum energy efficiency, reduced environmental emissions and for bright decorative finishes.

Brief technical description

Zinc and zinc alloy coatings are the most widely used electrolytic surface treatment, providing corrosion resistance and/or cheap decorative coating to a very wide variety of iron and steel items for the automotive, construction and other industries.

For example, they are used for steel sheet or wire, screws, washers, nuts, bolts, shopping trolleys, construction frames (chassis) and casings for domestic appliances (such as washing machines) and many other kinds of applications.

Acid zinc electrolytes give bright decorative layers, and used, for example, on furniture frames, shopping trolleys and baskets. In conjunction with post-treatments, they provide corrosion resistance comparable with finishes from alkaline-type electrolytes. Metal distribution is poor to acceptable, but this improves with warm electrolytes.

Electrolytes contain zinc chloride (30 – 55 g zinc/l), potassium and/or sodium chloride (130 - 180 g/l), boric acid (10 – 40 g/l) and wetting agent. Only soluble anodes are used. The solutions have good conductivity and high cathode efficiency, typically 93 - 96 %. It has a lower energy demand than alkali processes.

Achieved environmental benefits

Current efficiency of the electrolyte means lower power consumption.

Cross-media effects

Increased sludge production, from dissolution of some of steel substrates and with soluble anodes. May require fume extraction for acid mists, but not necessary for chloride-based solutions. However, extraction is advisable.

Operational data

Needs to be preceded by high quality degreasing systems. Needs skilled process control and management. Soluble and insoluble anodes can be used instead of only soluble ones, giving better quality control.

Applicability

The metal distribution is poor to acceptable, increasing with warm electrolytes.

Economics

Large savings in power consumption.

Example plants

Surface treatment of metals plants.

2.3.7.5 Extracted air

Reduction of heating losses from process solutions in the surface treatment industries

It is BAT to reduce heating losses by:

- seeking opportunities for heat recovery
- reducing the amount of air extracted across the heated solutions
- optimising the process solution composition and working temperature range. Monitor temperature of processes and control within these optimised process ranges.
- insulating heated solution tanks by one or more of the following techniques:
  - o using double skinned tanks
  - o using pre-insulated tanks
  - o applying insulation
- insulating the surface of heated tanks by using floating insulation sections such as spheres or hexagonals. Exceptions are where:
  - o workpieces on racks are small, light and may be displaced by the insulation
  - o workpieces are sufficiently large to trap the insulation sections (such as vehicle bodies)
  - o the insulation sections can mask or otherwise interfere with the treatment in the tank.

It is not BAT to use air agitation with heated process solutions where the evaporation caused increases the energy demand.

There are limited options to substitute for PFOS and health and safety may be a particularly important factor. Where PFOS is used, it is BAT to minimise the use by minimising air emissions by using floating insulation sections.

Brief technical description

It is normal practice to minimise heating losses from process solutions but actual techniques used may depend on the options to re-use heat, the availability of renewable energy supplies and local climatic conditions.

Temperatures of heated processes can be monitored manually or automatically (according to the size and energy demand of the vat being heated), with automatic and/or lockable controls.

Energy losses from the surface area of heated process solutions related to processing temperatures demonstrates that the highest energy loss occurs from the solution surface with air extraction and with liquid agitation. Air extraction above the surface of process solutions enhances evaporation and thus the energy loss. Techniques to reduce the volume of warm air extracted and reduce energy losses by evaporation.

Where there is a temperature range for a process, the temperature can be controlled to minimise the energy input:

- operating temperature of process solutions that require heating may be reduced,
- processes that require cooling may be operated at higher temperatures.

Heated process tanks can be insulated to reduce heating losses by:

- using double skinned tanks
- using pre-insulated tanks
- applying insulation.

Floating spheres are widely used to insulate the solution surface without restricting the access of workpieces or substrates. They allow jigs, barrels, coils or individual components to pass between them.

Process solutions may be heated by energy coming from process steps generating energy. Water from the cooling circuit of various process solutions may be used to heat lower temperature solutions, incoming air, etc. Alternatively, the hot cooling water is collected in a central tank and cooled through a suitable heat pump. The gain in energy may be used to heat process solutions with process temperatures up to 65 °C, or to heat up water for other purposes.

Achieved environmental benefits

Energy saving.

Reduction of the volume of extracted air reduces energy consumption and any required treatment processes, chemicals, etc.

Operational data

Seek technical support when changing operating temperatures changes to processes.

Applicability

To all heated solutions.

Reducing the operating temperature of solutions will depend on support from the proprietary process suppliers or in-house expertise in developing solutions or processes that are viable at lower or higher temperature ranges. It may also be a factor in choice of process solution chemistry.

Many solutions have a narrow operating range, and cannot be operated outside of these. Other optimal operating factors may have to be considered, such as processing time.

In anodising, the heat of spent seal solutions can be used to heat the water used for a new sealing process, using a heat exchanger or piping the incoming cold water through the hot seal solution.

In automatic lines, floating spheres may be carried to the rinsing tanks by barrels or by components. The spheres may block pipes and cause malfunctions for pumps and transport tubes. This can be limited to some extent by the choice of size of spheres and installing simple coarse screens to critical pipework and equipment. The spheres can cause tidiness problems in the workplace by being carried outside of the tanks. The system can be used in manual lines, and in automatic plants.

Attention needs to be paid to energy efficiency in all installations using air extraction.

Process control is feasible for all installations. Other options will be site-specific.

Where the processing line is enclosed, the maintenance of the plant and solutions may become more complicated and time-consuming This technique is likely to be most effective with new installations, rather than retrofitting.

Economics

Applicable to all heated solutions.

Floating spheres are cheap.

Capital investment for sophisticated heat-exchange systems may be high.

Case-specific, but they are Example Plant where the operational savings gave a two year payback, and one year payback if capital savings are included.

Driving force for implementation

Cost saving and process quality control.

Example plants

Surface treatment of metals plants.

Best practices

REDUCTION OF THE VOLUME OF EXTRACTED AIR

Description

The most common system uses extraction hoods located laterally to the entrance area for plating jigs on flight bars and plating barrels above processing vats. The efficiency of the air extraction is determined by the minimal air velocity (vx) necessary to capture the uprising vapour, fumes or aerosols at the most distant point from the extraction hood.

There are three options to reduce the volume of extracted air:

1. Reduction of free surface area above tanks:

Lids hinged to the tank, driven individually and automatically opening and closing when jigs and barrels enter and leave the processing tank are another appropriate but more expensive design. Usually this system is combined with a device designed to automatically increase the volume of extracted air when the lids are opened. A reduction in extraction rate of up to 90 % may be achieved.

2. Push-pull system

This method is designed to create an airflow over the surface of the processing bath. It works with an extraction hood opposite a blowing duct. The surface of the processing solution must not have any frame or obstacle to the airflow. Therefore its application remains quite limited.

3. Enclosure of the plating line

Recently, the complete segregation of the process plant has been achieved in some installations.

The plating line is installed inside an enclosure, while all plant operations, the plant management systems, and the loading/unloading stations are located outside.

Since a substantial amount of extracted air is still necessary to prevent corrosion of the equipment within the enclosure, an energy saving higher than the figures for other techniques cannot be expected.

Achieved environmental benefits

Reduction of the volume of extracted air reduces energy consumption and any required treatment processes, chemicals, etc.

Applicability

Attention needs to be paid to energy efficiency in all installations using air extraction. Process control is feasible for all installations. Other options will be site-specific.

Where the processing line is enclosed, the maintenance of the plant and solutions may become more complicated and time-consuming This technique is likely to be most effective with new installations, rather than retrofitting.

Economics

Case-specific, but sometimes the operational savings gave a two year payback, and one year payback if capital savings are included.

Driving force for implementation

Health and safety in the work place.

Exemple Plant

Goodrich Aerospace Landing Gear Division, Tullahoma, Tennessee, US

2.3.7.6 *Pickling*

Extension of the service life of pickling solutions by diffusion dialysis

Where consumption of acid for pickling is high, it is BAT to extend the life of the acid by using diffusion dialysis.

Brief technical description

If the concentration of the metal salts in the pickling solution, formed by dissolution, becomes too high, no more pickling effect can be achieved even with further addition of acid. At this point, the pickling bath is useless and is usually discarde. Further use of the pickling solution is possible only by selective separation of the dissolved metal salts.

Diffusion dialysis separates acid from its metal contaminants via an acid concentration gradient between two solution compartments (contaminated acid and deionised water) that are divided by an anion exchange membrane. Acid is diffused across the membrane into the deionised water whereas metals are blocked due to their charge and the selectivity of the membrane. A key difference between diffusion dialysis and other membrane technologies such as electrodialysis or reverse osmosis is that diffusion dialysis does not employ an electrical potential or pressure across the membrane. Rather, the transport of acid is caused by the difference in acid concentration on either side of the membrane. As such, the energy requirements for this technology are low.

Achieved environmental benefits

Extension of service life of the chemical process solution.

Lower power consumption than techniques using pressure

Cross-media effects

The concentration of recovered acid will normally be lower than that of the feed acid, and make-up acid must be added to bring the concentration up to the process level. When the feed has a significant salt concentration, the concentration of recovered acid can exceed the concentration of the feed acid.

The depleted acid waste stream (after diffusion dialysis processing) is approximately equal in volumetric flow to the waste acid influent. Depending on the application-specific acid removal and metals rejection rates, the depleted acid waste stream (retentate) typically contains 5 to 20% of the acid and 60 to 95% of the metals from the influent waste acid stream. This stream is usually sent to waste water treatment.

Operational data

To prevent mechanical blocking, pickling acids must be pre-filtered before using dialysis.

For diffusion dialysis processing, an increase in membrane area per unit of acid flow increases the acid recovery rate. If the flowrate of DI water increases, the acid recycling rate increases and the recycled acid concentration decreases.

Diffusion dialysis systems can be used for batch or continuous flow applications. Small systems are often configured as mobile units.

Limitations in using diffusion dialysis to recover surface finishing process acids include:

- acids not highly dissociated (e.g., phosphoric acid) will not diffuse across the membrane
- complexed metal anions (e.g., fluorotitanium anions) can readily diffuse across the anion exchange membrane and are not efficiently separated from the acid.

Cooling is typically needed if influent waste acid temperature exceeds 50 °C.

Heating may be needed for low temperature influent waste acid. A temperature drop of 2 °C reduces the acid recycling rate by approximately 1.5%.

Solvents can cause membrane swelling.

Strong oxidising substances (e.g., chromic acid) can cause membrane deterioration.

Applicability

Diffusion dialysis is a purification/recycling technology that can be used to maintain or reclaim spent or contaminated acids where acid concentrations are greater than 3 % by weight.

Diffusion dialysis is most typically used where contaminant metals concentrations are less than 1 gram per litre. Surface finishing process solutions amenable to the use of diffusion dialysis include:

- hydrochloric acid (HCl) pickle and strip solutions
- sulphuric acid (H_2SO_4) anodising solutions
- sulphuric acid pickle and strip solutions
- nitric acid (HNO_3) pickle and strip solutions
- nitric acid/hydrofluoric acid (HNO_3/HF) stainless steel pickling solutions
- hydrochloric acid/sulphuric acid (HCl/H_2SO_4) aluminium etch solutions
- methane sulphonic acid (MSA) solutions.

Economics

Diffusion dialysis may be expensive in capital and running costs for simple applications, and complex to run. The most cost-effective use for it may be, for example:

- where there is significant use of the more expensive and/or concentrated acids (e.g. phosphoric),
- in expensive etching techniques such as methyl sulphonic acid used with tin and tin/lead.

Driving force for implementation

Process consistency and quality.

Reduction in fresh acid, waste acid treatment or disposal costs.

Example plants

Surface treatment of metals plants.

2.3.8 Pumping systems

Optimalisation of pumping systems

BAT is to optimise pumping systems by:

- minimising of the number of valves and bends commensurate with keeping ease of operation and maintenance,

- avoiding using too many bends (especially tight bends),
- ensuring the pipework diameter is not too small (correct pipework diameter).

Brief technical description

The pipework system determines the choice of the pump performance. Indeed, its characteristics have to be combined with those of the pumps to obtain the required performance of t he pumping installation.

The energy consumption directly connected to the piping system is the consequence of the friction loss on the liquid being moved, in pipes, valves, and other equipment in the system.

This loss is proportional to the square of the flowrate. Friction loss can be minimised by means such as:

- avoiding the use of too many valves,
- avoiding the use of too many bends (especially tight bends) in the piping system,
- ensuring the pipework diameter is not too small.

Achieved environmental benefits

Save energy

Some studies have shown that 30 to 50% of the energy consumed by pumping systems could be saved through equipment or control system changes.

Cross-media effects

None reported.

Operational data

Note that throttle control is less energy wasteful than bypass control or no control. However, all are wasteful of energy and should be considered for replacement according to size of the pump and how frequently it is used.

Applicability

All cases at design and installation (including changes). May need qualified technical advice.

The applicability of particular measures, and the extent of cost savings depend upon the size and specific nature of the installation and system. Only an assessment of a system and the installation needs can determine which measures provide the correct cost-benefit. This could be done by a qualified pumping system service provider or by qualified in-house engineering staff.

The assessment conclusions will identify the measures that are applicable to a system, and will include an estimate of the savings, the cost of the measure, as well as the payback time.

Economics

Pumping systems often have a lifespan of 15 to 20 years, so a consideration of lifetime costs against initial (purchase) costs are important.

Pumps are typically purchased as individual components, although they provide a service only when operating as part of the system, so a consideration of the system is important to enable a proper assessment of the cost-benefit.

Driving force for implementation

Energy and cost savings.

Example plants

The optimisation techniques are widely used.

2.3.9 Rinsing

Regeneration by reverse osmosis – closed loop electroplating

It is BAT to reduce water consumption by using multiple rinsing

Eco-rinse can be combined with other rinse stages to increase effectiveness of the multiple rinsing system.

The reference value for water discharged from the process line using a combination of BAT to minimise water usage is 3 – 20 l/m². The value may be calculated to relate to other throughput factors (such as weight of metal deposited, weight of substrate throughput, etc) at individual installations.

Brief technical description

Rinsing water can, in some cases, be regenerated by reverse osmosis.

Reverse osmosis (RO) uses a hydrostatic pressure gradient across a semi-permeable membrane to separate water from a solution of salts. The pressure applied exceeds the osmotic pressure of the feed solution causing water to flow from the concentrated solution to the more dilute solution: the reverse of the natural osmotic diffusion. Dissolved solids are rejected by the membrane surface. Many multi-charged ions can be rejected at rates exceeding 99%. Single-charged ions typically have rejection rates in the range of 90 - 96%.

Achieved environmental benefits

The achieved environmental benefits are more than just a reduction in water usage and extend to energy savings and a significant reduction in chemical use in waste water treatment.

Cross-media effects

Construction and operation of the ion exchanger with consumption of energy and regeneration chemicals. The salt content of the residual water is high and may be difficult to treat in a typical waste water treatment plant. The membranes also need rinsing with fresh water.

Operational data

Reverse osmosis is used in the surface finishing industry for purifying rinse-water and for ecovery of chemicals from rinse-waters. It has also been used to purify raw water for the generation of high-quality deionised water in rinsing and plating solutions. Reverse osmosis applications involving the separation of plating chemical drag-out from rinse-water have been applied mainly to nickel plating operations (sulphamate, fluoborate, Watts and bright nickel). Other common applications include copper (acid and cyanide) and acid zinc. Recently, RO has been applied successfully to chromate rinse-water. In the typical configuration, the RO unit is operated in a loop with the first rinse following plating. The concentrate stream is recycled to the plating bath and the permeate stream is recycled to the final rinse. Reverse osmosis is commonly used for water treatment(with and without ion exchange) applications requiring production of high-quality water from high total dissolved solids (TDS) sources. Large scale waste water recycling is evolving as an important application for RO in the surface finishing industry.

Membrane performance of all polymer-based membranes decreases over time and permeate flow (flux) and membrane rejection performance are reduced. RO membranes are susceptible to fouling by organics, water hardness, and suspended solids in the feed stream or materials that precipitate during processing. Installing prefilters can control solids in the feed stream. Changing operational parameters, such as pH, inhibits precipitation. Oxidising chemicals like peroxide, chlorine and chromic acid can also damage polymer membranes. Acid and alkaline solutions with concentrations greater than 0.025 molar can also deteriorate membranes. In most applications, the feed solution will have significant osmotic pressure that must be overcome by the hydrostatic pressure. This pressure requirement limits the practical application of this technology to solutions with total dissolved solids concentrations below approximately 5000 ppm (with the exception of disc tube applications). Specific ionic levels in the concentrate must be kept below the solubility product points to prevent precipitation and fouling. Ionic species differ with respect to rejection percentage. Some ions such as borates exhibit relatively poor rejection rates for conventional membranes.

Applicability

The water to be treated may not be suitable or may need pretreatment because of solids or undissolved particles, organics, calcium, aluminium and heavy metals

Economics

Payback can be short.

Example plants

Surface treatment of metals plants.

Best practices

DISFLEX

<u>Description</u>

Nickel is deposited on a flexible support before decorative chromium plating. Water from the first cascade rinsing is recovered. This water is rich in nickel because of the drag-out, and is passed through activated carbon and it is sent to a buffer tank. The solution is pumped at 20 bars pressure through the membranes of the reverse osmosis unit. The recovered nickel solution is returned to the treatment bath and the water is reintroduced in the first stage of the cascade rinsings.

The process conditions are:

- nickel bath temperature: 60 °C
- nickel bath volume: 6000 l
- nickel bath concentration: 80 g/l
- five cascade rinsing tanks, volume: five tanks at 400 litres
- buffer tank volume (after activated carbon and before reverse osmosis):300 litres

Nickel concentration of the different cascade rinsings to judge the system efficiency:

- nickel bath = 80g/l
- rinse 1 Ni = 6.3 g/l
- rinse 2 Ni = 1.6 g/l
- rinse 3 Ni = 0.54 g/l
- rinse 4 Ni = 0.250 g/l (250 mg/l)
- rinse 5 Ni = 0.065 g/l (65 mg/l).

The size of the reverse osmosis unit is not large and comprises two blocks of membranes each one metre long.

Benefits:

* Recovery of nickel solution, both metal and other additives.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

* Reduced waste water treatment costs.
* Reduced water consumption.

Economics for this example:
o electric consumption of the pump: 2.5 kWh
o membrane maintenance costs (change and cleaning): EUR 2000 for 3 years
o monitoring of the system (in time and manpower), levels control and filters cleaning:
o 1 hour each day
o cost of a reverse osmosis unit: EUR 30 000.

Other driving forces for implementation:

There is no loss of nickel to solid waste or water. All the nickel bought is deposited, so there is 100 % efficiency. Better quality of the products because rinsing is more effective.

2.4 Recovery

Recovery and/or recycling of metals from waste waters

It is BAT to recover and/or recycle metals from waste waters.

Brief technical description

This refers to recovery systems within installations, not to external processes.

Metals may be recovered by electrolysis. The system is widely used for precious metal recovery, but can also be used to recover other metals such as nickel and chromium from drag-outs. Suitable electrolysis cells are marketed in different sizes and can operate down to metal contents of less than 100 mg/l.

May be operated in conjunction with other techniques to achieve low emission levels for water, or recycling of rinse-waters, etc.

Achieved environmental benefits

Recovery of metals for re-use.

Reduction of metals in drag-out and their consequent decrease in effluent concentrations.

In the electrolytic separation of metal solutions containing cyanide, the anodically oxidative destruction of the cyanide takes place in parallel to the metal winning.

Cross-media effects

Power consumption at low current efficiencies.

Operational data

Precious metals electrolytic recovery requires the electrolytic reactor to be able to reduce the metal concentration down to a very low concentration (1 ppm or less). The current efficiency at this level is very low. In all cases, a simple flat plate cathode would be sufficient in theory, but when high current efficiencies are required (for both precious and transition metals) sophisticated cathode design is needed (rotating tube cell, graphite fibre cathode), or a fluidised bed to overcome cathode surface depletion. In all cases (including anodic oxidation) the anode must be of the 'insoluble' type.

Cathodes are usually sheets, foil or particles, generally made of the same metal to be recovered, but also of stainless steel or other metals, which allow either a mechanical parting of the deposit from the cathode blank, or its removal by anodic dissolution. Iron, stainless steel, porous carbon, graphite particles, glass or plastic metallised beads and metallised fabrics are all examples of common materials used. Cathode material selection is largely determined by the nature of the treatment, which follows the metal deposition. In any case, maximising both the cathode surface area and the diffusion process are the most important means to enhance the efficiency of the electrolytic reactor.

Anodic material includes: graphite, lead, lead alloys with antimony, silver or tin, stainless steel, cast iron, ferro-silicon and the valve metals (titanium, tantalum, tungsten, niobium) coated with noble metals (platinum iridium) or with noble metal oxides (iridium, ruthenium oxides).

Anodic material selection is usually a compromise based on:

- over-voltage behaviour for the particular reaction on a given material
- anode corrosion, mechanical properties and the form in which the material is available
- price.

Operating conditions vary as a function of the metal to be recovered; for gold the recommended conditions are: pH minimum of 10, cell voltage 8 V, current density 20 A/dm^2 temperature >60 °C, and an anode-cathode gap from 8 to 16 cm.

Further advantages of the electrolytic recovery over the ion exchange method are:

- it does not produce any increase in the dissolved salt concentration
- the presence of other metals in similar concentrations does not affect the rate of removal of the desired species
- may also oxidise unwanted species, such as cyanide

Noble metals, because of their electropositive character, are more readily electrodeposited than non-noble ones.

For electrolytic metal recovery, the following streams are particularly suitable:

- rinsing (drag-out) concentrates from electroplating metal
- rinsing (drag-out) concentrates and used process solutions from chemical metal plating excluding solutions-containing phosphate
- sulphuric acid regenerates of cation exchangers from the treatment of rinsing waters: these contain non-ferrous metals.

The purity of the generated metals may permit a direct in-house use as an anode material, otherwise re-use is via the scrap metal trade.

Applicability

Gold and silver have been recovered electrolytically for well over 50 years.

Electrolytic recovery has wider applicability than precious metals: it can also be used for transition metals.

Fluidised bed cells increase the process efficiency.

Economics

Cost-effective for precious metals.

Can be cost-effective for transition metals, for example, where it reduces the waste water treatment costs (capital and running costs).

In-house electrolysis has costs in investments and personnel (both time and skills) as well as a substantial energy expenditure because of the low electricity yield (kg/amp hour). This may be offset for cyanide solutions where the cyanide is destroyed in parallel.

For a fluidised bed cell: although the technique can be utilised on most metals, economic considerations limit the application to either valuable or easily re-usable metals. Units can recover from 1 kg/week to 150 kg/week of electrolytically pure metal from solution. The solutions can be very dilute, typically containing 100 – 500 parts per million (0.1 – 0.5 gm/l).

Example plants

Surface treatment of metals plants e.g.

- Silver recovery from waste photographic solutions
- Copper Recovery - Printed Circuit Manufacturer

Best practices

ELECTROPLATING NICKEL

Description

Electrodialysis technique allows to maintain a sufficiently low concentration of nickel in the wash water while the concentration of the metal in the concentrate solution.

The resulting concentrate may serve to supplement the content of plating baths.

The degree of recovery of this method exceeds 90%.

Energy consumption is 3.1 kWh/kg Ni

Exemple Plant

Asahi Glass – Japan

ELECTROPLATING COPPER

Description

As a result of electrodialysis desalinated water produced (which can be re-used for washing) and concentrate copper cyanide plating baths directed to.

The copper concentration in the rinsing water is less than 1 gCU/dm^3.

The concentrate has a concentration of 65 gCU/dm^3.

Energy consumption is 1-2 kWh/kg Cu 94% in the recovery of copper from the rinsing water.

Economics

Annual net profit plating is 1,500 Euro for the recovery of 292 kgCu.

Exemple Plant

Fractional installation Technical France.

ELECTROPLATING CHROME

Description

As a result of electrodialysis water is formed (which can be reused for irrigation) and chromic acid deprived of 60-90% of heavy metals.

Energy consumption is 12-15 kWh / kg CrO_3.

After application of reverse osmosis water is obtained with a high purity (95% retention of chromium) and concentrate all the components of sewage strip.

Exemple Plant

Installation of fractional technical in Germany.

SULPHURIC ACID PLANT OPERATING UNDER IDEAL CONDITIONS

Description

Double contact sulphuric acid plant, 4 passes modern caesium catalyst. Monsanto Enviro Chem 3:1 IPA process

Achieved environmental benefits

Maximum recovery of sulphur dioxide.

Cross-media effects

Positive effect - Reduction of main emissions of sulphur dioxide, recovery of energy.

Operational data: Status of development

Treatment of combined FSF and FCF gases with 30–40% SO_2, diluted to 14% at contact plant inlet at an annual average flow of 171300 Nm^3 achieved. Plant relies on a high, constant sulphur dioxide feed, sophisticated gas cleaning and inter-pass cooling and Cs doped catalyst. Sulphur dioxide emission in the tail gas (as annual average) is around 150 mg/Nm^3

Applicability

Specific case for ideal feed gas conditions.

Economics

Not assessed but the process has been recently installed and is operating economically.

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638"

PART 3: **HEAT AND ELECTRICITY**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

3.1 Organizational aspects

3.1.1 Design, operating and control

3.1.1.1 Drying, separation and concentration processes

Process automation in thermal drying processes

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

In the vast majority of applications with thermal drying processes, dryers are normally controlled using target value specifications and/or predominantly empirical values (operator experience). The retention time, throughput speed, starting moisture content, temperature and product quality are all used as control parameters. Moisture sensors with linear characteristics and low interferences, while still offering high service lives, are required to determine the moisture content. A computer can calculate these measurements in real time and compare them with target values calculated from the mathematical model of the drying process. This requires an exact knowledge of the drying process and suitable software. The controller changes the corresponding control variable by comparing the target and actual values.

Examples from different plants show that savings of between 5 and 10% can be achieved compared with using traditional empirical controllers.

Achieved environmental benefits

Energy savings.

Cross-media effects

No data submitted.

Operational data

Savings of between 5 and 10% can be achieved compared with using traditional empirical controllers.

Applicability

All cases.

Select the optimum separation technology or combination of techniques to meet the specific process equipments

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

Drying is an energy intensive process. It is considered here with separation and concentration techniques, as the use of different techniques or combinations offer energy savings.

Heat may be transferred by convection (direct dryers), by conduction (contact or indirect dryers), by thermal radiation such as infrared, icrowave or high requency electromagnetic field (radiative dryers) or by a combination of the these. Most industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium.

Separation is a process which transforms a mixture into at least two streams (which may be product-product or product-waste streams) which are different in composition. The separation technology consists, therefore, in partitioning and isolating the wanted products from a mixture containing either different substances or a pure substance in several phases or sizes.

Alternatively, it may be used to separate waste streams.

The separation process takes place in a separation device with a separation gradient applied by a separating agent. In this section, the separation methods have been classified according to the different principles of separation and separating agents used.

The purpose of this section is not to describe exhaustively every separation technique, but to focus mainly on those issues which have a higher potential for energy savings. For further details of a particular method, see the Reference information.

Classification of the separation methods:

- input of energy into the system: detailed classification for these techniques can be structured considering the different types of energy provided to the system as listed below:
  - heat (vaporisation, sublimation, drying)
  - radiation
  - pressure (mechanical vapour recompression)
  - electricity (electrofiltration of gases, electrodialysis)
  - magnetism (use of magnets)
  - kinetic (centrifugal separation) or potential energy (decantation)
- withdrawal of energy out of the system:
  - cooling or freezing (condensation, precipitation, crystallisation, etc.)
- mechanical barriers:
  - filters or membranes (nano, ultra or microfiltration, gas permeation, sieving)
- others:
  - physico-chemical interactions (solution/precipitation, adsorption, flotation, chemical reactions)
  - differences in ot her physical or chemical properties of the substances such as density, polarity, etc.

Selecting a separation technology often has more than one solution. The choice depends on the characteristics of the feed and the required outputs and other constraints linked to the type of plant and sector. The separation process also has its own constraints. Technologies can be used in stages, e.g. two or stages of the same technology or combinations of different technologies.

Achieved environmental benefits

Minimising energy usage. A significant amount of energy can be saved where it is possible to use two or more separation stages or pretreatments

Cross-media effects

None reported.

Operational data

Some factors related to either the feed material, the final product or the process which should be considered before selecting a separation technique, are:

- feed material:

- type, shape: liquid, pasty, granular, powdery, fibrous, plane, belt, already in shape
- mechanical fragility
- thermosensitivity
- moisture content
- flowrate/quantity to be treated
- if applicable: shape and size, size of droplets, viscosity

• final product specifications:
- moisture content
- shape and size
- quality: colour, oxidation, taste

• process:
- batch/continuous
- heat sources: fossil fuels (natural gas, fuel, coal, etc.), electricity, renewable (solar, wood, etc.)
- heat transfer through: convection (hot air, superheated steam), conduction, thermal radiation (radiant energies: infrared, microwaves, high frequency)
- maximum temperature
- capacity
- residence time
- mechanical action on the product.

A feasibility study is necessary to define the best solution(s) from a technical, economic, energy, and environmental point of view. Requirements should be precisely defined:

- feed and product parameters mass and flow characteristics), especially the moisture content of the product: the last moisture percentages are usually the more difficult to dry and so are the most energy consuming
- list of all the utilities available (electricity, refrigeration, compressed air, steam, other cold or hot sources) and their characteristics
- available possible space
- possible pretreatment
- waste heat recovery potential of the process
- high energy efficiency utilities equipment and sources (high efficiency motors, use of waste heat, etc.).

A comparative analysis of the proposals has to be made on a technical, economic, energy, and environmental basis:

- within the same boundaries, including utilities, effluent treatment, etc.
- taking into account each environmental impact (air, water, waste, etc.)
- taking into account maintenance and security
- quantifing the time and cost of training of the operators.

Applicability

Identification of the appropriate technologies is applicable in all cases. Installation of new equipment is usually carried out on a cost-benefit basis and/or for production quality or throughput reasons.

Economics

No data submitted.

Driving force for implementation

- cost reduction
- product quality
- process throughput capacity.

Example plants

When drying liquids (e.g. spray dryng), the pretreatment can be membrane filtration (reverse osmosis, nanofiltration, ultrafiltration or microfiltration). Membrane filtration has an energy consumption of 1-3 orders of magnitude lower than evaporative drying, and can be used as a first pretreatment stage. For example, in the drying industry, milk can be concentrated to 76% moisture content before spray drying.

3.1.1.2 Heating, ventilation and air conditioning (HVAC) systems

Air filtering

BAT is to optimise heating, ventilation and air conditioning systems.

Brief technical description

An air filter allows the air in the ventilated premises to be re-used. The flow of air to be renewed and reconditioned is thereby reduced, providing significant energy savings. Opting for an air filter when the ventilation installation is designed is advisable because the extra cost at that stage will be relatively small compared with its installation at a later stage. It is essential to check that the pollutants that remain can be recycled. Where this solution is possible, it is important to know the following parameters:

- recycling efficiency,
- pressure loss,
- behaviour when filter is fouled.

Achieved environmental benefits

Energy saved after optimising all the parameters of the ventilation system will produce, on average, a reduction in the order of 30% of the energy bill associated with its operation.

Cross-media effects

None reported.

Operational data

The energy consumption of a ventilation system increases over time for an identical service. To maintain its efficiency, it is necessary to monitor the system and when necessary carry out maintenance operations, which will produce substantial energy savings whilst increasing the lifetime of the system. These operations may consist of:

- conducting leak detection and repair campaigns on the air duct system
- changing filters regularly, particularly in the air cleaning devices, because:
  - loss of pressure increases very rapidly with a worn out filter
  - the filter's efficiency at removing particles deteriorates over time
- checking compliance with health and safety standards associated with pollutant removal

- measuring and recording regularly the key values for the installation (electricity consumption and pressure loss in devices, airflow).

Applicability

Applicable to all existing systems.

Economics

In most audited installations, potential energy savings of up to 30% consumption have been detected. There are many possible actions giving a return on investment often within two years.

Driving force for implementation

- health and safety conditions at work,
- cost savings,
- product quality.

Example plants

Widely used.

Energy savings for heating and cooling

BAT is to optimise heating, ventilation and air conditioning systems.

Brief technical description

The consumption of energy in space heating/cooling is considerable. For instance, in France it is about 30 TWh, representing nearly 10% fuel consumption. It is quite common to have high heating temperatures in industrial buildings that could be easily reduced by 1 or 2°C; conversely, when cooling, it is common to have temperatures that could be increased by 1 or 2°C without degrading the comfort. These measures imply a change for the employees and they should be implemented with an information campaign.

Energy savings can be achieved in two ways:

1. reducing the heating/cooling needs by:
   - building insulation
   - efficient glazing
   - air infiltration reduction
   - automatic closure of doors
   - destratification
   - lower temperature settings during non-production periods (programmable regulation)
   - reducing set point
2. improving the efficiency of heating systems through:
   - recovery or use of waste heat
   - heat pumps
   - radiative and local heating systems coupled with reduced temperatures in the unoccupied areas of the buildings.

Achieved environmental benefits

Improve energy efficiency.

Cross-media effects

No data submitted.

Operational data

To lower the temperature set point of 1°C for heating, and raising it by 1°C for air conditioning can reduce energy consumption about 5-10%, depending on the average temperature difference between indoors and outdoors. Generally, raising air conditioning temperatures saves more, as the temperature differentials are generally higher. These are generalisations, and the actual savings will vary according to climate, on a regional basis.

Limiting heating/cooling during non-production periods can save 40% of electrical consumption for a plant working on an 8 hours per day basis. Limiting heating coupled with a permanent reduced temperature in unoccupied areas and local radiative heating in occupied areas, can generate nearly 80 % energy savings depending on the percentage of occupied areas.

Applicability

New or significant upgrade. Consider for retrofit on lifetime cost benefit.

Temperatures may be set by other criteria, e .g. regulatory minimum temperatures for staff, maximum temperatures to maintain product quality for food.

Energy savings for ventilation

BAT is to optimise heating, ventilation and air conditioning systems.

Brief technical description

An existing ventilation system can be improved at three levels:

- optimising the operation of the installation
- introducing a maintenance and monitoring plan for the installation
- investment in more efficient technical solutions.

Energy savings can be achieved in few ways:

- Optimise the number, shape and size of intakes
- Manage airflow, including considering dual flow ventilation
- Stop or reduce ventilation where possible
- Use automatic control systems and integrate with centralised technical management systems
- Check system is balanced
- Ensure system is airtight, check joints
- Integration of air filters into air duct system and heat recovery from exhaust air (heat exchangers)
- Optymalize air system design:
  - ducts are of a sufficient size
  - circular ducts
  - avoid long runs and obstacles such as bends, narrow sections

Note that improving ventilation system efficiency sometimes also brings improvements in:

- the comfort and safety of personnel
- product quality.

Achieved environmental benefits

It is estimated that 10% of the electricity consumption in companies is by ventilation systems. Where there is also air conditioning, ventilation and air conditioning can take up an even larger share of the corporate energy budget.

Operational data

• fans: fans are the principal source of electricity consumption in the installation. Their type, size and controls are major factors from the point of view of energy. Note: choosing a high efficiency fan of the correct size may mean that a smaller fan can be chosen and savings on the purchase price can be obtained. When designing or modifying an installation, key issues are:

- a fan with a high efficiency rating: the maximum efficiency of fans is generally between 60 and 85 % depending on the type of fan. Manufacturers are developing ranges of even more efficient fans
- a fan designed to operate as close as possible to its optimal rate: with a single fan, efficiency can vary according to its operating rate. It is therefore essential to choose the correct size of fan for the installation, so that it operates as close as possible to maximum efficiency

• the air system: the design of an air system must meet certain conditions in order to be energy efficient:

- ducts must be sufficiently large in diameter (a 10 % in crease in diameter can produce a 72 % reduction in the power absorbed)
- circular ducts, which offer less pressure loss, are better than rectangular ducts of an equal section
- avoid long runs and obstacles (bends, narrower sections, etc.)
- check that the system is airtight, particularly at joints
- check that the system is balanced at the design stage, to make sure all 'users' receive the necessary ventilation. Balancing the system after it has been installed means that single leaf dampers have to be installed in some ducts, increasing losses in pressure and energy

• electric motors (and coupling with fans): choose the correct type and size of motor

• managing airflow: airflow is a basic parameter when it comes to energy consumption by ventilation s ystems. For example: for a 20 % reduction in flow, 50 % less power is consumed by the fan. Most ventilation installations do not have to operate constantly at their maximum rate. So it is important to be able to adjust the fan operating speed in accordance with, e.g:

- production (quantity, product type, machine on/off, etc.)
- period (year, month, day, etc.)
- human occupation of the work area

It is essential to analyse needs using presence detectors, a clock, and process-driven controls, and to design a controlled ventilation installation.

'Dual flow' ventilation, which combines blowing (the intake of fresh air) with extraction (the removal of polluted air), provides better airflow control and is more easily controlled, e.g. by a process air conditioning and energy recovery management system. Installing automatic controls can provide a method of controlling the ventilation system using various (measured, defined, etc.) parameters and optimising its operation at all times.

There are many techniques for varying airflow in line with demand, but they are not all equally energy efficient:

- electronic speed controls can be used to adapt the rate of operation of fans whilst optimising energy consumption by the motor, producing significant energy savings
- changing the blade angle of propeller fans also provides substantial energy savings

• energy recovery system: when ventilated premises have an air conditioning system, the renewed air needs to be reconditioned, which consumes large amounts of energy. Energy recovery systems (exchangers) can be used to recover some of the energy contained in the polluted air expelled from the work area. When choosing an energy recovery system, check the following three parameters:

- thermal efficiency
- pressure loss
- behaviour when fouled

• air filtering: an air filter allows the air in the ventilated premises to be re-used. The of air to be renewed and reconditioned is thereby reduced, providing significant energy savings. Opting for an air filter when the ventilation installation is designed is advisable because the extra cost at that stage will be relatively small compared with its installation at a later stage. It is essential to check that the pollutants that remain can be recycled.

Where this solution is possible, it is important to know the following parameters:

- recycling efficiency
- pressure loss
- behaviour when filter is fouled

Applicability

Applicable to all new systems or when upgrading.

Economics

In most audited installations, potential energy savings of up to 30% of consumption have been detected. There are many possible actions giving a return on investment often within 3 years.

Driving force for implementation

• health and safety conditions at work
• cost savings
• product quality.

Example plants

Widely used.

Free cooling

BAT is to improve the efficiency of cooling systems through the use of free cooling.

Brief technical description

Cooling, both for industrial processes and/or air conditioning can be enhanced from an energy efficiency point of view by adopting free cooling techniques. Free cooling takes place when the external ambient air enthalpy is less than the indoor air enthalpy. It is free because it makes use of ambient air.

This free contribution can be transferred to the system needing cooling either directly or indirectly. Normally indirect methods are used in practice. They consist, in general, of extraction-recirculation air systems. The regulation is done by automatic modulating valves: when cool outside air is a vailable (i.e. when the outside wet bulb temperature drops below the required chilled water set point), valves automatically increase the intake of the cool air, reducing at the same time the internal recirculation to a minimum to maximise the use of the free cooling. By using techniques such as this, refrigeration equipment is partially avoided in certain seasons of the year and/or during the night. There are various technical possibilities to take advantage of free cooling.

The water returning from the thermal load, and directed to the chiller, is automatically diverted by the 3-way valve to the free cooler. Here, the water is precooled, and this reduces the thermal load on the chiller and the energy consumed by the compressors. The more the ambient temperature drops under the return water temperature, the greater the free cooling effect and the greater the energy savings.

Achieved environmental benefits

Normally chillers are driven by electric motors, and sometimes by endothermic drives, so there is less consumption of primary energy resources.

Cross-media effects

None known.

Operational data

Free cooling is best considered when the ambient temperature is at least 1°C below the temperature of water coming from the thermal load, i.e. entering the chiller. For example, if T1 (temperature of water returning from the thermal load) is 11°C, free cooling can be activated when T2 (outside air temperature) drops under 10 °C.

Applicability

Applicable in specific circumstances.

Free cooling is applicable in specific circumstances: for indirect transferring, ambient air temperature must be below the temperature of refrigerant fluid returning to the chiller; for direct uses, the outside air temperature must be below or equal the required temperature. Possible extra space for the equipment must also be taken into account.

It is estimated that it is applicable in 25 % of cases.

Free cooling exchangers can be retrofitted to existing chilled water systems and/or incorporated into new ones.

Economics

Adoption of free cooling techniques involves a series of economic a dvantages, such as: the source of cold is free, a reduction of running time of compressors with consequential energy savings in terms of kWh no longer used from the electrical network, a reduction of electric power supply cost.

It is usually better to investigate the use of free cooling during the project planning for a new or upgraded system. Payback for a new system could be as little as 12 months; payback for retrofitting units is up to 3 years.

Driving force for implementation

- simplicity of installation

• energy and money savings.

Example plants

Widely used.

Optimising electric motors and considering installing a VSD

BAT is to optimise heating, ventilation and air conditioning systems.

Brief technical description

When designing or modifying an installation, key issues are electric motors (and coupling with fans): choose the correct type and size of motor and consider installing a VSD.

There are at least two different ways to approach the concept of energy efficiency in motor driven systems. One is to look at individual components and their efficiencies, and ensure that only high efficiency equipment is employed. The other is to take a systems approach: the energy efficiency in motor driven systems can be assessed by studying the demands of the (production) process and how the driven machine should be operated.

Achieved environmental benefits

It is estimated that 10% of the electricity consumption in companies is by ventilation systems. Where there is also air conditioning, ventilation and air conditioning can take up an even larger share of the corporate energy budget.

Cross-media effects

None reported.

Operational data

Energy efficient motors (EEMs) and high efficiency motors (H EMs) offer greater energy efficiency. The additional initial purchase cost may be 20-30% or higher for motors of greater than 20 kW, and may be 50-100% higher for motors under 15 kW, depending on the energy savings category (and therefore the amount of additional steel and copper use) etc. However, energy savings of 2-8% can be achieved for motors of 1 - 15 kW.

The maximum efficiency is obtained for the motors of between 60 to 100% full load. The induction motor efficiency typically peaks near 75 % full load and is relatively flat down to the 50% load point. Under 40% full load, an electrical motor does not work at optimised conditions and t he efficiency falls very quickly. Motors in t he larger size ranges can operate with reasonably high efficiencies at loads down to 30% of rated load.

The adjustment of the motor speed through the use of variable speed drives (VSDs) can lead to significant energy savings associated to better process control, less wear in the mechanical equipment and less acoustical noise. When loads vary, VSDs can reduce electrical energy consumption particularly in centrifugal pumps, compressors and fan applications typically in the range of 4-50%.

Applicability

All cases. Cost effective retrofit.

Economics

In most audited installations, potential energy savings of up to 30% of consumption have been detected. There are many possible actions giving a return on investment often within 3 years.

Driving force for implementation

- health and safety conditions at work
- cost savings
- product quality.

Example plants

Widely used.

Usage of fans of high efficiency and designed to operate at optimal rate

BAT is to optimise heating, ventilation and air conditioning systems.

Brief technical description

Fans are the principal source of electricity consumption in the installation. Their type, size and controls are major factors from the point of view of energy. Note: choosing a high efficiency fan of the correct size may mean that a smaller fan can be chosen and savings on the purchase price can be obtained. When designing or modifying an installation, key issues are:

- a fan with a high efficiency rating: the maximum efficiency of fans is generally between 60 and 85% depending on the type of fan. Manufacturers are developing ranges of even more efficient fans
- a fan designed to operate as close as possible to its optimal rate: with a single fan, efficiency can vary according to its operating rate. It is therefore essential to choose the correct size of fan for the installation, so that it operates as close as possible to maximum efficiency

Cost-effective action:

- fit fans where there is a variable flow with an electronic speed control (ESC)
- install high efficiency fans
- install fans with an optimum operating rate that suits the specific needs of the installation

Achieved environmental benefits

It is estimated that 10% of the electricity consumption in companies is by ventilation systems. Where there is also air conditioning, ventilation and air conditioning can take up an even larger share of the corporate energy budget.

Cross-media effects

None reported.

Applicability

Applicable to all existing systems.

Economics

In most audited installations, potential energy savings of up to 30% consumption have been detected. There are many possible actions giving a return on investment often within two years.

Driving force for implementation

- health and safety conditions at work
- cost savings
- product quality.

Example plants

Widely used.

3.1.1.3 Raw Materials

Save heat energy and fuel

Processes that "flow" directly into the following process if possible to minimise handling and conserve heat energy.

Achieved environmental benefits

Energy and fuel saving.

Example plants

Non Ferrous Metals Industries.

Best practices

RAW MATERIAL SAMPLING AND RECEPTION SYSTEM

Description

Concentrate reception and sampling system. Enclosed vehicle tipping area, sealed transfer system and computerised sampling. Enclosed storage and blending area, enclosed conveyors.

Achieved environmental benefits

Prevention of fugitive dust. Defined feed for the process.

Cross-media effects

Positive effect - reduction in energy usage, reduction of main emissions.

Operational data: Status of development

Not available but visual indications are of a very high standard.

Applicability

Most primary processes.

Economics

No data available but it can be concluded by common practice that these techniques are economically viable. Production efficiency increased.

3.1.1.4 Steam systems

Energy efficient design and installation of steam distribution pipework

BAT for steam systems is to optimise the energy efficiency by using this tape of techniques.

Brief technical description

The distribution system transports steam from the boiler to the various end-uses. Although distribution systems may appear to be passive, in reality, these systems regulate the delivery of steam and respond to changing temperatures and pressure requirements. Consequently, proper performance of the distribution system requires careful design practices and effective maintenance. The piping should be properly sized, supported, insulated, and configured with adequate flexibility. Pressure-regulating devices such as pressure-reducing valves and backpressure turbines should be configured to rovide a proper steam balance among the different steam headers. Additionally, the distribution system should be configured to allow adequate condensate drainage, which requires adequate drip leg capacity and proper steam trap selection.

Maintenance of the system is important, especially:

- to ensure that traps operate correctly,
- that insulation is installed and maintained,
- that leaks are detected and dealt with sy stematically by planned maintenance. This is assisted by leaks being reported by operators and dealt with promptly. Leaks include air leaks on the suction side of pumps,
- checking for and eliminating unused steam lines.

Achieved environmental benefits

Savings in energy from unnecessary losses.

Cross-media effects

No data submitted.

Operational data

Steam piping transports steam from the boiler to the end-uses. Important characteristics of well designed steam system piping are that it is a dequately sized, configured, and supported. The installation of larger pipe diameters may be more expensive, but can create less pressure drop for a given flowrate. Additionally, larger pipe diameters help to reduce the noise associated with steam flow. As such, consideration should be given to the type of environment in which the steam piping will be located when selecting the pipe diameter. Important configuration issues are flexibility and drainage. With respect to flexibility, the piping (especially a equipment connections) needs to accommodate thermal reactions during system startups and shutdowns.

Additionally, piping should be equipped with as ufficient number of appropriately sized drip legs to promote effective condensate drainage. Additionally, the piping should be pitched properly to promote the drainage of condensate to these drip lines. Typically, these drainage points experience two different operating conditions, normal operation and startup; both load conditions should be considered at the initial design stage.

Applicability

All steam systems. Adequate sizing of pipework, minimising the number of tight bends, etc. Can best be dealt with at the design and installation stages (including significant repairs, changes and upgrading).

Economics

- proper sizing at the design stage has a good payback within the lifetime of the system,
- maintenance measures (such as minimising leaks) also exhibit rapid payback.

Driving force for implementation

- cost savings,
- health and safety

Example plants

Widely used.

Throttling devices and the use of backpressure turbines: utilise backpressure turbines instead of PRVs

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

Throttling devices are very common in industry and are used to control and reduce pressure mainly t hrough valves. Since the throttling process is isenthalpic (where the enthalpy up and down flows are equal) no energy is lost and according to the first law of thermodynamics, its efficiency is optimal. However, this has an inherent typical mechanical i rreversibility which reduces pressure and i ncreases the entropy of the fluid without giving any additional benefit.

Consequently, exergy is lost and the fluid (after the pressure drop) is less capable of producing energy, e.g. in a subsequent turbine expansion process.

Therefore, the aim is to reduce the pressure of a fluid, it is desirable to use isentropic expansions and provide useful work in addition through turbines. If this is not possible, the working pressure should always be as low as possible, to avoid large pressure changes, with associated exergy losses through valves, measuring devices or by using compressors or pumps to input additional energy.

A regular practice in industrial installations is to keep the pressure at the inlet of a turbine at the design conditions. This usually implies the use (and abuse) of inlet valves to control the turbine.

According to the second law of thermodynamics, it is better to have variation of the pressure specifications (sliding pressure) and to keep the admission valves completely open.

As a general r ecommendation, valves should be sized as large as possible. As atisfactory throttling process can be achieved with a pressure drop of 5-10% at maximum flow, instead of 25 – 50% as has been past practice with valves of too small a size. The pump driving the fluid must be also sized to take account of the variable conditions.

However, a better alternative is to use a backpressure turbine, which almost retains the isentropic conditions and is completely reversible (in thermodynamic terms). The turbine is used to generate electricity.

Achieved environmental benefits

Provides a more efficient method of reducing steam pressure for low pressure services.

Reduces exergy losses.

Cross-media effects

Increases fuel consumption.

Applicability

Applicable when size and the use of a turbine.

Applicable in new or significantly refurbished systems, according to the economics and the following factors:

- the turbine is used to generate electricity or to provide mechanical power to a motor, compressor or fan. Whereas backpressure turbines are the most attractive from a point of view of energy efficiency, the quantity of steam passing through the backpressure turbines should fit with the overall steam balance of the whole site. Use of excessive numbers of backpressure turbines will result in more steam being generated at low pressure levels than can be consumed by the plant/site. This excess team would then have to be vented, which is not energy efficient. The steam flow from the backpressure turbine also needs to be available for a large percentage of the time, and in a predicable way. An unpredictable or discontinuous source cannot be used reliably (unless, rarely, peaks in supply and demand can be matched)
- backpressure turbines are not useful when the two pressure levels are close together, as the turbines need a high flow and pressure differential. In the steel industry in the blast furnace process, pressure drop turbines are used be cause of the huge number of gases which flow through the blast furnace.

Economics

Turbines are several orders of magnitude more expensive than control valves. The minimum size to be effective and to be considered before substituting therefore has to be considered with the steam balance. In the case of low mass flows, turbines are not reasonable from an economic point of view. To be economic, the recovered energy should be sufficiently reliable, available for a large percentage of production time and match demand.

Driving force for implementation

Where they can be used, cost savings in the steam supply.

Best practices

THROTTLING DEVICES

Description

Throttling devices are very common in industry and are used to control and reduce pressure mainly through valves. Since the throttling process is isenthalpic (where the enthalpy up and down flows are equal) no energy is lost and according to the first law of thermodynamics, its efficiency is optimal.

However, this is a typical mechanical irreversibility which reduces pressure and increases the entropy of the fluid, without giving any additional benefit. Consequently, exergy is lost and the fluid is less capable of producing energy in a turbine expansion process, for instance.

Therefore, if the point is to reduce the pressure of a fluid, it is desirable to tend to isentropic expansions providing useful work as an additional result through turbines. If this is not possible, the working pressure should always be the highest possible because this will avoid the use of compressors or pumps for fluid transportation (additional useful energy).

A very frequent practice in industrial installations is to keep the pressure at the in let of the turbine at the design conditions. This usually implies the use and abuse of admission valves to control the turbine. According to the second law, it is better to have flotation of the pressure specifications (sliding pressure) and to keep the admission valves completely open.

As a general recommendation, valves should be sized as large as possible. As atisfactory throttling process can be achieved with a pressure drop of 5 - 10 % at maximum flow instead of 25-50% as has happened in the past, where valves were small sized. Of course the pump driving the fluid must be also sized according to the variable conditions.

Finally, it must be stressed that pipes also act as throttling devices, decreasing the pressure of the fluid flowing through them. Therefore, a good design with good materials and few obstacles such as unnecessary valves, elbows, bows, etc. will limit the exergy losses across the process.

In any case, it is clear that an exergy accounting that considers all the energy levels existing in the plant must be performed, because from the first law point of view, irreversibilities are very difficult or impossible to identify.

Numerical example

During a unit commissioning in a power p ant, as team extraction coming from the high pressure turbine (P = 40 kg/cm^2).

Since the turbopump operates at an inlet pressure of 8 kg/cm^2 pressure turbine must be throttled. In the following thermodynamic example, variables of the steam are evaluated at the inlet and outlet of the valve. The process is sketched on the T-s and h-s diagrams and the exergy flow is obtained when the nominal flow is 45 000 kg/h.

Solution

The first law of thermodynamics reveals that the process is isenthalpic since no work or heat transfer is associated with the throttling process:

0 = m1(H2 H1) >H2 =H1

The specific enthalpy and entropy obtained through the property tables are:

- at P1 and T1: h1 = 3091.95 kJ/kg and S1 = 6.58 kJ/kg K
- at P2 and h2 = h1, T2 = 319 oC, S2 = 7.30 kJ/kg K

The specific flow exergy is calculated as: e = H – T0s

Where T0 = 273 K and the potential and kinetic energy are considered negligible. Hence:

- e1 = 3091.95 – 273 x 6.58 = 1295.61 kJ/kg

and

- e2 = 3091.95 – 273 x 7.30 = 1099.05 kJ/kg

This process is completely irreversible (mechanical irreversibility). The exergy loss is obtained through an exergy balance to the system.

HEAT EXCHANGERS

<u>Description</u>

Heat exchangers are devices where two streams exchange heat. Every heat transfer is the result of a temperature difference and thus is always associated with entropy generation and exergy destruction. Therefore, there is a contradiction between the ideas of minimum exergy loss and maximum heat transfer efficiency.

In a counterflow heat exchanger, where a hot fluid at T1,in is cooled down to T1,out, by releasing heat to a cold fluid that heats up from T2,in to T2,out, therefore, the exergy loss in the process is calculated as follows:

The changes in kinetic and potential energy are usually negligible and no work interactions are present. For a first approximation, the pressure drop can also be considered negligible. The irreversibility created in the heat exchanger is given by:

I = (e1,in + e2,in) – (e1,out + e2,out) = (h1,in + h2,in) – (h1,out + h2,out)

T1,out T2,out - T [(s1,in + s2,in) – (s1,out + s2,out)] = T0 [m1Cp1 ln T1,in

It can be demonstrated from the equation above that I is always positive and increases with the temperature differences at the inlet a nd outlet of t he fluids i n the counterflow exchanger and between the top and bottom in a parallel-flow exchanger. In any case, a counterflow exchanger is always better than a concurrent one (parallel-flow) from the exergy point of view, because exergy is always being given off to a system at a similar temperature.

The irreversibilities taking place in heat exchangers are due to two factors: heat transfer caused by the temperature difference and pressure loss associated with the fluid circulation. Both fluid friction and irreversible heat transfer can be reduced decreasing the fluid flow. However, in order to obtain the same effect of heat exchange, a larger transfer area is required, i.e. larger heat exchangers must be designed.

The idea of extending the use of counterflow heat exchange to the whole installation, i .e. extending it to all flows to be heated or c ooled i n the pl ant, so that the temperature change through which heat must flow is reasonably low, leads to the energy integration of processes and the use of energy cascades. This is the philosophy of the pinch methodology, developed for the integration of heat exchanger networks. The integration can also be extended to power cycles, heat pumps and refrigeration cycles in the most efficient way. In summary, this procedure a ssures the lowest steam consumption (or any a nother heat s ource) and the lowest cooling water (or any other cold source) under the thermodynamic and technical conditions that may be assessed.

MIXING PROCESSES

Description

The mixing of fluids with different compositions or temperatures is another process very common in industry. This concept includes tempering processes for temperature control, mixing processes for quality control, substance purifying processes, distillation, etc.

For example, an adiabatic mixture of two different ideal gases flow at the same temperature and pressure and n1 and n2 equals the number of moles of each flow. The generation of entropy in the mixing process corresponds to the sum of the entropy increase of each gas due to their expansions from P to their new partial pressure of the mixture.

Improve operating procedures and boiler controls

BAT for steam systems is to optimise the energy efficiency by using this tape of techniques.

Brief technical description

For simple installations, the availability of cheaper and easier monitoring, electronic data capture and control, make it easier for operators to gather data, assess process energy needs, and to control processes. This can start with simple timing, on-off switching, temperature and pressure controls, data loggers, etc. and is facilitated by using software models for more sophisticated control.

At the more complex levels, a large installation will have an information management system (manufacturing and execution systems), logging and controlling all the process conditions.

A specific application is in managing the way energy is sourced and supplied (supply side energy management, distribution management or utilities management). This uses a software model linked to control systems to optimise and manage the energy utilities (electricity, steam, cooling, etc.).

Achieved environmental benefits

Energy savings.

Applicability

The installation of more than one boiler may be considered to cope with varying demands over the working cycle. The boilers may be of different types, depending on the demand curve, cycle times, etc.

The use of sequential boilers may be limited when high steam availability guarantees are required.

Usage of sequential boiler controls (apply only to sites with more than one boiler)

BAT for steam systems is to optimise the energy efficiency by using this tape of techniques.

Brief technical description

Where a site has more than one boiler, the steam demand should be analysed and the boilers used to optimise energy usage, by reducing short cycling, etc.

Achieved environmental benefits

Energy savings.

Applicability

The installation of more than one boiler may be considered to cope with varying demands over the working cycle. The boilers may be of different types, depending on the demand curve, cycle times, etc.

The use of sequential boilers may be limited when high steam availability guarantees are required.

Install flue-gas isolation dampers (applicable only to sites with more than one boiler)

BAT for steam systems is to optimise the energy efficiency by using this tape of techniques.

Brief technical description

Installing flue-gas isolation dampers (applies only to systems where there are two or more boilers with a common chimney).

Achieved environmental benefits

Energy savings.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Applicability

The installation of more than one boiler may be considered to cope with varying demands over the working cycle. The boilers may be of different types, depending on the demand curve, cycle times, etc. The use of sequential boilers may be limited when high steam availability guarantees are required.

3.1.1.5 Other

Increased process integration

BAT is to seek to optimise the use of energy between more than one process or system within the installation or with a third party.

Brief technical description

There are additional benefits to seeking process integration, such as optimising raw material usage.

Achieved environmental benefits

Energy savings.

Operational data

The scope and nature (e.g. level of detail) of applying this technique will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

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 an IPPC permit. In many cases, public authorities have facilitated such arrangements or are the third party.

Applicability

All installations.

Maintaining the impetus of energy efficiency initiatives

BAT is to maintain the impetus of the energy efficiency programme by using a variety of techniques, such as:

a. implementing a specific energy management system,
b. accounting for energy based on real (metered) values, which places the obligation and credit for energy efficiency on the user/bill payer,
c. the creation of financial profit centres for energy efficiency,
d. benchmarking,
e. a fresh look at existing management systems,
f. using techniques to manage organisational change.

Brief technical description

Techniques such as the first three are applied according to the data in the relevant sections. Techniques such as the last three should be applied far enough apart for the progress of the ENE programme to be assessed, i.e. several years.

Achieved environmental benefits

Energy savings.

Operational data

To successfully achieve ongoing energy efficiency improvement over time, it is necessary to maintain the impetus of energy efficiency programmes.

It may be appropriate to use one technique or several techniques together. The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems. Techniques (a), (b) and (c) are applied and maintained according to the relevant sections referred to. The frequency of application of techniques such as (d), (e) and (f) should be far enough apart to enable the progress of the ENE programme to be assessed, and is therefore likely to be several years.

Applicability

All installations.

Maintaining expertise

BAT is to maintain expertise in energy efficiency and energy-using systems by using techniques such as:

- recruitment of skilled staff and/or training of staff. Training can be delivered by in-house staff, by external experts, by formal courses or by self-study/development,
- takings taff off-line periodically to perform fixed term/specific investigations (in their original installation or in others),
- sharing in-house resources between sites,
- use of appropriately skilled consultants for fixed term investigations,
- outsourcing specialist systems and/or functions.

Brief technical description

Human resources are required for the implementation and control of energy efficiency management, and staff whose work may affect energy should receive training

Achieved environmental benefits

Energy savings.

Operational data

The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

Applicability

All installations.

Effective control of processes

BAT is to ensure that the effective control of processes is implemented by techniques such as:

- having systems in place to ensure that procedures are known, understood and complied,

- ensuring that the key performance parameters are identified, optimised for energy efficiency and monitored,
- documenting or recording these parameters.

Achieved environmental benefits

Energy savings.

Operational data

The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

Applicability

All installations.

Maintenance

BAT is to carry out maintenance at installations to optimise energy efficiency by applying all of the following:

- clearly allocating responsibility for the planning and execution of maintenance,
- establishing a structured programme for maintenance based on technical descriptions of the equipment, norms, etc. as well as any equipment failures and consequences. Some maintenance activities may be best scheduled for plant shutdown periods,
- supporting the maintenance programme by appropriate record keeping systems and diagnostic testing,
- identifying from routine maintenance, breakdowns and/or abnormalities, possible losses in energy efficiency, or where energy efficiency could be improved,
- identifying leaks, broken equipment, worn be arings, etc. that affect or control energy usage, and rectifying them at the earliest opportunity.

Brief technical description

Carrying out repairs promptly has to be balanced with maintaining the product quality and process stability, as well as with health and safety issues.

Structured maintenance and the repair of equipment that uses energy and/or controls energy use at the earliest opportunity are essential for achieving and maintaining efficiency.

Achieved environmental benefits

Energy savings.

Operational data

The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems. Carrying out repairs promptly has to be balanced (where applicable) with maintaining the product quality and process stability and the health and safety issues of carrying out repairs on the operating plant (e.g. it may contain moving and/or hot equipment, etc.).

Applicability

All installations.

Monitoring and measurement

BAT is to establish and maintain documented procedures to monitor and measure, on a regular basis, the key caracteristics of operations and activities that can have a significant impact on energy efficiency.

Brief technical description

Monitoring and measurement are an essential part of checking in a 'plan-do-check-act' system, such as in energy management. It is also a part of the effective control of processes.

Achieved environmental benefits

Energy savings.

3.1.2 Energy management

Achieving energy efficiency in energy-using systems, processes, activities or equipment

The general BAT, identify the importance of seeing the installation as a whole, and assessing the needs and purposes of the various systems, their associated energies and their interactions. They also include:

- analysing and benchmarking the system and its performance,
- planning actions and investments to optimise energy efficiency considering the cost-benefits and cross-media effects,
- for new systems, optimising energy efficiency in the design of the installation, unit or system and in the selection of processes,
- for existing systems, optimising the energy efficiency of the system through its operation and management, including regular monitoring and maintenance.

Achieved environmental benefits

Energy savings.

A systems approach to energy management

BAT is to optimise energy efficiency by taking a systems approach to energy management in the installation. Systems to be considered for optimising as a whole are, for example:

- process units
- heating systems such as steam and hot water
- cooling and vacuum
- motor driven systems such as compressed air and pumping
- lighting
- drying, separation and concentration.

Brief technical description

The major energy efficiency gains are achieved by viewing the installation as a whole and assessing the needs and uses of the various systems, their associated energies and their interactions.

Achieved environmental benefits

Energy savings.

Operational data

The scope and nature (e.g. level of detail, frequency of optimisation, systems to be considered at any one time) of applying this technique will depend on factors such as the nature, scale and complexity of the installation, the energy requirements of the component processes and systems and the techniques considered for application.

Applicability

All installations.

Benchmarking

BAT is to carry out systematic and regular comparisons with sector, national or regional benchmarks, where validated data are available.

Brief technical description

The period between benchmarking is sector-specific and is usually several years, as benchmark data rarely change rapidly or significantly in a short time period.

Benchmarking is a powerful tool for assessing the performance of a plant and the effectiveness of energy efficiency measures, as well as overcoming paradigm blindness. Data may be found in sector BREFs, trade association information, national guidance documents, theoretical energy calculations for processes, etc. Data should be comparable and may need to be corrected, e.g. for type of feedstock.

Data confidentiality may be important, such as where energy consumption is a significant part of the cost of production, although it may be possible to protect data.

Achieved environmental benefits

Energy savings.

Operational data

Benchmarking can also be applied to processes and working methods.

The level of detail will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems. Confidentiality issues may need to be addressed: for instance, the results of benchmarking may remain confidential. The period between benchmarkings is sector-specific and usually long (i.e. years), as benchmark data rarely change rapidly or significantly in a short time period.

Applicability

All installations.

Cogeneration

BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Brief technical description

Cogeneration plants are those producing combined heat and power. They are different cogeneration technologies:

- Combined cycle gas turbines, (gas turbines combined with waste heat recovery boilers and one of the steam turbines mentioned below),
- Steam turbine plants (backpressure),
- Steam condensing extraction turbine (backpressure, uncontrolled extraction condensing turbines and extraction condensing turbines) ,
- Gas turbines with heat recovery boilers,
- Internal combustion engines (Otto or diesel (reciprocating) engines with heat utilisation),
- Microturbines,
- Stirling engines,
- Fuel cells (with heat utilisation),
- Steam engines,
- Organic Rankin cycles,
- Other types.

Cogeneration is as likely to depend as much on economic conditions as ENE optimisation. Cogeneration opportunities should be sought on the identification of possibilities, on investment either on the generator's side or potential customer's side, identification of potential partners or by changes in economic circumstances (heat, fuel prices, etc.).

In general, cogeneration can be considered when:

- the demands for heat and power are concurrent,
- the heat demand (on-site and/or off-site), in terms of quantity (operating times during year), temperature, etc. can be met using heat from the CHP plant, and no significant heat demand reductions can be expected.

Achieved environmental benefits

There are significant economic and environmental advantages to be gained from CHP production. Combined cycle plants make the maximum use of the fuel's energy by producing both electricity and heat with minimum energy wastage. The plants achieve a fuel efficiency of 80 - 90%, while, for the conventional steam condensing plants, the efficiencies remain at 35 - 45% and even for the combined cycle plants below 58%.

The high efficiency of CHP processes delivers substantial energy and emissions savings.

Typical values of a coal-fired CHP plant compared to the process in an individual heat-only boiler and acoal-fired electricity plant, but similar results can also be obtained with other fuels. In example, separate and CHP units produce the same amount of useful output.

However, separate production implies an overall loss of 98 energy units, compared to only 33 in CHP. The fuel efficiency in the separate production is 55%, while in the case of combined heat and power production, 78 % fuel efficiency is achieved. CHP production thus needs around 30% less fuel input to produce the same amount of useful energy. CHP can, therefore, reduce atmospheric emissions by an equivalent amount. However, this will depend on the local energy mix for electricity and/or heat (steam production).

As with electricity generation, a wide variety of fuels can be used for cogeneration, e.g. waste, renewable sources such as biomass, and fossil fuels such as coal oil and gas.

Cross-media effects

The electricity production may decrease where a plant is optimised for heat recovery (e.g in W-t-E plants). For example it can be shown that a W -t-E plant with, e .g. 18% electricity production (WFD equivalent 0.468) is congruent with a W-t-E plant with, e.g. 42.5% utilisation of district heat (WFD equivalent 0.468) or a plant with 42.5% (WFD equivalent 0.468) commercial use of steam.

Operational data

In many cases, public authorities (at local, regional or national level) have facilitated such arrangements or are the third party.

Applicability

The choice of CHP concept is based on a number of factors and even with similar energy requirements, no two sites are the same. The initial selection of a CHP plant is often dictated by the following factors:

- the critical factor is t hat there is sufficient demand for heat, in terms of quantity, temperature, etc. that can be met using heat from the CHP plant
- the base-load electrical demand of the site, i.e. the level below which the site electrical demand seldom falls
- the demands for heat and power are concurrent
- a convenient fuel price in ratio to the price of electricity
- high annual operation time (preferably more than 4 000 – 5 000 full load hours).

In general, CHP units are applicable to plants having significant heat demands at temperatures within the range of medium or low pressure steam. The evaluation of the cogeneration potential at a site should ensure that no significant heat demand reductions can be expected. Otherwise the cogeneration setup would be designed for a too large heat demand, and the cogeneration unit would operate inefficiently.

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 an IPPC permit.

Economics

- the economics depend on the ratio between fuel and electricity price, the price of heat, the load factor and the efficiency,
- the economics depend strongly on the long term delivery of heat and electricity,
- policy support and market mechanisms have a significant impact, such as the beneficial energy taxation regime, and liberalisation of the energy markets.

Driving force for implementation

In 2007, relatively small scale CHP can be economically feasible. The following explain which types of CHP are usually suitable in different cases. However, the limiting figures are exemplary only and may depend on local conditions. Usually the electricity can be sold to the national grid as the site demand varies. Utilities modelling, assists the optimisation of the generation and heat recovery systems, as well as managing the selling and buying of surplus energy.

Choice of CHP type:

- Steam turbines may be the appropriate choice for sites where:

  - the electrical base load is over 3 -5 MWe
  - there is a low value process steam requirement; and the power to heat demand ratio is greater than 1:4

- cheap, low premium fuel is available
- adequate plot space is available
- high grade process waste heat is available (e.g. from furnaces or incinerators)
- the existing boiler plant is in need of replacement
- the power to heat ratio is to be minimised. In CHP plants, the backpressure level must be minimised and the high pressure level must be maximised in order to maximise the power to heat ratio, especially when renewable fuels are used.

-Gas turbines may be suitable if:

- the power to heat ratio is planned to be maximised
- the power demand is continuous, and is over 3 MWe (smaller gas turbines are at the time of writing just starting to penetrate the market)
- natural gas is available (although this is not a limiting factor)
- there i s a high de mand for m edium/high pr essure steam or hot w ater, particularly at temperatures higher than 500 °C
- demand exists for hot gases at 450 °C or above – the exhaust gas can be diluted with ambient air to cool it, or put through an air heat exchanger. (Also consider using in a combined cycle with a steam turbine).

- Internal combustion or reciprocating engines may be suitable for sites where:

- power or processes are cyclical or not continuous
- low pressure steam or medium or low temperature hot water is required
- there is a high power to heat demand ratio
- natural gas is available – gas powered internal combustion engines are preferred
- natural gas is not available – fuel oil or LPG powered diesel engines may be suitable
- the electrical load is less than 1 M We – spark ignition (units a vailable from 0.003 to 10 MWe)
- the el ectrical load is greater than 1 MWe – compression ignition (units from 3 to 20 MWe).

Electric motor driven sub-systems

BAT is to optimise electric motors in the following order:

- optimise the entire system the motor(s) is part of (e.g. cooling system)
- then optimise the motor(s) in the system according to the newly-determined load requirements, by applying one or more of the techniques described, according to applicability
- when the energy-using systems have been optimised, then optimise the remaining (non-optimised) motors according the techniques described and criteria such as:
  - i) prioritising the remaining motors running more than 2000 hrs per year for replacement with EEMs
  - ii) electric motors driving a variable load operating at less than 50% of capacity more than 20% of their operating time and operating for more than 2000 hours a year should be considered for equipping with variable speed drives.

Brief technical description

Replacement by electrically efficient motors (EEMs) and variable speed drives (VSDs) is one of the easiest measures when considering energy efficiency. However, this should be done in the context of considering the whole system the motor sits in, otherwise there are risks of:

- losing the po tential benefits of optimising the use and size of the systems, and subsequently optimising the motor drive requirements
- losing energy if a VSD is applied in the wrong context.

Achieved environmental benefits

Energy savings.

Electrical power supply

BAT is to:

- increase the power factor according to the requirements of the local electricity distributor,
- check the power supply for harmonics and apply filters if required,
- optimise the power supply efficiency.

Achieved environmental benefits

Energy savings.

ENEMS

BAT is to implement and adhere to an energy efficiency management system (ENEMS).

Brief technical description

BAT is to implement and adhere to an energy efficiency management system (ENEMS) that incorporates, as appropriate to the local circumstances, the following features:

- commitment of top management
- definition of an energy efficiency policy for the installation by top management
- planning and establishing objectives and targets
- implementation and operation of procedures paying particular attention to: staff s tructure a nd responsibilities; t raining, aw areness and competence; communication; employee involvement; documentation; efficient control of processes; maintenance programmes; emergency preparedness and response; safeguarding c ompliance with energy ef ficiency related legislation and agreements (where such agreements exist)
- benchmarking
- checking performance and taking corrective action paying particular attention to: monitoring and measurement; corrective and preventive action; maintenance of records; independent (where practicable) internal auditing to determine whether or not the ENEMS conforms to planned arrangements and has been properly implemented and maintained
- review of the ENEMS and its continuing suitability, adequacy and effectiveness by top management
- when designing a new unit, taking into account the environmental impact from the eventual decommissioning
- development of energy efficient technologies and to follow developments in energy efficiency techniques.

An ENEMS may optionally include the following steps:

- preparation and publication (with or without external validation) of a regular energy efficiency statement, allowing for year-by-year comparison against objectives and targets

- having the management system and audit procedure examined and validated externally
- implementation and adherence to a nationally management system for energy efficiency.

Achieved environmental benefits

Energy savings.

Applicability

All installations. The scope and nature (e.g. level of detail) of applying this ENEMS will depend on the nature, scale and complexity of the installation, and the energy requirements of the component processes and systems.

Energy audit

BAT is to identify the aspects of an installation that influence energy efficiency by carrying out an audit. It is important that an audit is coherent with a systems approach.

This is applicable to all existing installations and prior to planning upgrades rebuilds. An audit may be external or internal.

• When carrying out an audit, BAT is to ensure that an audit identifies the following aspects:

- energy use and type in the installation and its component systems and processes
- energy-using equipment, and the type and quantity of energy used in the installation
- possibilities to minimise energy use, such as:
  * controlling/reducing operating times, e.g. switching off when not in use
  * ensuring insulation is optimised
  * optimising utilities, associated systems and processes
- possibilities to use alternative sources or use of energy that is more efficient, in particular energy surplus from other processes and/or systems
- possibilities to apply energy surplus to other processes and/or systems
- possibilities to upgrade heat quality.

• BAT is to use appropriate tools or methodologies to assist with identifying and quantifying energy optimisation, such as:

- energy models, databases and balances
- a technique such as pinch methodology, exergy or enthalpy analysis or thermoeconomics
- estimates and calculations.

The choice of the appropriate tools depends on the sector and complexity of the site.

• BAT is to identify opportunities to optimise energy recovery within the installation, between systems within the installation and/or with a third party (or parties).

This BAT depends on the existence of a suitable use for the surplus heat of the type and quantity that may be recovered.

Brief technical description

The scope of the audit and nature (e.g. level of detail, the time between audits) will depend on the nature, scale and complexity of the installation and the energy consumption of the component processes and systems, e.g.:

- in large installations with many systems and individual energy-using components such as motors, it will be necessary to prioritise data collection to necessary information and significant uses
- in smaller installations, a walk-through type audit may be sufficient.

The first energy audit for an installation may be called an energy diagnosis.

Achieved environmental benefits

Energy savings.

Operational data

The scope of the audit and the nature (e.g. level of detail) will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems.

The choice of appropriate tool or tools will depend on the sector, and the size, complexity and energy usage of the site.

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 an IPPC permit. In many cases, public authorities have facilitated such arrangements or are the third party.

Applicability

All existing installations and prior to planning upgrades or rebuilds. An audit may be internal or external. The scope for energy recovery depends on the existence of a suitable use for the heat at the type and quantity recovered. Opportunities may be identified at various times, such as a result of audits or other investigations, when considering upgrades or new plants, or when the local situation changes (such as a use for surplus heat is identified in a nearby activity).

Energy efficient design (EED)

BAT is to optimise energy efficiency when planning a new installation, unit or system or a significant upgrade by considering all of the following:

- energy efficient design (EED) should be initiated at the early stages of the conceptual design/basic design phase, even though the planned investments may not be well-defined, and should be taken into account in the tendering process
- the development and/or selection of energy efficient technologies
- additional data collection may need to be carried out as part of the design project or separately to supplement the existing data or fill gaps in knowledge
- the EED work should be carried out by an energy expert
- the initial mapping of energy consumption should also address which parties in the project organisations influence the future energy consumption and optimise the EED of the future plant with them. For example, the staff in the existing installation who may be responsible for specifying operational parameters.

Brief technical description

Where relevant in-house expertise on energy efficiency is not available (e.g. non-energy intensive industries), external ENE expertise should be sought.

The planning phase of a new installation, unit or system (or one undergoing major refurbishment) offers the opportunity to consider the lifetime energy costs of processes, equipment and utility systems, and to select the most energy efficient options, with the best lifetime costs

Achieved environmental benefits

Energy savings.

Operational data

Where relevant in-house expertise on ENE is not available (e.g. non-energy intensive industries), external ENE expertise should be sought.

Applicability

All new and significantly refurbished installations, major processes and systems.

Establishing and reviewing energy efficiency objectives and indicators

BAT is to establish energy efficiency indicators by carrying out all of the following:

- identifying suitable energy efficiency indicators for the installation, and where necessary, individual processes, systems and/or units, and measure their change over time or after the implementation of energy efficiency measures
- identifying and recording appropriate boundaries associated with the indicators
- identifying and recording factors that can cause variation in the energy efficiency of the relevant processes, systems and/or units.

Brief technical description

Secondary or final energies are usually used for monitoring ongoing situations. In some cases, more than one secondary or final energy indicator may be used for each process (e.g. both steam and electricity). When deciding on the use (or change) in energy vectors and utilities, the indicator may also be the secondary or final energy. However, other indicators such as primary energy or carbon balance may be used to take account of the efficiency of production of any secondary energy vector and its cross-media effects, depending on local circumstances.

Achieved environmental benefits

Quantifiable, recorded energy efficiency objectives are crucial for achieving and maintaining energy efficiency. Areas for improvement are identified from an audit. Indicators need to be established to assess the effectiveness of energy efficiency measures. For process industries, these are preferably indicators related to production or service throughput (e.g. GJ/t product), termed specific energy consumption (SEC). Where as ingle energy objective (such as SEC) cannot be set, or where it is helpful, the efficiency of individual processes, units or systems may be assessed.

Production parameters (such as production rate, product type) vary and these may affect the measured energy efficiency and should be recorded to explain variations and to ensure that energy efficiency is realised by the techniques applied. Energy use and transfers may be complicated and the boundary of the installation or system being assessed should be carefully defined on the basis of entire systems. Energy should be calculated on the basis of primary energy, or the energy uses shown as secondary energy for the different utilities (e.g. process heat as steam use in GJ/t).

Operational data

The scope and nature (e.g. level of detail) of applying these techniques will depend on the nature, scale and complexity of the installation, and the energy consumption of the component processes and systems.

Secondary or final energies are usually used for monitoring ongoing situations. In some cases, it may be most convenient to use more than one secondary or final energy indicator, for example, in the pulp and paper industry, where both electricity and steam are given as joint energy efficiency indicators. When deciding on the use (or change) of energy vectors and utilities, the energy indicator used may also be the secondary or final energy. However, other indicators such as primary energy or carbon balance may be used, to take account of the production of any secondary energy vector and the cross-media effects, depending on local circumstances.

Applicability

All installations.

Heat recovery

BAT is to maintain the efficiency of heat exchangers by both monitoring the efficiency periodically and preventing or removing fouling.

Achieved environmental benefits

Energy savings.

Planning and establishing objectives and targets - Continuous environmental improvement

BAT is to continuously minimise the environmental impact of an installation by planning actions and investments on an integrated basis and for the short, medium and long term, considering the cost-benefits and cross-media effects.

Brief technical description

An important aspect of environmental management systems is continuing environmental improvement. This requires maintaining a balance for an installation between consumption of energy, raw materials and water, and the emissions. Planned continuous i mprovement can also achieve the best cost-benefit for achieving energy savings (and other environmental benefits).

Achieved environmental benefits

Energy savings.

Cross-media effects

The environmental benefits may not be linear, e.g. 2% energy savings every year for 10 years.

They may be stepwise, reflecting investment in ENE projects, etc. Equally, there may be cross-media effects: for example it may be necessary to increase energy consumption to abate an air pollutant.

Environmental impacts can never be reduced to zero, and there will be points in time where there is little or no cost-benefit to further actions. However, over a longer period, with changing technology and costs (e.g. energy prices), the viability may also change.

Operational data

'Continuously' means the actions are repeated over time, i.e. all planning and investment decisions should consider the overall long term aim to reduce the environmental impacts of the operation. This may mean avoiding short term actions to better use available investments over a longer term, e.g. changes to the core process may require more investment and take longer to implement, but may bring bigger reductions in energy use and emissions.

Applicability

All installations.

Techniques for cooling

BAT is to seek to use surplus heat, rather than dissipate it through cooling. Where cooling is required, the advantages of free cooling (using ambient air) should be considered.

Achieved environmental benefits

Energy savings.

3.2 Processes

3.2.1 Combustion

3.2.1.1 Biomass and peat combustion

Bark pressing

BAT is to optimise the energy efficiency of combustion by relevant techniques.

Achieved environmental benefits

Increased combustion efficiency. Energy savings.

Cross-media effects

High BOD releases to water and high energy use and maintenance.

Operational data

High.

Applicability

Possible.

Biomass gasification

BAT is to optimise the energy efficiency of combustion by relevant techniques.

Achieved environmental benefits

Increased plant efficiency and lower emission levels Gas can be used as reburning fuel to reduce emissions of NO_X.

Energy savings.

Operational data

Limited experience.

Applicability

Possible but until now only applied in demonstration and pilot plants.

Economics

Expensive in small scale.

Cogeneration

BAT is to optimise the energy efficiency of combustion by relevant techniques BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Brief technical description

For the combustion of biomass and peat, pulverised combustion, fluidised bed combustion, (BFBC and CFBC) as well as the spreader stoker grate-firing technique for wood and the vibrating, water-cooled grate for straw-firing are considered to be. BAT.

The use of advanced computerised control system in order to achieve a high boiler performance with increased combustion conditions that support the reduction of emissions are also considered as BAT.

Achieved environmental benefits

Energy savings.

Low excess air

BAT is to optimise the energy efficiency of combustion.

Achieved environmental benefits

Reduction of NO_X, CO, and N_2O emissions, also an increased efficiency. Energy savings.

Cross-media effects

Reduction of NO_X emissions leads to higher unburned carboninash.

Operational data

High.

Applicability

Possible in new and retrofitable plants.

Economics

Plant specific.

3.2.1.2 Coal and lignite combustion

Advanced computerised control of combustion conditions for emission reduction and boiler performance

BAT is to optimise the energy efficiency of combustion.

Brief technical description

For the combustion of coal and lignite, pulverised combustion (PC), fluidised bed combustion (CFBC and BFBC) as well as pressurised fluidised bed combustion (PFBC) and grate firing are all considered to be BAT for new and existing plants. Grate firing should preferably only be applied to new plants with a rated thermal input below 100 MW.

For the design of new boilers or retrofit projects for existing plants, those firing systems are BAT which assure a high boiler efficiency and which include primary measures to reduce the generation of NO_X emissions, such as air and fuel staging, advanced low-NO_X burners and/or reburning, etc. The use of advanced computerised control system in order to achieve a high boiler performance with increased combustion conditions that support the reduction of emissions are also considered as BAT.

Achieved environmental benefits

Increased efficiency higher boiler performance reduced emissions. Energy savings.

Cross-media effects

None.

Operational data

High.

Applicability

New plants and retrofitable.

Economics

Not available.

Coal gasification

BAT is to optimise the energy efficiency of combustion.

Achieved environmental benefits

Increased plant efficiency and lower emission levels particularly for NO_X. Energy savings.

Operational data

Only applied in demonstration plants.

Applicability

New plants - Possible but until now only applied in demonstration plants.
Retrofitable - Not possible

Economics

Not available for normal operation.

Cooling tower discharge

BAT is to optimise the energy efficiency of combustion.

Achieved environmental benefits

Reheating of flue-gas after the FGD plant is not necessary. Energy savings.

Cross-media effects

No stack is needed.

Operational data

High.

Applicability

Possible in new and retrofitable plants.

Economics

No additional cost for constructing and maintenance of a stack.

Lignite pre-drying

BAT is to optimise the energy efficiency of combustion.

Achieved environmental benefits

Increased efficiency of approximately 3 – 5 percentage points. Energy savings.

Cross-media effects

Increased efficiency.

Operational data

Limited experience because only applied as pilot plant.

Applicability

Possible.

Economics

Additional cost of lignite dryers.

3.2.1.3 Gaseous fuels combustion

Advanced computerised control of combustion conditions for emission reduction and boiler performance

BAT is to optimise the energy efficiency of combustion.

Brief technical description

To reduce greenhouse gases, in particular releases of CO_2 from gas-fired combustion plants such as gas turbines, gas engines and gas-fired boilers, the best available options from today's point of view are techniques and operational measures to increase the thermal efficiency of the plant.

Achieved environmental benefits

Increased boiler efficiency.

Cross-media effects

None.

Operational data

High.

Applicability

Possible in new and retrofitable plants.

Economics

Plant specific.

Cogeneration

BAT is to optimise the energy efficiency of combustion by relevant techniques. BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Brief technical description

To reduce greenhouse gases, in particular releases of CO_2 from gas-fired combustion plants such as gas turbines, gas engines and gas-fired boilers, the best available options from today's point of view are techniques and operational measures to increase the thermal efficiency of the plant.

For gas-fired combustion plants, the application of gas turbine combined cycles and the cogeneration of heat and power (CHP) are technically the most efficient means of increasing the energy efficiency (fuel utilisation) of an energy supply system. A combined cycle operation and co-generation of heat and power is, therefore, to be considered as the first BAT option, i.e. whenever the local heat demand is great enough to warrant the construction of such a system.

The use of an advanced computerised control system in order to achieve a high boiler performance with increased combustion conditions that support the reduction of emissions are also considered as BAT.

Achieved environmental benefits

Energy savings.

3.2.1.4 Liquid fuels combustion

Advanced computerised control of combustion conditions for emission reduction and boiler performance

BAT is to optimise the energy efficiency of combustion.

Brief technical description

For the reduction of greenhouse gases, in particular the releases of CO_2 from liquid fuel-fired combustion plants, the best available options, from today's point of view, are techniques and operational measures to increase thermal efficiency. This goes along with the application of advanced computerised control systems for controlling the combustion conditions to maximise the emission reduction and boiler performance.

Achieved environmental benefits

Increased boiler efficiency. Energy savings.

Operational data

High

Applicability

Possible in new and retrofitable plants

Economics

Plant specific

Cogeneration

BAT is to optimise the energy efficiency of combustion by relevant techniques. BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Brief technical description

For the reduction of greenhouse gases, in particular releases of CO_2 from coal- and lignite-fired combustion plants, the best available options from today's point of view are techniques and operational measures to increase thermal efficiency.

Highest efficiencies are only achieved with extremely high steam parameters used in base load plants.Peak load plants with frequent start-up cycles have to be designed with lower steam parameters resulting in lower efficiencies.

Achieved environmental benefits

Energy savings

Cooling tower discharge

BAT is to optimise the energy efficiency of combustion.

Achieved environmental benefits

Reheating of flue-gas after the FGD plant is not necessary. Energy savings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Cross-media effects

No stack is needed

Operational data

High

Applicability

Possible in new and retrofitable plants

Economics

No additional cost for constructing and maintenance of a stack

3.2.1.5 Other

Burner regulation and control

BAT is to optimise the energy efficiency of combustion

Brief technical description

Automatic burner regulation and control can be used to control combustion by monitoring and controlling fuel flow, air flow, oxygen levels in the flue-gas and heat demand.

Achieved environmental benefits

This achieves energy savings by reducing excess air flow and optimising fuel usage to optimise burnout and to supply only the heat required for a process.

It can be used to minimise NO_x formation in the combustion process.

Cross-media effects

None foreseen.

Operational data

There will be an initial set-up stage, with periodic recalibration of the automatic controls.

Applicability

Widely used.

Economics

Cost effective, and the payback period is site-specific.

Driving force for implementation

Cost savings on fuel use.

Cogeneration CHP

BAT is to optimise the energy efficiency of combustion by relevant techniques. BAT is to seek possibilities for cogeneration, inside and/or outside the installation (with a third party).

Brief technical description

Cogeneration plants are those producing combined heat and power. They are different cogeneration technologies:

- Combined cycle gas turbines, (gas turbines combined with waste heat recovery boilers and one of the steam turbines mentioned below)
- Steam turbine plants (backpressure)
- Steam condensing extraction turbine (backpressure, uncontrolled extraction condensing turbines and extraction condensing turbines)
- Gas turbines with heat recovery boilers
- Internal combustion engines (Otto or diesel (reciprocating) engines with heat utilisation)
- Microturbines
- Stirling engines
- Fuel cells (with heat utilisation)
- Steam engines
- Organic Rankin cycles
- Other types

Cogeneration is as likely to depend as much on economic conditions as ENE optimisation. Cogeneration opportunities should be sought on the identification of possibilities, on investment either on the generator's side or potential customer's side, identification of potential partners or by changes in economic circumstances (heat, fuel prices, etc.).

In general, cogeneration can be considered when:

- the demands for heat and power are concurrent
- the heat demand (on-site and/or off-site), in terms of quantity (operating times during year), temperature, etc. can be met using heat from the CHP plant, and no significant heat demand reductions can be expected.

Achieved environmental benefits

There are significant economic and environmental advantages to be gained from CHP production. Combined cycle plants make the maximum use of the fuel's energy by producing both electricity and heat with minimum energy wastage. The plants achieve a fuel efficiency of 80-90%, while, for the conventional steam condensing plants, the efficiencies remain at 35-45% and even for the combined cycle plants below 58%.

The high efficiency of CHP processes delivers substantial energy and emissions savings.

Typical values of a coal-fired CHP plant compared to the process in an individual heat-only boiler and acoal-fired electricity plant, but similar results can also be obtained with other fuels. In example, separate and CHP units produce the same amount of useful output.

However, separate production implies an overall loss of 98 energy units, compared to only 33 in CHP. The fuel efficiency in the separate production is 55 %, while in the case of combined heat and power production, 78% fuel efficiency is achieved. CHP production thus needs around 30% less fuel input to produce the same amount of useful energy. CHP can, therefore, reduce atmospheric emissions by an equivalent amount. However, this will depend on the local energy mix for electricity and/or heat (steam production).

As with electricity generation, a wide variety of fuels can be used for cogeneration, e.g. waste, renewable sources such as biomass, and fossil fuels such as coal oil and gas.

Cross-media effects

The electricity production may decrease where a plant is optimised for heat recovery (e.g in W-t-E plants). For example it can be shown that a W-t-E plant with, e .g. 18% electricity production (WFD equivalent 0.468) is congruent with a W-t-E plant with, e.g. 42.5% utilisation of district heat (WFD equivalent 0.468) or a plant with 42.5% (WFD equivalent 0.468) commercial use of steam.

Operational data

Successful implementation may depend on a suitable fuel and/or heat price in relation to the price of electricity. In many cases, public authorities (at local, regional or national level) have facilitated such arrangements or are the third party.

Applicability

The choice of CHP concept is based on a number of factors and even with similar energy requirements, no two sites are the same. The initial selection of a CHP plant is often dictated by the following factors:

- the critical factor is t hat there is sufficient demand for heat, in terms of quantity, temperature, etc. that can be met using heat from the CHP plant
- the base-load electrical demand of the site, i.e. the level below which the site electrical demand seldom falls
- the demands for heat and power are concurrent
- a convenient fuel price in ratio to the price of electricity
- high annual operation time (preferably more than 4 000 – 5 000 full load hours).

In general, CHP units are applicable to plants having significant heat demands at temperatures within the range of medium or low pressure steam. The evaluation of the cogeneration potential at a site should ensure that no significant heat demand reductions can be expected. Otherwise the cogeneration setup would be designed for a too large heat demand, and the cogeneration unit would operate inefficiently.

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 an IPPC permit.

Economics

- the economics depend on the ratio between fuel and electricity price, the price of heat, the load factor and the efficiency
- the economics depend strongly on the long term delivery of heat and electricity
- policy support and market mechanisms have a significant impact, such as the beneficial energy taxation regime, and liberalisation of the energy markets.

Driving force for implementation

In 2007, relatively small scale CHP can be economically feasible. The following explain which types of CHP are usually suitable in different cases. However, the limiting figures are exemplary only and may depend on local conditions. Usually the electricity can be sold to the national grid as the site demand varies. Utilities modelling, assists the optimisation of the generation and heat recovery systems, as well as managing the selling and buying of surplus energy.

Choice of CHP type:

- Steam turbines may be the appropriate choice for sites where:

  - the electrical base load is over 3 -5 MWe

- there is a low value process steam requirement; and the power to heat demand ratio is greater than 1:4
- cheap, low premium fuel is available
- adequate plot space is available
- high grade process waste heat is available (e.g. from furnaces or incinerators)
- the existing boiler plant is in need of replacement
- the power to heat ratio is to be minimised. In CHP plants, the backpressure level must be minimised and the high pressure level must be maximised in order to maximise the power to heat ratio, especially when renewable fuels are used.

-Gas turbines may be suitable if:

- the power to heat ratio is planned to be maximised
- the power demand is continuous, and is over 3 MWe (smaller gas turbines are at the time of writing just starting to penetrate the market)
- natural gas is available (although this is not a limiting factor)
- there i s a high de mand for m edium/high pr essure steam or hot w ater, particularly at temperatures higher than 500°C
- demand exists for hot gases at 450°C or above – the e xhaust g as can be diluted with ambient air to cool it, or put through an air h eat exchanger. (Also consider using in a combined cycle with a steam turbine).

- Internal combustion or reciprocating engines may be suitable for sites where:

- power or processes are cyclical or not continuous
- low pressure steam or medium or low temperature hot water is required
- there is a high power to heat demand ratio
- natural gas is available – gas powered internal combustion engines are preferred
- natural gas is not available – fuel oil or LPG powered diesel engines may be suitable
- the electrical load is less than 1 MWe – spark ignition (units a vailable from 0.003 to 10 MWe)
- the el ectrical load is greater than 1 MWe – compression ignition (units from 3 to 20 MWe).

Best practices

BACKPRESSURE

The simplest cogeneration power plant is the so-called 'backpressure power plant', where CHP electricity and heat is generated in a steam turbine. The electrical capacity of steam turbine plants w orking on t he ba ckpressure process is usually a few dozen megawatts.

The power to heat ratio is normally about 0.3 - 0.5. The power capacity of gas turbine plants is usually slightly smaller than that of steam turbine plants, but the power to heat ratio is often close to 0.5.

The amount of industrial backpressure power depends on the heat consumption of a process and on the properties of high pressure, medium pressure and backpressure steam. The major determining factor of the backpressure steam production is the power to heat ratio. In a district heating power plant, the steam is condensed in the heat exchangers below the steam turbine and circulated to consumers as hot water. In industrial plants, the steam from a backpressure power plant a gain is fed to the factory where it surrenders its heat. The backpressure is lower in a district heating power plant than in industrial backpressure plants.

This explains why the power to heat ratio of industrial backpressure power plants is lower than that of district heating power plants.

EXTRACTION CONDENSING

A condensing power plant only generates electricity whereas in an extraction condensing power plant some of the steam is extracted from the turbine to generate heat.

GAS TURBINE HEAT RECOVERY BOILER

In gas turbine heat recovery boiler power plants, heat is generated with the hot flue-gases of the turbine. The fuel used in most cases is natural gas, oil, or a combination of these. Gas turbines can also be fired with gasified solid or liquid fuels.

COMBINED CYCLE POWER PLANT

A combined cycle power plant consists of one or more gas turbines connected to one or more steam turbines. A combined cycle power plant is often used for combined heat and power production. The heat from the exhaust gases of a gas turbine process is recovered for the steam turbine process. The recovered heat is, in many cases, subsequently converted to more electricity, instead of being used for heating purposes. The benefit of the system is a high power to heat r atio and a high efficiency. The latest de velopment in combustion technology, the gasification of solid fuel, has also been linked with combined cycle plants and cogeneration.

The gasification technique will reduce the sulphur and nitric oxide emissions to a considerably lower level than conventional combustion techniques by means of the gas treatment operations downstream of gasification and upstream of the gas turbine combined cycle.

INTERNAL COMBUSTION ENGINES (RECIPROCATING ENGINES)

In an internal combustion or reciprocating engine, heat can be recovered from lubrication oil and engine cooling water as well as from exhaust gases. Internal combustion engines convert chemically bou nd energy in fuel to thermal energy by combustion. Thermal expansion of flue-gas takes place in a cylinder, forcing the movement of a piston. The mechanical energy from the piston movement is transferred to the flywheel by the crankshaft and further transformed into electricity by an alternator connected to the flywheel.

This direct conversion of the high temperature thermal expansion into mechanical energy and further into electrical energy gives internal combustion engines the highest thermal efficiency (produced electric energy per used fuel unit) a mong single cycle prime movers, i.e. also the lowest specific CO_2 emissions.

Low speed (<300 rpm) two stroke engines are available up to 80 MWe unit sizes. Medium speed (300 <n <1500 rpm) four stroke engines are available up to 20 MWe unit sizes. Medium speed engines are usually selected for continuous power generation a pplications. High speed (>1500 rpm) four stroke engines available up to around 3 M We are mostly used in peak load applications.

The most used engine types can further be divided into diesel, spark/micro pilot ignited and dual fuel e ngines. C overing a wide r ange of fuel a lternatives from na tural, associated, landfill, mining (coal bed), bio and even pyrolysis gases and liquid biofuels, diesel oil, crude oil, heavy fuel oil, fuel emulsions to refinery residuals.

Stationary engine plants (i.e. not mobile generators) commonly have several engine driven generator sets working in parallel. Multiple engine installations in combination with the ability of engines to maintain high efficiency when operated at part load, gives operation flexibility with optimal matching of different load demands and excellent availability. Cold start up time is short compared to coal-, oil- or gas-fired boiler steam turbine plants or combined cycle gas turbine plant. A running engine has a quick response capability to network and can therefore be utilised to stabilise the grid quickly.

Closed radiator cooling systems are suitable for this technology, keeping the water consumption of stationary engine plants very low. Their c ompact de sign makes engine plants suitable for distributed combined heat and power (CHP) production, close to electricity and heat consumers in urban and industrial areas. Thus, associated energy losses in transformers and transmission lines and heat transfer pipes are reduced. Typical transmission losses associated with central electricity production account, on the average, for 5 to 8% of the generated electricity, correspondingly heat energy losses in municipal district heating networks may be less than 10 %. It should be borne in mind that the highest transmission losses generally occur in low voltage grids and in-house serving connections. On the other hand, electricity production in bigger plants is usually more effective.

The high single cycle efficiency of internal combustion engines together with relatively high exhaust gas and cooling water temperatures makes them ideal for CHP solutions. Typically, about 30% of the energy released in the combustion of the fuel can be found in the exhaust gas and about 20% in the cooling waters treams. Exhaust gas energy can be recovered by connecting a boiler downstream of the engine, producing steam, hot water or hot oil. Hot exhaust gas can also be used directly or indirectly via heat exchangers, e.g. in drying processes.

Cooling water streams can be divided into low and high temperature circuits and the degree of recovery potential is related to the lowest temperature that can be utilised by the heat customer. The whole cooling water energy potential can be recovered in district heating networks with low return temperatures. Engine cooling heat sources in connection with an exhaust gas boiler and an economiser can then result in a fuel (electricity + heat recovery) utilisation of up to 85% with liquid, and up to 90% in gas fuel applications.

Heat energy can be delivered to end users as steam (typically up to 20 bar superheated), hot water or hot oil depending on the need of the end user. The h eat can also be utilised by an absorption chiller process to produce chilled water.

It is also possible to use absorption heat pumps to transfer energy from the engine low temperature cooling circuit to a higher t emperature that can be utilised in district heating networks with high return temperatures.

Hot and chilled water accumulators can be used to stabilise an imbalance between electricity and heating/cooling demands over shorter periods. Internal combustion or reciprocating engines typically have fuel efficiencies in the range of 40 – 48% when producing electricity and fuel efficiencies may come up to 85 – 90% in combined heat and power cycles when the heat can be effectively used. Flexibility in trigeneration can be improved by us ing hot water and chilled water storage, and by using the topping-up control capacity offered by compressor chillers or direct-fired auxiliary boilers.

<u>Achieved environmental benefits</u>

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TRIGENERATION

Description

Trigeneration is generally understood to mean the simultaneous conversion of a fuel into three useful energy products: electricity, hot water or steam and chilled water. A trigeneration system is actually a cogeneration system with an absorption chiller that uses some of the heat to produce chilled water.

They are compares two concepts of chilled water production: compressor chillers using electricity and trigeneration using recovered heat in a lithium bromide absorption chiller. Heat is r ecovered from both the exhaust gas and the engine high temperature cooling circuit. Flexibility in trigeneration can be improved by using topping-up control capacity offered by compressor chillers or direct-fired auxiliary boilers.

Single-stage lithium bromide absorption chillers are able to use hot water with temperatures as low as 90 °C a s the energy source, while two-stage lithium bromide absorption chillers need about 170 °C, which means that they are normally steam-fired. A single-stage lithium bromide absorption chiller producing water at 6 8 °C has a coefficient of performance (COP) of about 0.7 a nd a two-stage chiller has a COP of about 1.2. This means they can produce a chilling capacity corresponding to 0.7 or 1.2 times the heat source capacity.

For an engine-driven CHP plant, single- and two-stage systems can be applied. However, as the engine has residual heat split in exhaust gas and engine cooling, the single stage is more suitable because more heat can be recovered and transferred to the absorption chiller.

Achieved environmental benefits

The main advantage of trigeneration is the achievement of the same output with considerably less fuel input than with separate power and heat generation.

The flexibility of using the recovered heat for heating during one season (winter) and cooling during another season (summer) provides an efficient way of maximising the running hours at high total plant efficiency, benefiting both the owner and the environment.

The running philosophy and control strategy are of importance and should be properly evaluated. The optimal solution is seldom based on a solution where the entire chilled water capacity is produced by absorption chillers. For air conditioning, for instance, most of the annual cooling needs can be met with 70% of the peak cooling capacity, while the remaining 30% can be topped up with compressor chillers.

In this way, the total investment cost for the chillers can be minimised.

Applicability

Trigeneration and distributed power generation. Since it is more difficult and costly to distribute hot or chilled water than electricity, trigeneration a utomatically leads to distributed power production since the trigeneration plant needs to be located close to the hot or chilled water consumers.

In order to maximise the fuel efficiency of the plant, the concept is based on the joint need for hot and chilled water. A power plant located close to the hot and chilled water consumer also has lower electricity distribution losses. Trigeneration is cogeneration taken one step further by including a chiller. Clearly there is no advantage to making that extra investment if all the recovered heat can be used effectively during all the plant's running hours.

However, the extra investment starts to pay off if there are periods when not all the heat can be used, or when no heat demand exists but there is a use for chilled water or air. For example, trigeneration i soften used for air conditioning in buildings, for heating during winter and cooling during summer, or for heating in one area and cooling in another area.

Many i ndustrial facilities and pub lic bu ildings a lso have s uch a s uitable m ix of he ating and cooling needs, four examples being breweries, shopping malls, airports and hospitals.

Driving force for implementation

Cost savings.

DISTRICT COOLING

Description

District cooling is another aspect of cogeneration: where cogeneration provides centralised production of heat, which drives on absorption chillers and the electricity, is sold to the grid.

Cogeneration can also deliver district cooling (DC) by means of centralised production and distribution of cooling energy. Cooling energy is delivered to customers via chilled water transferred in a separate distribution network.

District cooling can be produced in different ways depending on the season and the outside temperature. In the winter, at least in Nordic countries, cooling can be carried out by cold water from the sea. In the summer, district cooling can be produced by absorption technology. District cooling is used for air conditioning, for cooling of office and commercial buildings, and for residential buildings.

Achieved environmental benefits

Improving the eco-efficiency of district heating (DH) and district cooling (DC) in Helsinki, Finland, has achieved many sustainability goals as shown below:

- greenhouse gas and other emissions, such as nitrogen oxides, sulphur dioxide and particles, have been greatly reduced
- the drop in electricity consumption will also cut down the electricity consumption peaks that building-specific cooling units cause on warm days
- from October until May, all DC energy is renewable, obtained from cold seawater. This represents 30% of yearly DC consumption
- in the warmer season, absorption chillers use the excess heat of CHP p ants which otherwise would be led to the sea. Although the fuel consumption in the CHP plant may increase, the total fuel consumption compared to the situation with separate cooling systems in buildings will decrease
- in DC, harmful noise and the vibration of cooling equipment has been removed
- the space reserved for cooling equipment in buildings is freed for other purposes
- the problem of microbial growth in the water of condensing towers is also avoided
- contrary to the cooling agents used in building-specific compressor cooling, no harmful substances (e.g. CFC and HCFC compounds) evaporate in the processes of DC
- DC improves the aesthetics of cityscape: the production units and pipelines are not visible. The big condensers on the roofs of buildings and multiple coolers in windows will no longer be needed
- the life cycle of the DH and DC systems is much longer than that of building-specific units, e.g. the service life of a cooling plant is double compared to separate units. The technical service life of the main pipelines of DH and DC systems extends over a century.

Cross-media effects

Impacts of installing a distribution system.

Operational data: Status of development

Reliable.

Applicability

This technique could have wide application. However, this depends on local circumstances.

Economics

Large investments are required for the distribution systems.

Fuel choice

Combustion system techniques to improve energy efficiency.

Brief technical description

The type of fuel chosen for the combustion process affects the amount of heat energy supplied per unit of fuel used. The required excess air ratio is dependent on the fuel used, and this dependence increases for solids. The choice of fuel is therefore an option for reducing excess air and increasing energy efficiency in the combustion process. Generally, the higher heat value of the fuel, the more efficient the combustion process.

Achieved environmental benefits

This achieves energy savings by reducing excess air flow and optimising fuel usage. Some fuels produce less pollutants during combustion, depending on source (e.g. natural gas contains very little sulphur to oxidise to SO_x, no metals). There is information on these emissions and benefits in various vertical sector BREFs where fuel choice is known to have a significant effect on emissions.

The choice of using a fuel with a lower heat value may be influenced by other environmental factors:

- fuel from a sustainable source
- recovery of thermal energy from waste gases, waste liquids or solids used as fuels
- the minimisation of other environmental impacts, e.g. transport.

Cross-media effects

Various emissions are associated with certain fuels, e .g. particulates, SO_x, and metals are associated with coals.

Operational data

None given.

Applicability

Widely applied during the selection of a design for a new or upgraded plant.

For existing plants, the choice of fuels will be limited by the combustion plant design (i.e. a coal fire plant may not be readily converted to burn natural gas). It may also be restricted by the core business of the installation, e.g. for a waste incinerator.

The fuel choice may also be influenced by legislation and regulations, including local and transboundary environmental requirements.

Economics

Fuel selection is predominately cost-based.

Driving force for implementation

- combustion process efficiency
- reduction of other pollutants emitted.

Example plants

- wastes burnt as a service in waste-to-energy plants (waste incinerators with heat recovery)
- wastes burnt in cement kilns

- waste gases burnt, e.g. hydrocarbon gases in a refinery or CO in non-ferrous metals processing
- biomass heat and/or electrical power plants.

Lowering of exhaust gas temperatures

BAT is to optimise the energy efficiency of combustion.

Brief technical description

Reduction of the flue-gas temperature by:

- dimensioning for the maximum performance plus a calculated safety factor for surcharges
- increasing heat transfer to the process by increasing either the heat transferrate, or increasing or improving the heat transfer surfaces
- heat recovery by combining an additional process (for example, steam generation by using economisers,) to recover the waste heat in the flue-gases
- installing an air or water preheater or preheating the fuel by exchanging heat with flue-gases. Note that the process can require air preheating when a high flame temperature is needed (glass, cement, etc.)
- cleaning of heat transfer surfaces that are progressively covered by ashes or carbonaceous particulates, in order to maintain high heat transfer efficiency. Soot blowers operating periodically may keep the convection zones clean. Cleaning of the heat transfer surfaces in the combustion zone is generally made during inspection and maintenance shutdown, but online cleaning can be applied in some cases (e.g. refinery heaters)

Achieved environmental benefits

Energy savings

Cross-media effects

Reducing flue-gas temperatures may be in conflict with air quality in some cases, e.g:

- preheating combustion air leads to a higher flame temperature, with a consequence of an increase of NO_x formation that may lead to levels that are higher than the emissions limit value. Retrofitting an existing combustion installation to preheat the air may be difficult to justify due to space requirements, the installation of extra fans, and the addition of a NO_x removal process if NO_x emissions exceed emission limit values. It should be noted that a NO_x removal pr ocess based on a mmonia or urea injection induces a potential of ammonia slippage in the flue-gases, which can only be controlled by a costly ammonia sensor and a control loop, and, in case of large load variations, a dding a complicated injection system (for example, with two injection ramps at different levels) to inject the NO_x reducing agent in the right temperature zone
- gas cleaning systems, like NO_x or SO_x removal systems, only work in a given temperature range. When they have to be installed to meet the emission limit values, the arrangement of gas cleaning and heat recovery systems becomes more complicated and can be difficult to justify from an economic point of view
- in some cases, the local authorities require a minimum temperature at the stack to ensure proper dispersion of the flue-gases and to prevent plume formation. This practice is often carried out to maintain a good public image. A plume from a plant's stack may suggest to the general public that the plant is causing pollution. The absence of a plume suggests clean

operation and und ercertain weather conditions some plants (e.g. in the case of waste incinerators) reheat the flue-gases with natural gas before they are released from the stack. This is a waste of energy.

Operational data

The lower the flue-gas temperature, the better the energy efficiency. Nevertheless, certain drawbacks can emerge when the flue-gas temperatures are lowered below certain levels. In particular, when running below the acid dew point (a temperature below which the condensation of water and sulphuric acid occurs, typically from 110 to 170 °C, depending essentially on the fuel's sulphur content), damage of metallic surfaces may be induced. Materials which are resistant to corrosion can be used and are available for oil, waste and gas fired units although the acid condensate may require collection and treatment.

Applicability

The strategies above apart the periodic cleaning require additional investment and are best applied at the design and construction of the installation. However, retrofitting an existing installation is possible (if space is available).

Some applications may be limited by the difference between the process inlet temperature and the flue-gas exhaust temperature. The quantitative value of the difference is the result of a compromise between the energy recovery and cost of equipment.

Recovery of heat is always dependent on there being a suitable use.

See the potential for pollutant formation, in Cross-media effects.

Economics

Payback time can be from under five years to as long as to fifty years depending on many parameters, such as the size of the installation, and the temperatures of the flue gases.

Driving force for implementation

Increased process efficiency where there is direct heating (e.g. glass, cement).

Oxy-firing (oxyfuel)

BAT is to optimise the energy efficiency of combustion.

Brief technical description

Oxygen is used instead of ambient air and is either extracted from air on the site, or more usually, bought in bulk.

Achieved environmental benefits

Its use has various benefits:

- an increased oxygen content results in rise in combustion temperature, increasing energy transfer to the process, which helps to reduce the amount of unburnt fuel, thereby increasing energy efficiency while reducing NO_x emissions
- as air is about 80% nitrogen, the mass flow of gases is reduced accordingly, and hence a reduction in the flue-gas mass flow
- this also results in reduced NO_x emissions, as nitrogen levels at the burners are considerably reduced

- the reduction in flue gas mass flows may also result in smaller waste gas treatment systems and consequent energy demands, e.g. for NO_x where still required, particulates, etc.
- where oxygen is produced on site, the nitrogen separated may be used, e.g. in stirring and/or providing an inert atmosphere in furnaces where reactions can occur in oxidising conditions (such as pyrophoric reactions in non-ferrous metals industries)
- a future benefit may be the reduced quantity of gases (and high concentration of CO_2) which would make the capture and sequestration of CO_2 easier, and possibly less energy-demanding.

Cross-media effects

The energy requirement to concentrate oxygen from the air is considerable, and this should be included in any energy calculations.

Within the glass industry, there is a large diversity in glass melt production capacities, glass types and applied glass furnace types. For several cases, a conversion to oxygen firing (e.g. compared to recuperative furnaces, for relatively small furnaces and for special glass) very often improves the overall energy efficiency (taking into account the primary energy equivalent required to produce the oxygen). However, for other cases the energy consumption for oxygen generation is as high or even higher than the saved energy. This is especially the case when comparing overall energy efficiency of oxygen-fired glass furnaces with end-port fired regenerative glass furnaces for large scale container glass production. However, it is expected that further developments in oxygen-fired glass furnaces will improve their energy efficiency in the near future. Energy savings do not always offset the costs of the oxygen to be purchased.

Operational data

Special safety requirements have to be taken into account for handling oxygen due to the higher risk of explosion with pure oxygen streams than with air streams.

Extra safety precautions may be needed when handling oxygen, as the oxygen pipelines may operate at very low temperatures.

Applicability

Not widely used in all sectors. In the glass sector, producers try to control temperatures in the glass furnace combustion space to levels acceptable for the applied refractory materials and necessary to melt glass of the required quality. A conversion to oxygen firing generally does not mean increased furnace temperatures (refractory or glass temperatures), but may improve heat transfer. In the case of oxygen firing, furnace temperatures need to be more tightly controlled, but are not higher than those in air-fired furnaces (only temperatures of the cores of the flames may be higher).

Economics

The price for bought-in oxygen is high or if self-produced has a high demand on electrical power. The investment in an air separation unit is substantial and will strongly determine the cost effectiveness of firing with oxygen.

Driving force for implementation

Reduced waste gas flows will result in the requirement for smaller waste gas treatment systems, e.g. deNO_x. However, this only applies in new builds, or to places where waste treatment plants are to be installed or replaced.

Example plants

Used in the glass and metal refining industries (in Poland, together with the use of nitrogen).

Preheating of combustion air

BAT is to optimise the energy efficiency of combustion.

Brief technical description

Reduction of the flue-gas temperature: installing an air preheater by exchanging heat with flue-gases. Note that the process can require air preheating when a high flame temperature is needed (glass, cement, etc.)

Achieved environmental benefits

Energy savings

Cross-media effects

Reducing flue-gas temperatures may be in conflict with air quality in some cases, e.g:

- preheating combustion air leads to a higher flame temperature, with a consequence of an increase of NO_x formation that may lead to levels that are higher than the emissions limit value. Retrofitting an existing combustion installation to preheat the air may be difficult to justify due to space requirements, the installation of extra fans, and the addition of a NO_x removal process if NO_x emissions exceed emission limit values. It should be noted that a NO_x removal pr ocess based on a mmonia or urea injection induces a potential of ammonia slippage in the flue-gases, which can only be controlled by a costly ammonia sensor and a control loop, and, in case of large load variations, a dding a complicated injection system (for example, with two injection ramps at different levels) to inject the NO_x reducing agent in the right temperature zone
- gas cleaning systems, like NO_x or SO_x removal systems, only work in a given temperature range. When they have to be installed to meet the emission limit values, the arrangement of gas cleaning and heat recovery systems becomes more complicated and can be difficult to justify from an economic point of view
- in some cases, the local authorities require a minimum temperature at the stack to ensure proper dispersion of the flue-gases and to prevent plume formation. This practice is often carried out to maintain a good public image. A plume from a plant's stack may suggest to the general public that the plant is causing pollution. The absence of a plume suggests clean operation and und ercertain weather conditions some plants (e.g. in the case of waste incinerators) reheat the flue-gases with natural gas before they are released from the stack. This is a waste of energy.

Operational data

The lower the flue-gas temperature, the better the energy efficiency. Nevertheless, certain drawbacks can emerge when the flue-gas temperatures are lowered below certain levels. In particular, when running below the acid dew point (a temperature below which the condensation of water and sulphuric acid occurs, typically from 110 to 170 oC, depending essentially on the fuel's sulphur content), damage of metallic surfaces may be induced. Materials which are resistant to corrosion can be used and are available for oil, waste and gas fired units although the acid condensate may require collection and treatment.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Applicability

The strategies above apart the periodic cleaning require additional investment and are best applied at the design and construction of the installation. However, retrofitting an existing installation is possible (if space is available).

Some applications may be limited by the difference between the process inlet temperature and the flue-gas exhaust temperature. The quantitative value of the difference is the result of a compromise between the energy recovery and cost of equipment.

Recovery of heat is always dependent on there being a suitable use.

See the potential for pollutant formation, in Cross-media effects.

Economics

Payback time can be from under five years to as long as to fifty years depending on many parameters, such as the size of the installation, and the temperatures of the flue gases.

Driving force for implementation

Increased process efficiency where there is direct heating (e.g. glass, cement).

Preheating of fuel gas by using waste heat

BAT is to optimise the energy efficiency of combustion

Brief technical description

Installing an air or water preheater. Besides an economiser, an air preheater (air-air heat exchanger) can also be installed. The air preheater or APH heats the air which flows to the burner. This means flue-gases can be cooled down even more, as the air is often at ambient temperature. A higher air temperature improves combustion, and the general efficiency of the boiler ill increase. In general for every decrease of 20 °C in flue-gas temperature, a 1% increase in efficiency can be achieved.

A less efficient but simpler way of preheating might be to install the air intake of the burner on the ceiling of the boilerhouse. Generally, the air here is often 10 to 20 °C warmer compared to the outdoor temperature. This might compensate in part for efficiency losses.

Another solution is to draw air for the burner via a double walled exhaust pipe. Flue-gases exit the boiler room via the inner pipe, and air for the burner is drawn via the second layer. This can preheat the air via losses from the flue-gases.

Alternatively, an air-water heat exchanger can be installed

Achieved environmental benefits

In practice, an APH can raise efficiency by 3 to 5%. Other benefits of an APH might be:

- that the hot air can be used to dry fuel. This is especially applicable for coal or organic fuel
- that a smaller boiler can be used when taking into account an APH at the design stage
- used to preheat raw materials.

Cross-media effects

There are, however, also some practical disadvantages related to an APH, which often inhibit installation:

- the APH is a gas-gas heat exchanger, and thus takes up a lot of space. The heat exchange is also not as efficient as a gas-water exchange
- a higher drop pressure of the flue-gases means the ventilator of the burner has to provide higher pressure
- the burner must ensure that the system is fed with preheated air. Heated air uses up more volume. This also poses a bigger problem for flame stability
- there may be higher emissions of NOx due to higher flame temperatures.

Operational data

Feeding the burner with heated air has an impact on the amount of flue-gas losses in the boiler. The percentage of flue-gas losses is generally determined using the Siegert formula. The Siegert coefficient depends on the flue-gas temperature, the CO2 concentration and the type of fuel.

Applicability

The installation of an air preheater is cost effective for a new boiler. The change in air supply or the installation of the APH often is limited due to technical reasons or fire safety. The fitting of an APH in an existing boiler is often too complex and has a limited efficiency.

Air preheaters are gas-gas heat exchangers, whose designs depend on the range of temperatures.

Air preheating is not possible for natural draught burners.

Preheated water can be used as boiler feed or in hot water systems (such as district schemes).

Economics

In practice, the possible savings from combustion air preheating amount to several per cent of the steam volume generated. Therefore, the energy savings even in small boilers can be in the range of several GWh per year. For example, with a 15 MW boiler, savings of roughly 2 GWh/yr, some EUR 30 000/yr and about 400 t CO_2/yr can be attained.

Possible savings in combustion air preheating
Energy savings: Several thousand MWh/yr
CO2 reduction: Several hundred t/yr
Savings in EUR: Tens of thousands EUR/yr
Annual operating hours: 8700 h/yr

Driving force for implementation

Increased energy efficiency of processes.

Example plants

Widely used

Best practices

INSTALLING AN AIR OR WATER PREHEATER

<u>Description</u>

A steam boiler fired with high quality natural gas has the following flue-gas data:
tgas =240 °C and CO_2 = 9.8 %.

The air supply is modified and the hotter air near the ceiling of the boiler house is taken in. Previously the air was taken in at outdoor temperature. The average out door t emperature is 10 °C, while the annual average temperature near the ceiling of the boiler house is 30 °C.

The Siegert coefficient in this case is: 0.390 + 0.00860 x 9.8 = 0.4743. Prior to the intervention, the flue-gas loss was:

WR =0,4743× ((240-10) /9,8) = 11.1%

After the intervention this becomes:

WR =0,4743× ((240-30) /9,8) = 10.2%

This amounts to an increase in efficiency of 0.9% where this can be achieved simply, e.g. by repositioning air intake.

Recuperative and regenerative burners

BAT is to optimise the energy efficiency of combustion.

Brief technical description

One major problem for industrial furnace heating processes is the energy losses. With conventional technology about 70% of the heat input is lost though flue-gases at temperatures of around 1300°C. Energy savings measures therefore play an important role especially for high temperature processes (temperatures from 400 to 1600°C).

Recuperative and regenerative burners have thus been developed for direct waste heat recovery through combustion air preheating. A recuperator is a heat exchanger that extracts heat from the furnace waste gases to preheat the incoming combustion air. Compared with cold air combustion systems, recuperators can be expected to achieve energy savings of around 30%.

They will, however, normally only preheat the air to a maximum of 550 - 600 C. Recuperative burners can be used in high temperature processes (700 -1100 C).

Regenerative burners operate in pairs and work on the principle of short term heat storage using ceramic heat regenerators. They recover between 85-90% of the heat from the furnace waste gases; therefore, the incoming combustion air can be preheated to very high temperatures of up to 10°-150°C below the furnace operating temperature. Application temperatures range from 800 up to 1500°C. Fuel consumption can be reduced by up to 60%.

Recuperative and regenerative burners (HiTAC technology) are being implemented in a novel combustion mode with homogeneous flame temperature (flameless combustion), without the temperature peaks of a conventional flame, in a substantially extended combustion zone.

Achieved environmental benefits

Energy savings

Cross-media effects

The important constraint of state-of-the-art recuperative/regenerative burner technology is the conflict between technologies designed to reduce emissions and to focus on energy efficiency.

The NO_x formation, for fuels not containing nitrogen, is basically a function of temperature, oxygen concentration, and residence time. Due to high temperatures of the preheated air, and the residence time, conventional flames have high peak temperature which leads to strongly increase NO_x emissions.

Operational data

In the industrial furnace, the combustion air can be obtained at temperatures of 800 – 1350^{0}C using a high performance heat exchanger. For example, a modern regenerative heat exchanger switched to the high cycle can recover as much as 90% of the waste heat. Thus, a large energy saving is achieved.

Applicability

Widely used.

Economics

A drawback with these burners is the investment cost. The decreased costs for energy can rather seldom alone compensate the higher investment cost. Therefore, higher productivity in the furnace and lower emissions of nitrogen oxides are important factors to be included in the cost benefit analysis.

Driving force for implementation

Higher productivity in the furnace and lower emissions of nitrogen oxides are important factors.

Example plants

Widely used.

Reducing heat losses by insulation

BAT is to optimise the energy efficiency of combustion.

Brief technical description

The heat losses through the walls of the combustion system are determined by the diameter of the pipe and the thickness of the insulation. An optimum insulation thickness which relates energy consumption with economics should be found in every particular case.

Efficient thermal insulation to keep heat losses through the walls at a minimum is normally achieved at the commissioning stage of the installation. However, insulating material may progressively deteriorate, and must be replaced after inspection following maintenance programmes. Some techniques using infrared imaging are convenient to identify the zones of damaged insulation from outside while the combustion installation is in operation in order to plan repairs during shutdown.

Achieved environmental benefits

Energy savings

Cross-media effects

Use of insulation material.

Operational data

Regular maintenance and periodical control is important to check the absence of hidden leaks in the system (below the insulations). In negative pressure systems, leakage can cause an increase of the amount of gas in the system and a subsequent demand of electrical power at the fans.

In addition, uninsulated parts of the system may cause injuries to operators where:

- there is a risk of contact
- temperatures exceed 50 °C.

Applicability

All cases

Economics

Low cost, especially if carried out at shutdown times. Insulation repair can be carried out during campaigns.

Driving force for implementation

Maintaining process temperature.

Example plants

Insulation repair is carried out during campaigns in steel and glass industries.

Reducing losses through furnace doors

BAT is to optimise the energy efficiency of combustion.

Brief technical description

Heat l osses by radiation can occur via furnace openings for loading/unloading. This is especially significant in furnaces operating above 500 °C. Openings include furnace flues and stacks, peepholes used to visually check the process, doors left partially open to accommodate oversized work, loading and unloading materials and/or fuels, etc.

Achieved environmental benefits

Energy savings

Cross-media effects

No data submitted

Operational data

Losses are very apparent when making scans with infrared ameras. By improving design, osses via doors and peepholes can be minimised.

Reducing the mass flow of the flue-gases by reducing the excess air

BAT is to optimise the energy efficiency of combustion.

Brief technical description

Excess air can be minimised by adjusting the air flowrate in proportion to the fuel flowrate. This is greatly assisted by the automated measurement of oxygen content in the flue-gases.

Depending on how fast the heat demand of the process fluctuates, excess air can be manually set or automatically controlled. Too low an air level causes extinction of the flame, then re-ignition and backfire causing damage to the installation. For safety reasons, there should therefore always be some excess air present (typically 1 – 2% for gas and 10% for liquid fuels).

Achieved environmental benefits

Energy savings

Cross-media effects

As excess air is reduced, unburnt components like carbonaceous particulates, carbon monoxide and hydrocarbons are formed and may exceed emission limit values. This limits the possibility of energy efficiency gain by reducing excess air. In practice, excess air is adjusted to values where emissions are below the limit value.

Operational data

Reduction of excess air is limited due to the related increase of raw gas temperature; extremely high temperatures can damage the whole system.

Applicability

The minimum excess air that is reachable to maintain emissions within the limit depends on the burner and the process.

Note that the excess air will increase when burning solid wastes. However, waste incinerators are constructed to provide the service of waste combustion, and are optimised to waste as fuel.

Economics

The choice of fuels is often based on cost and may also be influenced by legislation and regulations.

Driving force for implementation

Achieves a higher process temperature, especially when direct firing.

Example plants

Some cement and lime and waste-to-energy plants.

3.2.2 Design, operating and control

3.2.2.1 Gas collection

Off Gas Collection Techniques

Good practice relies on the professional design and maintenance of the collection systems as well as on-line monitoring of emissions in the clean gas duct.

The use of sealed furnaces can contain gases and prevent fugitive emissions.

Brief technical description

Gas collection requires the movement of significant volumes of air. This can consume vast amounts of electrical power and modern systems focus the design on capture systems to increase the rate of capture and minimise the volume of air that is moved. The design of the collection or hood system is very important as this factor can maintain capture efficiency without excessive power consumption in the remainder of the system. Sealed systems such as sealed furnaces can allow a very high capture efficiency to be attained.

Ducts and fans are used to convey the collected gases to abatement or treatment processes. The effectiveness of collection depends on the efficiency of the hoods, the integrity of the ducts and on the use of a good pressure/flow control system. Variable speed fans are used to provide extraction rates that are suitable for changing conditions such as gas volume, with minimum energy consumption. The systems can also be designed to take account of the characteristics of the plant that it is associated with, e.g. the abatement plant or sulphuric acid plant. Good design and maintenance of the systems is practised.

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Achieved environmental benefits

Energy saving

Operational data

Examples are sealed smelting furnaces, sealed electric arc furnaces and the sealed point feeder cell for rimary aluminium production. Furnace sealing still relies on sufficient gas extraction rates to prevent pressurisation of the furnace. The point feeder cell is usually connected to a well-sized extraction system that provides a sufficient rate of extraction to prevent the escape of gases during the opening of cell covers for short periods e.g. anode changes.

Examples are the use of charging skips that seal against a furnace feed door and the use of through-hood charging systems.

An example of this is an adaptation of a short rotary furnace. The feed door and tapping holes are at the same end of the furnace and the fume collection hood allows full access for a slag ladle and feed conveyor, it is also robust enough to withstand minor impacts during use.

Driving force for implementation

This technique is applicable to new or extensively modified processes only. These techniques may be applicable to some new and existing processes particularly for non-continuous processes.

Example plants

Non Ferrous Metals Industries

3.2.2.2 Raw Materials

Membrane filtration of emulsifying degreasers (micro- or ultrafiltration)

To reduce materials usage and energy consumption, it is BAT to use one or a combination of the techniques for maintenance and extending the life of degreasing solutions.

Brief technical description

This technique can be used where, for technical reasons, the use of strongly emulsifying degreasing systems are necessary, and the regeneration of the cleaning solution by other methods may become expensive or even impossible.

Membrane filtration technology, particularly micro or ultrafiltration is a process of physical separation using membranes for the separation of particles from 0.005 to 0.1 micrometers (the separation of smaller particles is by nanofiltration or reverse osmosis). There is a small difference in pressure so that the liquid moves from one side of the membrane to the other.

Filtration is tangential, so that the fluid circulates in parallel with the membrane, rather than the traditional filtration which is perpendicular or frontal (therefore loading particles onto the filter).

Tangential filtration allows the accumulation of fouling particles without fouling the filtration surface. The liquid crossing the membrane is the filtrate or permeate and is a clean solution containing purified detergent solution that is fed back in the degreasing bath. The solution unable to cross the membrane is the retentate, containing oil and suspended material.

Achieved environmental benefits

Reduced chemical and energy consumption in degreasing heavily contaminated workpieces or substrates. Increase of the degreasing bath lifetime (up to 10 times). Reduction of detergent consumption by 50%.

Cross-media effects

Power consumption of pumping to microfiltration, although with tangential filtration the costs will be lower than for a perpendicular system.

Operational data

The surfactant components may also be lost by permeating through the membranes, and for the successful use of microfiltration, the composition of the chemicals in the cleaner must be maintained.

The oil concentration in the bath decreases to 2 or 3 g/l and is held constant depending on the filtering rate. The bath is filtered continuously, and with the constant efficiency of the degreasing bath (between 500 and 800 microns), there are fewer problems of fouling when used with spraying systems.

The choice of membranes have to be determined by tests, as there is a possibility of fouling during use.

Applicability

Only a few operators have successfully retained the cleaning quality in practice over longer periods. For this reason, the successful employment of the diaphragm cleaning system for degreasing solutions requires the close co-operation of operators, equipment manufacturers and chemical suppliers.

The cost effectiveness success of this technique is based on using the membrane best suited to the wide range of pollutants encountered in a degreasing bath. Most of the equipment is installed in in-house shops where the composition of oils to be removed is more constant.

Economics

Energy cost: electric consumption between 0.10 and 0.20 kWh per m^3 treated.

No draining down of hot used baths so less waste of heating energy.

No need to stop production to change degreasing baths.

The investment is relatively expensive. The cost of the ultrafiltration installation depends on the particular situation of the company (volume vats, degreasing quality, quantity of oil to eliminate, etc.). This cost is estimated between EUR 40000 and 200000 including the total price of the ultrafiltration unit (membranes, storage of the ultrafiltrate and, in some cases, installationof connection).

Driving force for implementation

Where heavily oiled/greased components require a strongly emulsifying degreasing system.

High throughput through degreasing process.

Strong demand for high quality and consistent degreasing.

High cost of rejection and reworking.

Example plants

Surface treatment of metals plants

3.2.3 Drying, separation and concentration processes

Direct heating

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

Direct heating is achieved primarily by convection. A warm or hot gas, usually air (which may be mixed with the combustion gases of the fuel) or steam is passed through, over or around the material(s) to be dried, which may be in e.g. a rotating drum, on racks or jigs.

Typical direct drying systems are:

- with a flowing gas:
  - e.g. rotating drum, drying oven or kiln, tunnel dryers, spiral belt dryers, tray dryers
- with aerated solids:
  - e.g. through circulator, batch dryers, stationary rack dryers
- with large scale agitation of solids:
  - e.g fluidised bed, spin flash drying.

Achieved environmental benefits

Direct heating, in particular with hot air warmed by direct combustion, avoids many of the heat losses in indirect systems, boilers and steam pipe lines, etc.

Cross-media effects

None identified

Operational data

Convective (direct) heat dryers may be the option with the lowest energy efficiency. The materials being dried and the liquids being removed must be compatible and safe to use with the system, e.g. not flammable if direct heating is by burning natural gas.

Applicability

Widely used.

Economics

None provided

Driving force for implementation

- cost reduction
- space
- simplicity (e.g. air drying reduces the need for steam).

Example plants

Widely used in many industries, such as in revolving drums drying organic chemicals, fertilisers, food products and sand. It is also used in the surface treatment of metals, and the drying components on jigs. The dryer is the last stage in the jig line, and is a tank, with a size compatible w ith the preceding tanks containing treatment solutions and rinses. The jigs are lowered and raised into the dryer, as they are into the treatment tanks. The dryer may be fitted with an automically opening lid.

Heat recovery (including MVR and heat pumps)

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

Drying is often a high temperature process and waste heat may be recovered:

- either directly, when the drying process is a direct one using hot air as the heating fluid:
  - mix the exhaust air with fresh air directly before the burner
  - if the exhaust air is contaminated too much (dust, moisture, etc.), recycle heat from exhaust air via an heat exchanger to preheat the product to be dried or the drying air
- or indirectly, using mechanical vapour recompression (MVR) to compress the exhaust vapour, especially when the heating fluid is superheated steam.

Only 'direct' recycling is considered here.

Concentration by evaporation coupled with MVR (mechanical vapour recompression) or a heat pump, is a highly efficient technique for waste water treatment. In particular, this technique makes it possible to significantly reduce waste water volumes sent to treatment at a low cost, as well as allowing water recycling.

To evaporate one tonne of water, 700 t o 800 kWh/t energy power is required. It is possible to reduce the energy needs by using heat recovery solutions, such as heat pumps, including mechanical vapour recompression (MVR), or multiple effect evaporators with thermo-compression.

Achieved environmental benefits

Minimise energy usage

Cross-media effects

Preheating the air before the burner via heat recovery may disturb the drying process by influencing the temperature-moisture content. Possible contaminants may appear when there is no heat exchanger. Regulation may be needed to correctly control the drying temperature.

The concentration of waste water streams may require different management and treatment techniques (i.e. may no longer be suitable for waste water discharge).

Operational data

- energy savings are always greater when ambient air is cold (in winter, for example)
- at least 5% energy savings are expected.

Applicability

This technique can be used for almost any continuous hot air convective dryers (tunnel, oven, drum, etc.). Attention is to be paid to burner adjustment and sizing of the different items: fan, pipe diameter, regulation valve and heat exchanger if applicable. Stainless steel is required for the heat exchanger. When the dryer burner works with fuel, exhaust air contains sulphur and SO2 and may damage the heat exchanger if condensation occurs.

Economics

Payback time may be very variable, depending on the energy cost, the evaporating capacity of the dryer and the number of running hours. Never forget to make a simulation with hypotheses on the rise of energy prices.

Driving force for implementation

Saving money through energy savings.

Example plants

Beet pulp drying (Cambrai, France): heat recovery on exhaust gases.

Best practices

MECHANICAL VAPOUR RECOMPRESSION

Description

ZF Lemforder Mecacentre manufactures different pieces for the car industry (suspension or steering balls, steering columns, etc.). In 1998, during the process of obtaining ISO 14001 certification, the company installed an MVR evaporator to concentrate wash water from cleaning workpieces.

Achieved environmental benefits

The equipment installed concentrates up to 120 litres of wastewater per hour with a power of 7.2 kWh and allows the recycling of 20 t o 25 m^3 of purified water per month in the production system. The residual concentrated liquid waste is sent to a suitable waste management treatment installation.

- annual saving obtained: EUR 76 224
- return on investment time: 14 months.

Economics

Investment cost: EUR 91 469

Mechanical processes, e.g. filtration, membrane filtration

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

The energy consumption for mechanical processes can be several orders of magnitude lower compared to thermal drying processes.

As long as the material to be dried lets it, it is recommendable to use predominantly mechanical primary separation processes to reduce the amount of energy used for the entire process. Generally speaking, the majority of products can be mechanically pretreated to average moisture content levels (the ratio between the liquid mass of the liquid to be removed and the mass of dry substance) of between 40 and 70 per cent. In practice, the use of the mechanical process is limited by the permissible material loads and/or economic draining times.

Sometimes mechanical processes a e also recommendable prior to thermal treatment. When drying solutions or suspensions (spray drying, for instance), the pretreatment can be membrane filtration (reverse osmosis, nanofiltration, ultrafiltration or microfiltration). For example, in the dairy industry, milk can be concentrated to 76 % moisture content before spray drying.

Achieved environmental benefits

Improve energy efficiency.

Cross-media effects

None reported

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Operational data

Energy consumption can be several orders of magnitude lower, but will not achieve high % dryness.

Applicability

Process dependent. To achieve high dryness at lowest energy consumption, consider these in combination with other techniques

Optimise insulation of the drying system

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

As with all heated equipment, heat losses can be reduced by insulating the drying system, such as ovens and steam pipes and condensate pipes. The type of insulation used and the thickness required depends on the operating temperature of the system, the materials being dried and if liquids other than water are being removed, or if the water vapour may be contaminated (e.g. with acid vapour).

The insulation needs to be maintained, as it can suffer deterioration with time due to embrittlement, mechanical damage, action of damp (e.g. from condensing water vapour, steam leaks) or contact with chemicals. Damaged insulation can be identified by visual inspection or by infrared scanning.

Achieved environmental benefits

Energy savings

Cross-media effects

None identified

Operational data

Where the hot surfaces may be in contact with personnel, a maximum surface temperature of 50°C is recommended.

Insulation can cover leaks and/or corrosion, and periodic checks need to be made to identify these.

Applicability

Consider for all systems. Can be retrofitted. When insulating a large drying system or refurbishing a plant.

Economics

These can be calculated on a project basis.

Driving force for implementation

Cost savings and health and safety.

Example plants

Widely used.

Radiation processes

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

In radiant energies such as infrared (IR), high frequency (HF) and microwaves (MW), energy is transferred b y t hermal radiation. Note that there is a difference between drying and curing:

- drying requires the raising of the solvent molecules to or above the latent heat of evaporation,
- whereas curing techniques provide the energy for cross-linking (polymerisation) or other reactions.

These technologies are applied in industrial production processes to heat products and thus, can be applied in drying processes. Radiant energies can be used alone or in combination with conduction or convection.

Achieved environmental benefits

Radiant energies have specific characteristics allowing energy savings in these processes:

- direct transfer of energy. Radiant energies allow direct transfer of energy from source to product, without using intermediate media. The heat transfer is thus optimum, especially by avoiding energy loss through ventilation systems. This can achieve significant energy savings. For example, for paint drying processes, about 80 % of energy is extracted with the waste gases
- high power density. Surface (IR) or volume (HF, MW) power densities are higher for radiant energies compared to conventional technologies such as hot air convection. This leads to a higher production velocity and allows treatment of high specific energy products such as some paints
- energy focusing. Energy can easily be focused on the required part of the product
- control flexibility. Thermal inertia is low with radiant energies and power variations are large. Flexible control can be used, which leads to energy savings and good quality manufactured products.

Cross-media effects

None reported

Operational data

Exhaust airflow is generally far lower because air is not the intermediate medium for heat transfer but is just used to extract steam or other solvents. Treatment of exhaust gases, if applicable, is thus easier and less expensive.

Other achieved benefits specific for IR:

- direct heating: reduction of hot air exhaust, thus energy saving; few or no hot fluids transported
- reduction of equipment size
- easier regulation

- retrofitting of plants.

Other achieved benefits specific for HF and MW:

- direct heating: reduction of hot air exhaust, thus energy saving; few or no hot fluids transported
- volume heating leads to rapid drying and less losses
- selective heating, water is heated preferentially
- homogeneous heating if the size of the products is compatible with wavelength
- efficient heat transfer.

Differential heating of heterogeneous products can occur and lead to poor quality products.

Some disadvantages for IR:

- larger investment (20 - 30%)
- essentially for flat or simple-shaped products
- often not the priority choice of constructors.

Some disadvantages for HF and MW:

- larger investment (20 - 30%)
- often not a priority choice of constructors.

Applicability

Radiant energies, in particular IR, can be used in retrofitting of installations or to boost the production line, coupled with convection or conduction.

In spite of their advantages (speed of action, quality of final products, energy savings), the use of radiant energies is not common in industrial applications, today known as having a great energy savings potential.

IR can be used in:

- curing of paint, ink and varnish
- drying of paper, paperboard, pre-drying of textiles
- drying powder in the chemical and plastics industries.

HF can be used in the drying of:

- massive (monolithic) products: textiles (reels of wire), ceramics
- powder in the chemical industry.

MW can be used in the drying of:

- massive (monolithic) products (wood, agro-industry) or flat products
- chemical and pharmaceutical products (under vacuum).

Economics

Investment is generally more expensive (20 – 30%) than conventional techniques.

Driving force for implementation

Radiant energies lead to compact systems. Lack of space availability can be a driving force. They can be used to boost existing production lines, especially IR.

Best practices

THE IMPLEMENTATION OF AN HF SYSTEM

Description

Biotex is a French plant producing latex pillows. Pillows are very difficult to dry and must have a moisture content of <1% to avoid problems during usage. The convective tunnel (impinging jet) was not sufficient for a good production quality and consumed a lot of energy.

Achieved environmental benefits

The implementation of an HF system at the output of the tunnel met the requirements in terms of quality and reduced the specific energy consumption per pillow by 41% (primary energy) with an eight fold reduction of production time. The convector tunnel leaves pillows with 19 to 45% moisture, HF achieves 1%.

Economics

Payback time was 4 years.

Superheated steam

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes

Brief technical description

Superheated steam is steam heated to a temperature higher than the boiling point of water at a given pressure. It cannot exist in contact with water, nor contain water, and resembles a perfect gas; it is also called surcharged steam, anhydrous steam, and steam gas. Superheated steam can be used as a heating fluid instead of hot air in any direct dryers (where the heating fluid is in direct contact with the product); for example, in spray drying, in a fluidised bed, in a spouted bed, in drums, etc.

Achieved environmental benefits

The advantage is that the limiting phenomenon is only heat transfer and not mass (water) transfer. The drying kinetic is thus better. Dryers are smaller and so are heat losses. Moreover, the energy (latent heat) of the water coming from the product can easily be recycled in the dryer via mechanical vapour recompression (MVR) or used in another process, increasing the energy savings.

Dealing with volatile organic compounds (VOCs) is easier because of the limited volume of exhaust gases. These compounds may be easily recovered.

Cross-media effects

Thermosensitive products can be damaged by the high temperature.

Operational data

Heat can be recovered from this process. Energy consumption is about 670 kWh/t evaporated water without heat recovery and 170 to 340 kWh/t with heat recovery (MVR, for example).

Process control is easier because the final moisture of the product and drying kinetic can be controlled through steam temperature. The elimination of air reduces the risks of fire and explosion.

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Applicability

Any direct dryers can be retrofitted with superheated steam. High cost, needs lifetime cost benefit assessment. High temperature may damage product.

Tests should be conducted to guarantee the product quality, and economic calculations have to be made.

Economics

The investment is generally higher, especially when MVR is used.

Driving force for implementation

Energy savings should be the first driving force for implementation. Better product quality is often reported, especially in the agro-food industry (better colour, absence of oxidation, etc.).

Example plants

- Sucrerie Lesaffre (Nangis, France): drying of beet pulp using superheated steam
- applications: sludge, beet pulp, alfalfa, detergent, technical ceramics, wood-based fuel, etc.

Thermal processes

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes. Thermal processes, e.g.

- directly heated dryers
- indirectly heated dryers
- multiple effect

Brief technical description

Drying is a commonly used method in many industrial sectors. In a dryer system, first of all the damp material is heated to the vaporisation temperature of water, then the water is evaporated at a constant temperature.

Qth = (cGmG + cWmW) ZT + mDZHV

Where:

- Qth = useful output in kWh/h
- mG, mW = mass flows of dry matter and proportion of water in the material in kg/s
- ZT = heating temperature change in Kelvin
- mD = quantity of water evaporated per unit of time in kg/s
- cG, cW = specific heat capacities of dry matter and proportion of water in the material in kJ/(kg K)
- ZHV = vapourisation heat of water at the respective evaporation temperature (approx. 2300 kJ/kg at 100 °C).

The vaporised water volume is generally removed using air from the drying chamber. The power demand Qpd required to heat the volume of input air (excluding the useful heat output Qth) can be calculated as shown in Equation

Qpd = VCpdZTpd

Where:

- Qpd = power demand required to heat the input air in kWh/h (thermal exhaust losses)

- V = flowrate of the input air in m3
- cpd = the air's specific heat capacity (approx. 1.2 kJ/m3 mbar)
- ZTpd = difference between the temperature of the fresh air and the exhaust air in Kelvin.

The plant's heat losses (such as surface loss) must also be covered above and beyond this power demand. These system losses correspond to the holding power Q hp (power demand of the system when unloaded, at working temperature, and in recirculating air mode only). The entire heat requirement is shown in Equation

QI = Qth + Qpd + Qhp

Where:

- QI = power output required
- Qhp = power demand for unloaded systems.

The thermal efficiency of the firing must be taken into account, depending on the firing equipment. This produces a consequent output Qtotal shown in Equation

Qtotal = QI/Yfuel

Where:

- Qtotal = total power output
- Yfuel = thermal efficiency.

For the purposes of comparison, it has been assumed that the convection dryers use electrical resistance heating.

Direct heating is achieved primarily by convection. A warm or hot gas, usually air (which may be mixed with the combustion gases of the fuel) or steam is passed through, over or around the material(s) to be dried, which may be in e.g. a rotating drum, on racks or jigs.

Typical direct drying systems are:

- with a flowing gas:

- e.g. rotating drum, drying oven or kiln, tunnel dryers, spiral belt dryers, tray dryers

- with aerated solids:

- e.g. through circulator, batch dryers, stationary rack dryers

- with large scale agitation of solids:

- e.g fluidised bed, spin flash drying.

Direct heating is achieved by conduction. The heat is transferred to the material to be dried by a heated surface. The material may be stationary or continually transferred from one hot surface to another.

Typical indirect drying systems are:

- flat a nd strip m aterials, such as textiles, paper or board use drum driers. The moist material is wrapped around rotating horizontal cylinders heated internally, usually with steam
- low viscosity materials such as solutions of organic or inorganic material, a roller drier is usually used. The material flows onto heated rollers as a thin layer, and the dreid solid is removed with a scaper blade as a film, flakes or powder
- pasty matrials are dried by:
  - grooved roller drier (which produces short segments for further drying),
  - hollow screw drier which use one or two hollow Archimedes screws turning in a trough. The screws are heated with hot water, saturated steam, or hot oils, etc.

- all phase drier which is a contact drier with stirrer and kneeder. The housing, lid, hollow main roller and its disc elements are heated with steam, hot water or hot oil
- Granular materials are dried by:
  - rotary driers, either with heated pipes within the drum or the material to be dried in whitn tubes in the heated drum. These have low air velocity, which is useful for dusty materials
  - screw conveyor driers with paddles which turn in a heated container
  - cone worm drier with a cone-shaped stirrer rotating in aheated funnel shaped jacket
  - tray driers, with heated trays
  - spiral tube driers, in which the material is only briefly in contact with the heated surface of the tube and is transported pneumatically. It can be sealed and may be used for organic solvent removal, with solvent recovery.

Achieved environmental benefits

Improve energy efficiency

Cross-media effects

Likely to use more energy than direct heating, due to losses in the transfer of heat, as this process has two stages: heating the surface then heating the material.

Operational data

Convective (direct) heat dryers may be the option with the lowest efficiency. Considering the use of mechanical separation processes as a possible pretreatment before drying could, in many cases, reduce significantly the energy.

The optimisation of air humidity in dryers is of vital importance to reduce the energy consumption to a minimum in drying processes.

Applicability

Widely used

Driving force for implementation

Applications such as where direct heating cannot be applied, or there are other constraints.

Example plants

Widely used

Use a combination of techniques

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

Drying is an energy intensive process. It is considered here with separation and concentration techniques, as the use of different techniques or combinations offer energy savings.

Heat may be transferred by convection (direct dryers), by conduction (contact or indirect dryers), by thermal radiation such as infrared, icrowave or high requency electromagnetic field (radiative

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dryers) or by a combination of the these. Most industrial dryers are of the convective type with hot air or direct combustion gases as the drying medium.

Separation is a process which transforms a mixture into at least two streams (which may be product-product or product-waste streams) which are different in composition. The separation technology consists, therefore, in partitioning and isolating the wanted products from a mixture containing either different substances or a pure substance in several phases or sizes.

Alternatively, it may be used to separate waste streams.

The separation process takes place in a separation device with a separation gradient applied by a separating agent. In this section, the separation methods have been classified according to the different principles of separation and separating agents used.

The purpose of this section is not to describe exhaustively every separation technique, but to focus mainly on those issues which have a higher potential for energy savings. For further details of a particular method, see the Reference information.

Classification of the separation methods:

- input of energy into the system: detailed classification for these techniques can be structured considering the different types of energy provided to the system as listed below:
  - heat (vaporisation, sublimation, drying)
  - radiation
  - pressure (mechanical vapour recompression)
  - electricity (electrofiltration of gases, electrodialysis)
  - magnetism (use of magnets)
  - kinetic (centrifugal separation) or potential energy (decantation)
- withdrawal of energy out of the system:
  - cooling or freezing (condensation, precipitation, crystallisation, etc.)
- mechanical barriers:
  - filters or membranes (nano, ultra or microfiltration, gas permeation, sieving)
- others:
  - physico-chemical interactions (solution/precipitation, adsorption, flotation, chemical reactions)
  - differences in ot her physical or chemical properties of the substances such as density, polarity, etc.

Selecting a separation technology often has more than one solution. The choice depends on the characteristics of the feed and the required outputs and other constraints linked to the type of plant and sector. The separation process also has its own constraints. Technologies can be used in stages, e.g. two or stages of the same technology or combinations of different technologies.

Combination of the previously mentioned principles of separation or separating agents may be used in several processes leading to hybrid separating techniques. Examples are:

- distillation (vaporisation and condensation)
- pervaporation (vaporisation and membrane)
- electrodialysis (electric field and ion-exchange membrane)
- cyclonic separation (kinetic energy and potential energy).

Achieved environmental benefits

Minimising energy usage. A significant amount of energy can be saved where it is possible to use two or more separation stages or pretreatments.

Operational data

May have production benefits, e.g. improved product quality, increased throughput.

Applicability

Identification of the appropriate technologies is applicable in all cases. Installation of new equipment is usually carried out on a cost-benefit basis and/or for production quality or throughput reasons.

Driving force for implementation

- cost reduction
- product quality
- process throughput capacity.

Example plants

When drying liquids (e.g. spray drying), the pretreatment can be membrane filtration (reverse osmosis, nanofiltration, ultrafiltration or microfiltration). Membrane filtration has an energy consumption of 1 - 3 orders of magnitude lower than evaporative drying, and can be used as a first pretreatment stage. For example, in the drying industry, milk can be concentrated to 76 % moisture content before spray drying.

Use of surplus heat from other processes

BAT is to optimise drying, separation and concentration processes and to seek opportunities to use mechanical separation in conjunction with thermal processes.

Brief technical description

Drying is an energy intensive process. It is considered here with separation and concentration techniques, as the use of different techniques or combinations offer energy savings.

However, it is important to note t hat the use of sustainable energy sources and/or 'wasted' or surplus heat may be more sustainable than using primary fuels, even if the energy efficiency in use is lower.

BAT is to identify opportunities to optimise energy recovery within the installation, between systems within the installation and/or with a third party (or parties).

The scope for energy recovery depends on the existence of a suitable use for the heat at the type and quantity recovered.. Opportunities may be identified at various times, such as a result of audits or other investigations, when considering upgrades or new plants, or when the local situation changes (such as a use for surplus heat is identified in a nearby activity).

Achieved environmental benefits

Minimising energy usage

Cross-media effects

None reported

Operational data

Drying is a good use for surplus heat.

A feasibility study is necessary to define the best solution(s) from a technical, economic, energy, and environmental point of view. Requirements should be precisely defined:

- feed and product parameters (mass and flow characteristics), especially the moisture content of the product: the last moisture percentages are usually the more difficult to dry and so are the most energy consuming
- list o f all the utilities available (electricity, refrigeration, compressed air, steam, other cold or hot sources) and their characteristics
- available possible space
- possible pretreatment
- waste heat recovery potential of the process
- high energy efficiency utilities equipment and sources (high efficiency motors, use of waste heat, etc.).

Applicability

Depends on the availability of surplus heat in the installation or from third party).

Identification of the appropriate technologies is applicable in all cases. Installation of new equipment is usually carried out on a cost-benefit basis and/or for production quality or throughput reasons.

Economics

No data submitted

Driving force for implementation

- cost reduction
- product quality
- process throughput capacity.

3.2.4 Processes

3.2.4.1 Alkali and alkaline Earth Metals

Pre-treatment techniques

Where a calcination process is needed for the raw material preparation e.g. for dolomite calcining, the gas suspension calciner technique (GSC) is advantageously used. The associated emission level for dust is less then 30 mg/Nm^3 if the dust-laden off-gas from the calciner is cleaned by using an EP and 5 mg/Nm^3 by using a bag filter. Due to high investment costs for the installation of such a calciner system, the plant used to be a certain production capacity.

Brief technical description

The production of magnesium metal is partly based on calcined dolomite and magnesite as a raw material. The calcination may be made in rotary or vertical furnaces. Different fuels, for instance natural gas, can heat the furnaces. A new technology used for calcining dolomite is the Gas Suspension Calcining (GSC)

Achieved environmental benefits

Reduction of fuel consumption

Best practices

GAS SUSPENSION-CALCINING PROCESS FOR DOLOMITE AND MAGNESITE CALCINING AS A PRE-TREATMENT PROCESS BY PRODUCING MAGNESIUM METAL

Description

The GSC process consists of several process stages. The first stage is drying the dolomite in a flash drier using the hot exit gases from the GSC plant. The dry material is than crushed in a special cone crusher. The pulverised feed is injected into the riser between tie second and the first pre-heater cyclone. On entering the riser duct, the material initially falls counter-current to the hot gas stream. After being preheated in the forth cyclone the material has reached calcining temperature and is directed to the calciner where complete calcination takes place. The calciner is basically a vertical cylinder where air, fuel and material enter at the bottom and exhaust gases carrying calcined material leave at the top. The calcined particles are carried by the gas stream to a disengaging cyclone from which the hot gases pass to the pre-heater while the product is discharged by the force of gravity to the cooler. The process is controlled by a high standard computerised instrumentation and control system.

Achieved environmental benefits

Reduction of fuel consumption compared to other system, due to the intensive use of product and off-gas heat energy.

Operational data: Status of development

Fuel consumption 1145 kcal//kg

Power consumption 33 kWh/t product

The emission level of dust using an EP is less then 30mg/Nm^3

Applicability

Applicable to new and existing plants (also of other production processes where calcination takes place e.g. in the lime production).

Economics

The GSC process has lower operating costs than other systems.

3.2.4.2 Aluminium from Primary Raw Materials and Secondary Raw Materials

Gas collection and abatement

Best Available Techniques for gas and fume treatment systems are those that use cooling and heat recovery if practical before a fabric filter. Fabric or ceramic filters that use modern high performance materials in a well-constructed and maintained structure are applicable. They feature bag burst detection systems and on-line cleaning methods.

The acid gas recovery systems, carbon/lime injection for the removal of dioxins and the associated dust and metal recovery stages are those described earlier in this document. The use of alumina as a scrubbing medium for fluoride and HF removal with the use of the reacted alumina in primary aluminium production is considered to be BAT.

Abatement applications considered as Best Available Techniques for primary aluminium production:

Processing Stage: Raw Materials
Fume collection: Yes (if dusty)
Fabric Filter: Yes (if dusty)
PAH removal: No
VOC removal: No

Processing Stage: Primary Smelting
Fume collection: Yes
Fabric Filter: Yes (with dry alumina scrubber)
PAH removal: Yes
VOC removal: No

Processing Stage: Integrated anode plant
Fume collection: Yes
Fabric Filter: Yes
PAH removal: Yes
VOC removal: Yes

Processing Stage: Alumina production
Fume collection: Yes
Fabric Filter: Yes (or EP)
PAH removal: No
VOC removal: No

Processing Stage: Holding and de-gassing
Fume collection: Yes
Fabric Filter: Yes
PAH removal: No
VOC removal: No

Abatement applications considered as Best Available Techniques for secondary aluminium production:

Processing Stage: Raw Materials
Fume collection: Yes (if dusty)
After burning: No
Filter: Yes (if dusty)
Acid gas removal: No
VOC removal: No

Processing Stage: Secondary Smelting
Fume collection: Yes
After burning: Yes (if needed)
Filter: Yes
Acid gas removal: Yes (if needed)
VOC removal: Yes (if needed)

Processing Stage: Swarf drying and de-coating
Fume collection: Yes (if needed)
After burning: Yes (if needed)
Filter: Yes (if needed)
Acid gas removal: Yes (if needed)
VOC removal: Yes (if needed)

Processing Stage: Holding and de-gassing
Fume collection: Yes (if needed)
After burning: No
Filter: Yes (if needed)
Acid gas removal: No
VOC removal: No

Processing Stage: Salt Slag or Skimmings Treatment
Fume collection: Yes
After burning: Yes (for hydrogen, phosphine etc)
Filter: Yes
Acid gas removal: No
VOC removal: No

The use of or the recycling of skimmings and filter dusts, if it is possible, is considered to be part of the processes. Energy recovery can be applied to most of the stages if there is sufficient heat available and a use for the heat recovered. In its simplest form heat recovery using recuperative burners and charge preheating could be used in secondary aluminium production.

Brief technical description

The fume collection systems used for both primary and secondary production should exploit cell or furnace sealing systems and be designed to maintain a suitable depression that avoids leaks and fugitive emissions. Systems that maintain furnace sealing or hood deployment should be used. Examples are through hood additions of material, sealed charging cars and the use of robust rotary valves on feed systems. Secondary fume collection is expensive and consumes a lot of energy. It is often practicable to use an intelligent system capable of targeting the fume extraction to the source and duration of any fume to minimise energy consumption.

Achieved environmental benefits

Minimise energy consumption

Example plants

Non Ferrous Metals Industries

Pre-treatment, refining, production of primary alumina

The particular technique used depends on the raw materials and other facilities available on or near the installation. They form part of the over all process in conjunction with the following processes:

Process Stage: Production of alumina
Technique: Bayer process
Comments: Optimised to reduce energy, remove dust and reuse red mud transport water.

Process Stage: Refining
Technique: Use of mixtures of chlorine and argon/nitrogen or salt flux (AlF_3).
Comments: Addition via an inline cell for Cl_2,Ar,N_2 injection.

Process Stage: Holding or de-gassing.
Technique: Fume collection from furnaces and launders, cooling, fabric filter if necessary.
Comments: Casting moulds depend on product.

Process Stage: Anode production.
Technique: Two types of furnace are used for anode baking; open and closed ring furnaces. Open furnaces use a horizontal duct and closed furnaces use a vertical flue. Open furnaces account for 60% of capacity. The horizontal ducts of the open furnace are separate and parallel, this allows the heating cycle to be optimised for each duct and so reduces fuel consumption. The use of multiple chambers in the furnace allows heat from one section to be used in other sections.

Achieved environmental benefits

Energy saving

Example plants

Non Ferrous Metals Industries

Best practices

USES OF SPENT POT LINING

Description

The use of SPL carbon content in thermal processes.

Achieved environmental benefits

Use of energy content of the carbon, use of residual AlF_3 as a flux. Destruction of any CN content.

Cross-media effects

Positive effects. Use of the energy value of SPL. Elimination of waste deposited on land. Avoidance of energy input and associated releases if the SPL is treated thermally.

Operational data: Status of development

Details not available but there have been successful applications in cement firing, as a carburant in steel production and as a coke substitute in rock wool production.

Applicability

All SPL provided that Waste Transfer regulations allow it.

Economics

No nett income but avoidance of treatment or disposal charges.

Pre-treatment, refining, production of secondary alumina

The particular technique used depends on the raw materials and other facilities available on or near the installation. They form part of the over all process in conjunction with the following processes:

Process Stage: Refining
Technique: Use of mixtures of chlorine and argon/nitrogen or salt flux (AlF_3).
Comments: Inert cover gas or dross press

Process Stage: Skimmings treatment.
Technique: Inert cover gas and cooling in a sealed drum or dross press
Comments: Ammonia formation if wet.

Process Stage: Holding or De-gassing.
Technique: Fume collection from furnaces and launders, cooling, filter if necessary.

Achieved environmental benefits

Energy saving

Operational data

It is recommended that the potential formation of dioxins during the refining and casting stages for secondary aluminium production is investigated further.

Example plants

Non Ferrous Metals Industries

Primary aluminium smelting

Taking these factors into consideration the use of centre worked prebaked cells with automatic multiple point feeding of alumina is considered to be BAT for the production of primary aluminium.

Brief technical description

The process will have the following features:

Computer control of the electrolysis process based on active cell databases and monitoring of cell operating parameters to minimise the energy consumption and reduce the number and duration of anode effects.

- Complete hood coverage of the cells, which is connected to a gas exhaust and filter. The use of robust cell covers and adequate extraction rates. Sealed anode butt cooling system.
- Better than 99% fume collection from cells on a long term basis. Minimisation of the time taken for opening covers and changing anodes. Use of a programmed system for cell operations and maintenance.
- The use of established efficient cleaning methods in the rodding plant to recover fluorides and carbon. The use of effective extraction and filtration systems in this area.
- If local, regional or long-range environmental impacts require sulphur dioxide reductions, the use of low sulphur carbon for the anodes or anode paste if practicable or a sulphur dioxide scrubbing system.

- Gases from the primary smelting process should be treated to remove dust, fluorides and HF using an alumina scrubber and fabric filter. The scrubbing efficiency for total fluoride should be > 99.8%, and the alumina used in the electrolytic cells.
- If there is an integrated anode plant the process gases should be treated in an alumina scrubber and fabric filter system and the alumina used in the electrolytic cells. Tars from mixing and forming processes can be treated in a coke filter.
- An established system for environmental management, operational control and maintenance.

Achieved environmental benefits

Energy saving

Cross-media effects

The production of aluminium from recycled metal uses down to 5% of the energy of primary production.

Operational data

The material and energy inputs to the process are significant. Approximately 2 tonnes of bauxite are required to produce 1 tonne of alumina, which in turn produces about 0.53 tonnes of aluminium. The carbon anodes are consumed, approximately 0.4 to 0.45 tonnes of carbon is used per tonne of aluminium produced. The energy costs are also high and could account for approximately 30% of the production costs.

The production of alumina requires energy for digestion and calcination. The energy use is influenced mainly by the origin and chemical composition of the bauxite, the type of digesters used and the type of calciners used. The range of energy used in European plants is 8.0 to 13.5 GJ per tonne with a mean value of 11 GJ per tonne. The quantities of NaOH and CaO used are also linked to the composition of the bauxite.

The reduction of energy demand is mainly influenced by the use of tube digesters, which are able to operate at higher temperatures using a fused salt heat transfer medium. These plants have an energy consumption of less than 10 GJ per tonne.

The electrolysis stage has a high energy use ranging from 53 GJ per tonne for the best operated CWPB cells (including anode production) to 61 GJ per tonne for some traditional Søderberg cells.

Example plants

Non Ferrous Metals Industries

Best practices

CONTROL OF CELL OPERATING CONDITIONS

Description

The bath temperature, voltage and electrical current are the only parameters for the electrolysis process that can directly be measured. Process control within the electrolysis process is therefore based on the data from this limited number of parameters. The development of microprocessors has made it possible for modern computers to simulate the electrolysis process by calculating complex models for dynamic kinetics and magnetic fields, based on the limited information available. This results in an improved process control and a more smooth operation of the electrolysis. Smooth process operation will in general result in lower emissions of fluorides and dust.

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Achieved environmental benefits

Improved process control can also be applied to reduce the emissions of PFCs. The anode effects, that cause the PFC emissions, are directly related to low alumina concentrations. The alumina concentration in the electrolyte can not directly be measured due to the very aggressive nature of this medium. Anode effects were therefore used as an additional method to control the alumina concentration. The anode effects occur when the alumina concentration has decreased below 1% and are therefore capable to identify a specific alumina concentration. By simulating the electrolysis, modern computers are capable of calculating and correcting the alumina concentration. The correction of the alumina concentration in the electrolyte reduces the number of anode effects. However, anode effects are still required for periodic adjustment of the simulated alumina concentration. Therefore this improved process control is often provided with an automated anode effect killing system. This system automatically disturbs the gaseous layer beneath the anode occurring during the anode effects using compressed air.

Cross-media effects

Improved process control within the electrolysis process results in a reduction of the electricity consumption. The conversion to point feeding is associated with higher fluoride emissions in the cell gases and will affect the size of the cell gas dry scrubbing system.

Operational data: Status of development

The emissions of PFCs can be reduced by improved process control. For example CWPB cells with central point feeding can in general be operated with an anode effect frequency of 0.2 to 0.5 anode effects per pot per day, resulting in a PFC emission of 0.05 to 0.1 kg per tonne aluminium. When modern computers are applied for process control, the number of anode effects can further be reduced to a frequency less than 0.1 anode effects. This reduces the emissions of PFCs to less than 0.03 kg per tonne aluminium.

Applicability

All Søderberg and CWPB plants have computer control but there are differences in the control technology and operating philosophy. There are opportunities for optimisation.

Economics

Conversion of conventional Søderberg or CWPB plants to point feeder with process controls ~ 100 to 250 € per tonne annual capacity.

Secondary aluminium smelting

The smelting and melting processes that are considered to be BAT are the Reverberatory furnace, Tilting rotary furnace, Rotary furnace, Meltower Induction furnace depending on the feed materials.

1. Furnace: Reverberatory furnace.
Gas Collection: Semi sealed
Advantages: Large metal capacity
Disadvantages: Lower efficiency, restricted feed-stock
Comments: Use of sealed charging system (charging car)

2. Furnace: Reverberatory furnace with side well/charging well.

Gas Collection: Semi sealed
Advantages: Charging well allows efficient recovery of fine material. Larger range of feed material
Disadvantages: Lower thermal efficiency
Comments: Use of sealed charging system (charging car)

3. Furnace: Rotary Furnace
Gas Collection: Semi sealed
Advantages: No feed stock restrictions. Good thermal efficiency
Disadvantages: Relatively high usage of salt slag.
Comments: Targeted fume extraction

4. Furnace: Tilting rotary furnace
Gas Collection: Semi sealed
Advantages: Efficient for low grade feed including skimmings. Good thermal efficiency
Disadvantages: Restricted metal capacity
Comments: Minimum use of salt flux compared to fixed rotary furnace.

5. Furnace: Induction Furnace
Gas Collection: Open, hooded
Advantages: No combustion gases
Disadvantages: Restricted metal capacity and feed stock
Comments: Useful for small loads of clean metal

6. Furnace: Shaft furnace (Meltower)
Gas Collection: Semi sealed
Advantages: Charge pre-heating
Comments: For clean metal

Brief technical description

For the production of aluminium from secondary raw materials, the variation in feed stock also has to be taken into account at a local level. This will influence the combination of furnaces, scrap sorting and pre-treatment and the associated collection and abatement systems that are used.

The process will have the following features:

- Selection of the feed material to suit the furnace type and abatement and to transfer unsuitable raw materials to other operators using equipment designed for them so that it is possible to:
    a. To prevent the use of salt where practical consistent with achieving the maximum practical yield;
    b. To minimise the use of salt in other cases;
    c. To recover as many by-products as possible e.g. recovery of any salt slag that is produced.

The aim is to prevent landfill if possible.

- The use of a sealed charging carriage or similar sealed feeding system if possible.
- The use of enclosures or hoods for the feeding and tapping areas and targeted fume extraction systems if practical to minimise energy usage.

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638"

- The removal of oil and organic materials using swarf centrifuge, swarf drying or other thermal de-coating method before the smelting or melting stage (to reduce the potential for the emissions of dioxins and organic matter and to maximise energy efficiency), unless the furnace is specifically designed to accommodate the organic content.
- The use of coreless-induction furnaces for relatively small quantities of clean metal.
- The use of afterburners where necessary to remove organic carbon including dioxins.
- The injection of activated carbon and lime if necessary to remove acid gases and organic carbon including dioxins.
- The use of heat recovery if practicable.
- The use of fabric or ceramic filters for dust removal.

Achieved environmental benefits

Energy saving

Example plants

Non Ferrous Metals Industries

Example plants

USE OF METAL PUMPING SYSTEM

Description

Reverberatory furnace with side well, charge well and pumped metal system.

Achieved environmental benefits

Potential elimination of salt flux. Greater range of raw materials than simple reverberatory furnace, improved capture of furnace gases.

Cross-media effects

Reduction of amount of waste produced that requires treatment. Associated reduction in energy usage and emissions from the furnace.

Operational data: Status of development

Improvement in metal yield from 83 to 88%, reduction in energy costs

Applicability

New and upgraded reverberatory furnaces. Cannot be used for batch processes. Other methods of pumping are also applicable.

Economics

Cost (1997) of 30 tonne furnace and Electro Magnetic Pumping system £1800000 (2.73 million €), estimated cost savings (energy, improved yield, flux savings and treatment savings) £832000 (1.26 million €) per year. Pay back 2.2 years.

Cost of pumping system and charge well ~ £300000 (456000 €).

MINIMISATION OF SALT FLUX

Description

Minimisation of salt flux by the use of a tilting rotary furnace.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638

Achieved environmental benefits

Reduction in the amount of salt slag produced from 1.8 to < 0.5 kg salt per kg non-metal content.

Cross-media effects

Reduction of amount of waste produced that requires treatment. Associated reduction in energy and emissions from treatment process.

Operational data: Status of development

Reduction of salt usage factor from 1 – 1.8 down to < 0.5

Applicability

New and upgraded furnaces. There are size restrictions. Not applicable for all feedstock.

Economics

Not known – cost of furnace less cost savings from purchase and treatment of salt. 4 plants are operating viably.

MINIMISATION OF SALT FLUX

Description

Minimisation of the quantity of waste generated by the pre-treatment of skimmings. Skimmings are milled and sieved to separate the mainly aluminium fraction from the oxide. The aluminium fraction is recovered in a rotary furnace but the pre-treatment reduces the quantity smelted as well as the amount of salt needed.

Achieved environmental benefits

Reduction in the amount of waste produced from 118 kg per 100 kg to 66 kg per 100 kg of skimmings recovered.

Cross-media effects

Reduction of amount of salt slag used reduces emissions of chloride, lower reliance on salt slag treatment or disposal. Associated reduction in energy and emissions from treatment process due to a lower furnace burden.

Operational data: Status of development

100 kg of untreated skimmings uses ~ 72 kg of salt for smelting and produces 45 kg of aluminium and 118 kg of salt slag residue. Total residue ~ 118 kg.

100 kg of skimmings, after pre-treatment by milling and sieving produces, 70 kg of aluminium grains, 12.5 kg of dust for treatment, 12.5 kg of reusable material and 5 kg of iron. The 70 kg of aluminium grains uses 32.5 kg of salt for smelting and produces 45 kg of aluminium and ~ 54 kg of salt slag residue. Total residue ~ 66 kg.

Applicability

Most skimmings with high oxide content.

Economics

Not known – cost of mill and sieve less cost savings from treatment or disposal charges. Many plants are operating viably.

USE OF TARGETED FUME COLLECTION

Description

A fume collection system can be designed so that the collection fan capacity can be directed to sources of fume that change over a charging, melting and tapping cycle. Targeting of fume collection capacity can be achieved by using automatically controlled dampers that are linked to the furnace controls e.g. door opening, burner state or furnace inclination. Damper operation can therefore be initiated by charging, melting and tapping operations and the fume collection effort targeted accordingly.

Achieved environmental benefits

Prevention and minimisation of fugitive emissions to air.

Cross-media effects

Positive effect. Prevention of fugitive emissions and optimising fan energy consumption.

Operational data: Status of development

Non available but observations indicate that such systems are very effective if designed and controlled well.

Applicability

Most installations.

Economics

Not available. Relatively low cost of control and damper system.

COLLECTION OF FUME

Description

Charging and tapping zone fume collection enclosure for a rotary furnace to allow the use of a single extraction point.

In applications for the production of other metals, tapping holes on the charging door have been used and allow a more compact enclosure. Furnace lining wear may mean that door end tapping holes may not allow all of the metal to be tapped.

Achieved environmental benefits

In applications for the production of other metals, tapping holes on the charging door have been used and allow a more compact enclosure. Furnace lining wear may mean that door end tapping holes may not allow all of the metal to be tapped.

Cross-media effects

Positive effect- good collection efficiency with reduced power consumption.

Operational data: Status of development

Non available but observation shows effective fume capture.

Applicability

All rotary furnaces.

Economics

Low cost of modification in use viably in several installations.

3.2.4.3 Copper and its alloys (including Sn and Be) from Primary and Secondary Raw Materials

Primary and secondary converting

Secondary copper smelters considered as BAT:

1. Blast Furnace.
Raw Materials: Oxidic material.
Abatement Technique: After-burning, gas cooling * and cleaning** (fabric filter)
Comments: High energy efficiency. Capacity normally 150 - 250 t/d.

2. Mini Smelter (Totally enclosed).
Raw Materials: Secondary inc. Fe, Pb & Sn
Abatement Technique: Gas cooling and cleaning (fabric filter)
Comments: Integrated with TBRC secondary process.

3. TBRC (Totally enclosed).
Raw Materials: Secondary (most grades).
Abatement Technique: Gas cooling and cleaning (fabric filter)
Comments: Converter stage – TBRC (Totally enclosed). Capacity up to 70 tonnes /batch.

4. Sealed Submerged Arc Electric Furnace.
Raw Materials: Secondary inc. Sn & Pb (except very low grade).
Abatement Technique: After-burning, gas cooling and cleaning**
Comments: Converter stage – Peirce-Smith (with primary and secondary fume collection). Capacity up to 25 t/h melting rate.

5. ISA Smelt. (Not proven for lower grade material under reducing conditions.)
Raw Materials: Secondary (most grades).
Abatement Technique: Gas cooling * and cleaning **
Comments: Converter stage – Peirce-Smith or Hoboken (with primary and secondary fume collection). Capacity for sulphidic material ~40000 t/a.

6. Reverberatory hearth furnace
Raw Materials: Secondary (higher grades). Blister copper, black copper.
Abatement Technique: After-burning, gas cooling and cleaning (fabric filter)**
Comments: Used for fire refining and smelting higher grades of secondary material.

7. Hearth shaft furnace.
Raw Materials: Secondary (higher grades). Blister copper, black copper.

Abatement Technique: After-burning, gas cooling and cleaning (fabric filter)**
Comments: Used for fire refining and fire refining.

8. Contimelt
Raw Materials: Secondary (higher grades). Blister copper.
Abatement Technique: After-burning (reduction furnace), WHB and cleaning (fabric filter)**
Comments: Used for fire refining and fire refining.

9. Peirce-Smith (or similar) Type Converter.
Raw Materials: Copper alloy scrap, black copper from blast furnace.
Abatement Technique: Gas cooling and cleaning** (fabric filter).
Comments: Ability to fume off other metals. Capacity 15 - 35 tonnes/batch.

Note.
*) If the temperature level is high enough waste heat recovery may be considered; for cleaning in fabric filters further cooling is required.
**) The off-gas may contain sulphur dioxide during certain campaigns and can be treated in a scrubber or an acid plant at these times.

Brief technical description

The converting stage that can be used with these furnaces is any of the techniques that are listed as techniques to consider. If batch operated converters such as the Peirce-Smith converters (or similar) are used they should be used with total enclosure or efficient primary and secondary fume collection systems.

This can be achieved by the use of a system of intelligent control to target fume emissions automatically as they occur during the cycle without the high-energy penalty of continuous operation. The blowing cycle of the converter and the fume collection system should be controlled automatically to prevent blowing while the converter is rolled out. Additions of materials through the hood or tuyeres should be used if possible. This combination provides potentially greater flexibility, allows the use of both primary and secondary raw materials and utilises the heat generated by the matte converting process for scrap.

The ISA Smelt furnace can be operated batch-wise. Smelting is carried out in a first followed by conversion of matte to blister or after secondary smelting under reducing conditions, for oxidisation of iron and eliminating zinc or tin in a second stage is also considered as BAT.

Achieved environmental benefits

Energy saving

Example plants

Non Ferrous Metals Industries

3.2.4.4 Ferro-Alloys

Energy recovery in Ferro-Alloys Techniques

Heat and energy recovery.

Brief technical description

The production of ferro-alloys is a high energy consuming process, because high temperatures are needed for the reduction of metal oxides and smelting. Factors affecting the energy consumption are among other things the quality of raw material and their pre-treatment before smelting, the utilisation of reaction energies and the heat content of the processes. The energy used in the process can be supplied as electrical energy or fossil fuel in form of coal, coke charcoal or sometimes natural gas. The supplied energy either in a blast furnace or in an electric arc furnace is transformed into chemical energy formed by the reduction process as well as off gas energy (CO rich gas) and heat.

The off-gas energy is mainly represented as process heat in case of a semi-closed furnace or by the content of CO, CH_4 and H_2 when a closed furnace is used. The process-gases are produced in the smelting process if carbon is used as a reducing agent. The CO can be utilised as a secondary fuel and transferred by means of pipelines within the plant area like any other fuel gas. It can be used by direct burning for instance in the sinter-furnace and for drying or pre-heating the furnace charge as well as for energy recovery in form of hot water, steam and/or electricity.

By producing HC FeMn in a blast furnace the CO rich top gas will be de-dusted and partly be used to heat up the hot stoves. The excess gas is burned in an adjacent power plant to produce superheated steam and subsequently electrical energy in a back-pressure turbine.

If a semi-closed submerged electric arc furnace is used for the production of FeCr, FeSi, silicon-metal, SiMn or FeMn, the CO gas from the smelting process burns in air thus creating a hot off-gas. Therefore the semi-closed furnaces are sometimes equipped with a waste heat boiler as an integrated energy recovery system. The waste heat boiler generates superheated steam that can be sold to neighbouring mills or used for electricity production in a back-pressure turbine.

During the production FeCr, FeMn or SiMn in a closed electric arc furnace the off-gas contains a very high percentage of CO, which is collected without being burned above the charge surface. This CO is a high quality fuel that is favourably being used for electricity production or supplied to a neighbouring industrial plant as a secondary fuel or as a synthesis gas that serves as a raw material in chemical processes. A typical composition of a CO rich gas, formed in a closed furnace producing HC FeCr, contains of 75 – 90% CO, 2 – 15% H_2, 2 – 10% CO_2, 2 – 5% N_2 and < 5% of H_2O.

Achieved environmental benefits

Energy recovery

Driving force for implementation

Ferro-Alloys.

Example plants

Non Ferrous Metals Industries.

Pre-reduction and pre-heating

The technology of pre-reducing ore and concentrates is fully implemented only in two plants world-wide. As reported, there are still some problems operating this technology. Pre-reduction is

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therefore not yet recommended as a general BAT in this sector. However, for the future pre-reduction for chromite and also for manganese ore seems to be a very promising technique because this enables a substantial reduction in unit power consumption, that means a reduction of the electrical power needed in the subsequent smelting process. This may as well increase the productivity of the furnace. Pre-reduced manganese ore might play in future also an important role in reducing the high coke consumption of a HC FeMn production in a blast furnace.

Pre-heating of charge materials is suitable as far as it is possible. Combustion of CO-gas from closed smelting furnace provides heat as energy for preheating for instance the furnace charge in the FeCr-production. Pre-heating reduces the electrical energy consumption by about 70 - 90 kWh/100 ºC increase in the pre-heating temperature of the furnace. The production capacity of a furnace is increased as well by pre-heating the charge materials.

Brief technical description

Pre-reduction of chromite and manganese ore reduce the specific electrical energy consumption and increases the productivity of the smelting furnace. In FeCr production, chromite ore fines are pelletised with coke as a reductant and fired in a rotary kiln. A pulverised coal/CO/oil burner heats the kiln. Waste heat from the kiln is recovered in a waste-heat recovery boiler to generate steam. The exhaust gas is cleaned in a bag filter. The pre-reduced pellets are stored in a completely sealed surge hopper designed to prevent re-oxidation. The reduced material is then charged hot to the furnace, which combines pre-heating and pre-reduction. It has been reported, that the fully implemented and continuously operated pre-reduction technique in a Japanese ferro-chrome plant decreases the energy consumption down to about 2000 - 2100 kWh/t of FeCr. The weakness of a pre-reduction process is a possible accretion formation in the kiln. World wide there are only two plants using this pre-reduction process and one plant using the Krupp-Codir (CDR) pre-reducing technique.

The electricity consumption of the smelting furnace can be decreased by pre-heating the feed materials Pre-heating for instance as it is used in the production of FeCr increases at the same time the productivity of the smelting furnace.

Best practices

PRE-HEATING IN A SHAFT-KILN

Description

The shaft type furnace is used to preheat the charging material for the production of FeCr in a closed electric arc furnace. The shaft type furnace has the advantage that crushing up of charge material and dusting is lower. The utilisation of fuel energy for instance CO from the smelting furnace or natural gas is higher and maintenance work is needed less.

Achieved environmental benefits

The pre-heating decreases the energy consumption By preheating the charge at 700 ºC the moisture and a major part of the volatiles can be removed before the material is charged into the electric furnace Thus the formation of reduction gases in the furnace is stable.

Cross-media effects

The use of CO gas as a fuel reduces the electrical energy required for the subsequent smelting process. This results in less generation of CO2, and reduces the impact of greenhouse gases to the atmosphere if the savings of external production of electrical energy are taken into account. The comparison of a shaft kiln has been done with a rotary kiln. Burning of CO generates CO_2.

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Operational data: Status of development

The electrical energy consumption of the subsequent smelting furnace is reduced by 70 - 90 kWh per 100 ^{o}C increase in the preheating temperature for the smelting furnace.

Applicability

To all new and existing plants. The usage of CO as a fuel is only possible for plants using closed furnaces.

Pre-treatment techniques

BAT for this sector is considered as follows:

- A shaft furnace is preferably used for coke drying were the use of recovered energy or the CO rich off-gas from the smelting furnace as a secondary fuel is suitable. Bag filters are used to clean the off-gas were the associated dust emission level is 5 mg/Nm^3
- A rotary kiln can be used for drying or degreasing of secondary raw material like turnings or metal scrap. For drying, bag filters are used to clean the off-gas were the associated emission level for dust is 5 mg/Nm^3 achieved by using an afterburner and subsequently a ceramic filter, which offers the possibility to recycle the hot air back to the dryer,
- For the degreasing of secondary raw material an afterburner can be used in order to destroy VOC's. The residence time of 2 sec. and a minimum temperature of 850 oC is suitable, however lower residence times (0.5 sec.) and may result in complete destroying of VOC's, but this should be demonstrated at a local level. The residence time can be optimised in order to minimise the emission of VOC's and the use of energy and subsequently the emission of CO_2 and other combustion products.
- Wet grinding, filtering and pelletising will produce an increased specific surface area of chromite and amend the reduction rate later in the smelting process. An additional effect is the reduced amount of dust generated by smelting process. By pelletising the fines, fugitive emissions are reduced and fine material that is more commonly available around the world may be used.

Best practices

DRYING OF COKE IN A SHAFT FURNACE

Description

A shaft furnace is used for coke drying in a ferro-chrome production. The furnace uses CO rich off-gas from the smelting furnace as a fuel. For the abatement equipment a bag filter or a wet scrubber can be used as well.

Achieved environmental benefits

A shaft furnace generates less dust and fines. The use of CO rich off gas as a fuel reduces the overall energy consumption of the process. The energy consumption from CO is 550 - 700 MJ.

Cross-media effects

The use of CO rich gas as a fuel reduces the consumption of other natural combustion fuels.

Operational data: Status of development

Non available.

Applicability

For all new and existing plants which use wet quenched coke. The use of CO rich off gas is due to plants operation closed furnaces.

Driving force for implementation

Metal scrap, turnings and swarf sometimes have to be liberated from oil and cutting liquids, which may take place by drying in a rotary kiln. The following example shows a titanium swarf degreasing plant that is used in the production of secondary ferro-titanium.

Routes of utilisation the CO gas or to recover the heat energy from a smelting process

BAT for: semi-closed electric arc furnace, closed electric arc furnace and blast furnace. Retrofitting of a smelting furnace with an appropriate energy recovery system.

According to the considered techniques and routes of utilisation the CO gas or to recover the heat energy from a smelting process, BAT for energy recovery in this sector is considered as follows:

Ferro-alloy: FeCr
Furnace: Closed
Energy medium: CO-gas
Energy recovery:

- Production of electrical energy
- Utilisation of CO as fuel in neighbouring plants
- Direct burning for drying, sintering pre-heating ladle heating etc.
- Use in a integrated FeCr and stainless steel plant

Ferro-alloy: FeCr
Furnace: Semi-closed
Energy medium: Heat
Energy recovery:

- Production of electrical energy
- Production of high pressure steam and utilisation in the own or neighbouring plants
- Production of hot water

Ferro-alloy: FeSi; Si-metal
Furnace: Semi-closed
Energy medium: Heat
Energy recovery:

- Production of electrical energy
- Production of high pressure steam and utilisation in the own or neighbouring plants
- Production of hot water

Ferro-alloy: FeMn; SiMn
Furnace: Closed
Energy medium: CO-gas
Energy recovery:

- Production of electrical energy
- Utilisation of CO as a raw material in neighbouring plants
- Direct burning for drying, sintering pre-heating ladle heating etc

Ferro-alloy: FeMn; SiMn
Furnace: Semi-closed
Energy medium: Heat
Energy recovery:

- Production of electrical energy
- Production of high pressure steam and utilisation in the own or neighbouring plants
- Production of hot water

Ferro-alloy: FeNi
Furnace: Semi-closed
Energy medium: Heat
Energy recovery:

- Production of electrical energy
- Production of high pressure steam and utilisation in the own or neighbouring plants
- Production of hot water

Ferro-alloy: FeV; FeMo; FeW; FeTi; FeB; FeNb
Special ferro-alloys are normally produced in small amounts compared to bulk ferro-alloys. The smelting process usually takes place as a batch process in a refractory lined crucible. The metallo-thermic reaction is exothermic where the heat is used as the energy source for the process which needs in some cases only a few minutes
The energy recovery from the excess process heat is difficult and doesn't justify a high investment for an energy recovery system.

Brief technical description

The best available techniques for energy recovery are techniques that are applicable to new plants and in case of a substantial change of an existing plant. This includes also the case where a furnace needs to be replaced.

For existing plants retrofitting of a smelting furnace with an appropriate energy recovery system is possible especially when an open furnace will be changed into a semi-closed furnace. The energy content can then be recovered by producing steam in a waste-heat boiler where the furnace hood can advantageously be integrated in the recovery system and used as superheater. The produced steam may be used in the process, in neighbouring mills but most often for the generation of electrical energy will be economically the best solution.

By building a closed furnace or replacing of an existing furnace by a closed one a cleaning and recovery system for the CO-gas is unavoidable. The CO, that otherwise needs to be flared off can be used as high quality secondary fuel for a variety of purposes or as raw material or fuel in neighbouring mills. Flaring of CO-gas is only acceptable in the case where customers inside or outside the plant are temporarily not available. The recovered CO gas can as well be used for the production of electrical energy.

- Production of electrical energy
- Production of high pressure steam and utilisation in the own or neighbouring plants
- Production of hot water

- Utilisation of CO as fuel in neighbouring plants
- Direct burning for drying, sintering pre-heating ladle heating etc.
- Use in a integrated FeCr and stainless steel plant

Achieved environmental benefits

Heat energy can be recovered.

Energy can be recovered from CO that can be used as secondary fuel.

Energy recovery using the CO-rich off gas for heating the hot stoves and electricity production.

The recovery of process energy reduces the consumption of natural energy resources and consequently contributes to minimise the CO_2 emissions and the effect of global warming if the total impact of the process, and the saved energy elsewhere are included into the global energy and CO_2 balance. Energy recovery is therefore a desirable option and will in future be more and more important, but it is suitable only if local conditions (e.g. local prices of energy, the presence of external energy customers, and periods of production) justify the investment. As already mentioned in the part of BAT for smelting furnaces the recovery of energy is strongly related to the used furnace type (semi-closed or closed furnace). Energy recovery should therefore also be seen in the context and the requirements of changing existing furnaces.

Cross-media effects

The recovery of process energy reduces the consumption of natural energy resources and consequently contributes to minimise the CO_2 emissions and the effect of global warming if the total impact of the process and the saved energy elsewhere are included into the global energy and CO_2 balance.

Operational data

Abatement technique: Bag filter

Combining the different recovery techniques can increase the overall efficiency of an energy recovery system.

Closed furnaces are operated in connection with different pre-treatment and peripheral techniques, such as sinter-plants, pre-heating furnaces etc. These techniques may all have a positive influence on the environmental impact, especially if CO rich off gas from the smelting furnace is used as a fuel.

Special ferro-alloys are normally produced only in small amounts, therefore the energy that can be recovered is low compared to bulk ferro-alloys Due to operational problems. FeSi and Si-metal can not yet be produced in a closed furnace.

Due to the high coke consumption the blast furnace has to be considered as BAT only if it is associated with an efficient recovery of the energy content of the CO-rich off-gas. This necessitates a high performance process control and abatement system. To reduce fugitive emissions appropriate hooding of tap holes and runners should be used. Under these conditions the blast furnace can be operated with a low environmental impact.

Applicability

The considered furnaces are in general all applicable to new and existing plants. However the long furnace life and the very high investment cost to build a new or replace an existing furnace should be taken into account. Therefore the best available techniques for smelting furnaces is strongly applicable only for new plants and a substantially change or replacement of a furnace.

This is especially the case for replacing an open furnace by a closed furnace, because main parts of the abatement technique need to be changed as well.

Two stage bag filter with injection of activated carbon or a 3 step venturi scrubber an wet EP and a mercury removal by a selenium filter.

Wet scrubber or dry cleaning system.

Bag filter.

Dust catcher, EP and a wet scrubber or dry cleaning system.

Economics

Special ferro-alloys are normally produced in small amounts compared to bulk ferro-alloys. The smelting process usually takes place as a batch process in a refractory lined crucible. The metallo-thermic reaction is exothermic where the heat is used as the energy source for the process which needs in some cases only a few minutes

The energy recovery from the excess process heat is difficult and doesn't justify a high investment for an energy recovery system.

Energy recovery is therefore a desirable option and will in future be more and more important, but it is suitable only if local conditions (e.g. local prices of energy, the presence of external energy customers, and periods of production) justify the investment. As already mentioned in the part of BAT for smelting furnaces the recovery of energy is strongly related to the used furnace type (semi-closed or closed furnace). Energy recovery should therefore also be seen in the context and the requirements of changing existing furnaces.

Driving force for implementation

Ferro-alloy production: HC FeCr, FeSi, Si-metal, HC FeMn, SiMn.

Other ferro-alloys produced by carbo-thermic reduction, but not FeSi and Si-metal.

Alloy recovery from steel mill residues.

Ferro-alloy production: HC FeMn.

Example plants

Non Ferrous Metals Industries

Best practices

A NORWEGIAN FECR PLANT

Description

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

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

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

Energy consumption and recovery

Electrical energy: 4060 kWh/t

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

Sintering

- Use of pre-treatment and transfer processes with well designed robust extraction and abatement equipment to prevent the emission of dust and other material. The design of this equipment should take account of the nature of the emissions, the maximum rate of emissions and all of the potential sources.
- Use of enclosed conveying systems for dusty materials. These systems should be provided with extraction and abatement equipment where dust emissions are possible.
- Processes that "flow" directly into the following process if possible to minimise handling and conserve heat energy.
- Use of wet grinding, blending and pelletising systems if other techniques for the control of dust are not possible or appropriate.
- Thermal cleaning and pyrolysis systems (e.g. swarf drying and de-coating) that use robust after-burning equipment to destroy combustion products e.g. VOCs and dioxins. The gases should be held at a temperature greater than 850 °C (1100 °C if there is more than 1% halogenated organic material), in the presence of at least 6% oxygen for a minimum of 2 seconds. Lower residence times may as well result in the complete destroying of VOCs and dioxins but this should be demonstrated on a local level. Gases should be cooled rapidly through the temperature window of dioxin reformation.
- To reduce the impact of VOC's, washing processes to remove oil or other contaminants should use benign solvents. Efficient solvent and vapour recovery systems should be used.
- Steel belt, up-draught or fully enclosed down-draft sintering processes are techniques to be considered. Steel belt sintering has several advantages for certain metal groups and can minimise gas volumes, reduce fugitive emissions and recover heat. These are discussed later. Off gas extraction systems should prevent fugitive emissions.
- The use of rotary kilns with wet ash quenching for the processes involving the volume reduction of material such as photographic film. Smaller installations may use a moving grate furnace. In both cases the combustion gases should be cleaned to remove dust and acid gases if they are present.
- If required to minimise the generation of smoke and fumes and to improve the melting rates, separation processes should be designed to produce clean materials that are suitable for recovery processes.
- Collection and treatment of liquid effluents before discharge from the process to remove non-ferrous metals and other components.
- The use of good design and construction practices and adequate maintenance.

Best practices

STEEL BELT SINTERING FURNACE

Description

The Steel Belt Sintering Furnace is used to sinter chromite pellets in the production of FeCr. The Steel Belt Sintering Furnace is closed. The off gases from the sintering furnace and the dusting points can be cleaned by a low pressure wet scrubber or a bag filter. The operation of the process is controlled by a computerised control system.

Achieved environmental benefits

The external energy consumption in a steel belt sintering furnace is lower compared to a shaft and a grate furnace. As a consequence the generation of CO_2 and SO_2 emissions are lower. The sludge from the off-gas treatment can be recycled back to the wet grinding step.

Cross-media effects

The use of CO gas as a fuel reduce the external energy required for the sinter process, which results in less generation of CO_2, and reduces the impact of greenhouse gases to the atmosphere if the saving of external energy resources is taken account. The wet scrubber generates a wastewater that can be recycled to the wet grinding step.

Operational data: Status of development

Energy consumption is 700 – 1400 MJ/t of pellets. CO from the smelter is used as a fuel together with coke fines. Emission levels for dust:
Wet scrubber < 10 mg/Nm^3
Cascade wet scrubber can achieve < 4 mg/Nm^3
Bag filter < 5 mg/Nm^3

Applicability

To all new and existing plants where sintered pellets are used as raw material for the furnace. The use of CO as a fuel is only possible for plants using a closed furnace.

Smelting processes for Ferro-Alloys

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

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

Brief technical description

In the production of ferro-alloys the most important stage is the reduction of metal oxides and alloying with the iron present in the process. Depending on the reducing agent, different types of smelting systems (such as the electric arc furnace, the blast furnace or a reaction crucible) are used. Electric arc furnaces are normally operated submerged as a closed, semi-closed or open type. The concept of the different smelting systems are influenced by the desired flexibility in the production, the range of raw material, the possibilities of energy recovery and the environmental performance. The different techniques considered for the recovery of energy, which are very much dependent on the used smelting system but also on local conditions that means local energy prices, periods of production and the presence of potential customers.

Achieved environmental benefits

Energy recovery

Operational data

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

Driving force for implementation

Ferro-Alloys

Example plants

Non Ferrous Metals Industries

Techniques to reduce the overall energy consumption for Ferro-Alloys

Heat and energy recovery.

Brief technical description

The production of ferro-alloys is an energy consuming process. For the slag processes producing HCFeCr or HCFeMn in closed furnaces, coke consumption for the furnace process itself lies in the range of 420 - 520 kg/tonne. Pre-reduction of the ore, can be done by using coal or other cheap carbon materials, both as an energy source and as a reductant. This will lower both the amount of coke and electric power in the reduction furnace, but might increase the total consumption of carbonaceous materials and the gross energy consumption of the process as a whole.

If all this carbon is assumed to be converted into CO, i.e. no reduction work is done by CO gas and no carbon is lost, the carbon could theoretically be recovered as CO gas. This could then be used as fuel for recovery of energy, either by burning above the top of a semi-closed furnace, or by collection from a closed furnace and later use. The quantity for instance would be between 770 and 1050 kg CO/tonne FeCr. This would be equivalent to between 2160 and 2950 kWh/tonne. In reality these figures would probably be 5 - 15% lower. The resulting amount of CO_2 produced by the furnace process alone would amount to 1200-1650 kg/tonne.

The difference in process energy consumption between production alternatives is not very big. Indeed, the "conventional" process routes may have an advantage if a considerable part of the recoverable energy can be sold externally. Most often plants do not have external energy customers. Choosing a process route that can utilise recovered heat, either for added process steps that increases efficiency and output, or for electricity generation, will then be advisable options.

An important point of the closed furnace process that uses pelletising/sintering and pre-heating is to minimise the use of fossil carbon per tonne of produced alloy, which will also minimise the specific CO_2 emission. However, the pelletising/sintering will only reduce the impact of greenhouse gases if an alternative, less energy efficient process would lead to a deficiency of Ore quality is also an important factor for energy consumption. Of primary importance is the content of metal oxide and the non ferrous metal/iron ratio, which should both be as high as possible. Secondarily the content of gangue minerals should be as low as possible in the ore or the ore mix (this will partly be a consequence of a high amount of metal oxide), and of a composition to minimise use of slag additives. This will lower the slag amount, and thus the proportion of the electric power necessary to melt slag.

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

There are some direct plant improvements that can be done to reduce the energy consumption, such as running the process with a high metal yield, improving the furnace design to achieve lower energy loss. In addition to the direct plant improvements about 15–20% of the electric energy consumed by the electric arc furnace can be recovered as electricity by an energy recovery system. This percentage is considerably higher for a system that produces electricity and uses the thermal energy of the furnace cooling and the off-gas volume. This will be as well the case if the CO-gas is utilised directly as a secondary fuel in order to replace fossil fuels. The following examples show the possibilities to recover energy from the different furnace types used in the ferro-alloy industry.

Achieved environmental benefits

Energy recovery

Driving force for implementation

Ferro-Alloys

Example plants

Non Ferrous Metals Industries

Best practices

ENERGY RECOVERY AND UTILISATION OF THE CO FROM A CLOSED ELECTRIC ARC FURNACE

Description

The main part of the process is a closed electric arc furnace, which generates a CO rich off-gas (70 – 90% of CO). The off-gas is cleaned by using a wet scrubber before it can be used as a secondary fuel. One possibility is the combustion with air in an stream boiler. The steam is fed to a set of high pressure and low pressure turbines. The Energy is then recovered as electricity. Beside the production of electricity the CO gas can also be transferred by means of pipelines in the plant area and used as a secondary fuel for many purposes. The best utilities are achieved in direct burning replacing fossil fuels, e.g. heavy oil or coal. In the production of FeCr, FeMn and SiMn CO gas can be used for drying of coke and other raw materials. CO gas can as well be used as a fuel in the steel belt sintering furnace in order to reduce the primary energy consumption of the furnace. By producing FeCr, the CO gas is used to preheat the charge material, which cut the consumption of electric energy by 70–90 kWh per a 100 ^{o}C increase in the preheating temperature. It can also be used in an adjacent stainless steel plant.

The CO rich gas can as well be cleaned and then supplied as a synthetic gas to a neighbouring chemical plant, in which the gas serves as a raw material.

In a semi-closed furnace the CO-gas from the smelting furnace burns in the suction air thus creating a hot off gas of about 400 – 800 °C with can also reach peaks up to 1200 °C. The furnaces can be equipped with an integrated energy recovery system, which contains the following components:

- Exhaust hood with furnace ducting
- Waste-heat boiler
- Feed-water system
- Heat distribution system or steam turbine with generator and condenser

Achieved environmental benefits

The recovery of electric energy from the CO gas reduces the overall energy consumption of the process, which consequently minimise the impact of global warming by emitting CO2 from burning fossil fuel.

Cross-media effects

The recovered energy replaces in most cases fossil fuel like oil or coal and reduces therefore at the same time the emission of SO_2

Operational data: Status of development

Steam produced 35 – 40 tonnes/h. Energy recovery 70 GWh/a = 13.5% of the electrical energy input

Applicability

To new and existing plants producing FeCr. FeMn and SiMn in closed furnaces

Driving force for implementation

Ferro-Alloys

ENERGY RECOVERY FOR A SEMI-CLOSED ELECTRIC ARC FURNACE

Description

The energy form hot off-gas of the furnace can be recovered in a waste heat boiler, which produces superheated steam. Relatively conventional water pipe boilers with super heater, economiser and condenser sections are used, combined with an efficient cleaning system to keep the heating surfaces clean in the heavily dust polluted flue gas. The furnace top hood is highly exposed to the internal furnace heat, and is conventionally cooled with a water piping system covered by a ceramic lining. About 25% of the furnace heat emissions are lost to the top hood cooling water. For energy recovery the top hood may be cooled by unshielded high-pressure water piping, producing steam to the recovery boiler system. Such hood exists and contributes substantially to the energy recovery. The steam can be used in a back pressure turbine in order to produce electricity or be sold to a neighbouring mill. The recovery system can be designed also to produce hot water, which can be used by a local heating system.

Achieved environmental benefits

The recovery of energy from the hot off gas reduces the overall energy consumption of the process, which consequently minimise the impact of global warming by emitting CO_2 from burning fossil fuel. The off-gas energy presented a large available, partly unexploited energy source that can provide new electricity without pollution and additional CO_2 emission.

Cross-media effects

The recovered energy replaces in most cases fossil fuel like oil or coal and reduces therefore at the same time the emission of SO_2. The energy recovery produces no pollution, as the flue gas composition is not changed by the recovery. The emission of hot cooling air and water from the plant is reduced. The energy recovery creates no visual changes of the landscape.

Operational data: Status of development

The off-gas energy can be used to produce electric power, heat energy or both. If the waste heat is utilised as electric power the recovery is up to 28 - 33% of the energy consumption. Alternately, the steam can be drained at mean pressure and be used for district heating, and the recovery will increase to approximately 80 - 90%. But then only 20% of the waste heat is recovered as electric power. The demand of district heating often varies trough the year and the most efficient solution is co-generation of electric power and heat energy to supply heat energy only when needed.

Applicability

The technology is in general applicable to both new and existing plants. Since this energy source normally presents existing installation, one of the obvious demands towards the energy recovery is that it is applicable to existing plants.

Economics

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

Capital cost 4.73 M €
Manning (5.5 Man-years) 0.25 M €
Total 5.76 M €

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

Capital cost 1.81 M €
Operation and maintenance, 0.45 M €
Manning (5.5 Man-years) 0.25 M €
Total 2.51 M €

Driving force for implementation

Ferro-Alloys

"This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 694638"

ENERGY RECOVERY FROM A BLAST FURNACE OFF-GAS

Description

The production of HC FeMn in a blast furnace results in the generation of a large amount of CO rich off-gas. This CO gas can partly be used as a secondary fuel to preheat the blast in the hot stoves. The excess gas is burned in an adjacent power plant to produce electricity.

Achieved environmental benefits

The use of the CO gas reduces the overall power and coke consumption of the process, which consequently minimise the impact of global warming by burning fossil fuel.

Cross-media effects

Blast furnace off-gas cleaning is unavoidable and thus induces generation of wastewater and a solid residue. It might be expected that preheating of the fuel media and an increase of the flue-gas temperature lead to higher NO_x emissions from the hot stoves. The application of modern burners may reduce the NO_x emissions.

Operational data: Status of development

For the production of FeSi and Si-metal is has been reported that a smelting furnace, which slowly rotates may contribute to the reduction of the overall energy consumption by about 10% and increase the metal yield.

The above possibilities of energy recovery are presently in operation in various systems in the ferro-alloy industry and performed satisfactory for many years. However it should be noticed that an appropriate energy recovery system means a high capital investment. Taking local conditions, such as local energy prices, periods of production and the absence of potential customers into account, the returns of investments may in several cases not be high enough to justify such investments from an economic point of view.

Applicability

Applicable to blast furnaces producing HC FeMn

Economics

The high investment costs are saved to a large extent to the energy savings by pre-heating the blast and the income from the sold electrical energy.

Driving force for implementation

Ferro-Alloys

ELECTRIC MOTOR

Description

A company carried out a survey of existing motor drives. An old motor was found with an electrical power input of 100 kW. The efficiency of the motor was 90% and, accordingly, the mechanical output power was 90 kW.

To improve the efficiency, the motor was replaced by a high efficiency motor. The electric power needed to produce the same output power, 90 kW, is now 96 kW due to the higher efficiency of the new motor. The energy efficiency improvement is thus 4 kW, or energy improvement = 4/100 = 4%.

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3.2.4.5 *Precious Metals*

Gas collection and abatement

Best Available Techniques for gas and fume treatment systems are those that use cooling and heat recovery if practical before a fabric filter. Fabric filters that use modern high performance materials in a well-constructed and maintained structure are applicable. They feature bag burst detection systems and on-line cleaning methods. Gas treatment for the smelting or incineration stage should include a sulphur dioxide removal stage and/or after-burning if this as considered necessary to avoid local, regional or long-range air quality problems or if dioxins may be present.

Brief technical description

The fume collection systems used should exploit furnace or reactor sealing systems and be designed to maintain a suitable depression that avoids leaks and fugitive emissions. Systems that maintain furnace sealing or hood deployment should be used. Examples are through electrode additions of material, additions via tuyeres or lances and the use of robust rotary valves on feed systems. Secondary fume collection is expensive and consumes a lot of energy but is needed in the case of some furnaces. The system used should be an intelligent system capable of targeting the fume extraction to the source and duration of any fume.

Achieved environmental benefits

Energy saving

Example plants

Non Ferrous Metals Industries

Best practices

TARGETED SECONDARY FUME TREATMENT

Description

Treatment of secondary fume and ventilation gases by SO_2 absorption and fabric filter.

Secondary gases from ventilation area: Converter secondary hoods, electric slag cleaning furnace hoods, electric slag cleaning furnace off-gases, ventilation systems at flash furnace, anode furnaces, reverts handling and preparation.

Inlet Conditions:
Max design volume : 580000 Nm^3/h
Volume variation: ~ 350000 to 550000 Nm^3/h
Absorbent for SO2 removal: Slaked lime
Average dust & absorbent content: 1500 mg/Nm^3
Range dust: 1 – 5 g/Nm^3
SO2 inlet range: 100 – 1500 mg/Nm^3

Outlet conditions:
Volume variation: ~ 350000 to 550000 Nm^3/h
Average residual dust: < 2 mg/Nm^3
Range residual dust : 1 - 7 mg/Nm^3
Range components:
Cd < 0.01 – 0.1 mg/Nm^3

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As < 0.01 – 0.8 mg/Nm^3
Ni < 0.01 – 0.3 mg/Nm^3
Se < 0.01 – 0.9 mg/Nm^3
Sb < 0.01 – 0.5 mg/Nm^3
Cu < 0.01 – 2 mg/Nm^3
Sulphur absorption ~50 to 70 %

The installation uses a system of 3 secondary hoods in addition to the main hood. These hoods can be connected either to the sulphuric acid plant (hood 1) or to the secondary cleaning system (hoods 2 & 3). During filling and pouring operations the individual hoods are motor-driven to the positions that ensure optimal collection efficiency. Intelligent controls are used.

Achieved environmental benefits

Collection and treatment of fugitive emissions. Minimisation of energy use.

Cross-media effects

Positive effect - Reduction in energy usage compared to total ventilation air capture, reduction of main emissions

Operational data: Status of development

99% fume capture achieved

Applicability

Most converter processes. Applicable to a range of furnaces such as the El Teniente and Noranda furnaces.

Economics

23 million DM for complete system including hooding, ducts, controls. Energy consumption 13.6 GWh/a.

INCINERATION OF PHOTOGRAPHIC MATERIAL

Description

Use of rotary kiln with good process control, gas collection and gas treatment.
Rotation and process control allows good mixing of material and air.

Achieved environmental benefits

Easier fume collection, after burning and gas treatment compared to static or box incinerators.

Cross-media effects

Positive effect- good collection efficiency with consumption, using the calorific value of the film compared to similar systems.

Operational data: Status of development

Non available.

Applicability

Incineration of all photographic material.

Economics

Capital cost estimated at £450000 for 500 kg/h plant (1988 data).

COLLECTION OF FUME

Description

Co-incident charging and tapping zone for a rotary furnace.

Furnace lining wear may mean that door end tapping holes may not allow all of the metal to be tapped.

Achieved environmental benefits

Easier fume collection from a single point.

Cross-media effects

Positive effect- good collection efficiency with reduced power consumption compared to similar systems.

Operational data: Status of development

Non available.

Applicability

All rotary furnaces.

Economics

Low cost of modification, viable in several installations.

3.2.4.6 Refractory Metals

Smelting, firing, hydrogen reduction and carburisation process

According to the different refractory metals produced and the environmental impact of the processes, which are widely be influenced by the used smelting, reduction and carburisation system, the following production systems are considered to be BAT for this sector. For the production of hardmetal powder from secondary raw material and hardmetal scrap the zinc process is economically attractive and environmentally of low potential risk.

Furnaces considered as BAT for the production of refractory metals:

Furnace type: Reaction chamber (firing pot)
Produced metal: Cr produced by metallo-thermic reduction
Gas collection and abatement: movable closed hood connected with a bag filter
Remarks: Recovery of heat energy will not be practised, because the metallo-thermic reduction takes place as a batch process, which needs only a short reaction time.

Furnace type: Pusher furnace
Produced metal: Ta-, W-powder Ta, W-carbides

Gas collection and abatement: bag filter Wet scrubber
Remarks:

- The reduction furnace of metal oxides is equipped with a closed system where excess hydrogen is being directly recycled. A condenser is used for removing water and dust carry-
  - over. The dust (metal- or carbide powder) is reused
  - Each furnace needs a nitrogen purge
  - The stoker arm has to be sealed to seal the tube entrance.
  - Boats are emptied over a screen into drums

Furnace type: Band furnace
Produced metal: Ta-, W-powder Ta, W-carbides
Gas collection and abatement: bag filter Wet scrubber
Remarks:

- The reduction furnace of metal oxides is equipped with a closed system where excess hydrogen is being directly recycled. A condenser is used for removing water and dust carry-over. The dust (hardmetal powder) is reused
- Each furnace needs a nitrogen purge

Furnace type: Rotary furnace
Produced metal: W-powder
Gas collection and abatement: bag filter Wet scrubber
Remarks:

- The kiln is sealed to prevent egress of fume and dust.
- By producing tungsten powder in the rotary furnace the discharge is into a closed chamber where the powder is purged with nitrogen. The powder is then discharged into churns which are kept under nitrogen

Furnace type: Batch furnace
Produced metal: Ta- and W-carbides
Gas collection and abatement: bag filter Wet scrubber
Remarks: The extraction system needs to be able to handle variable off-gas volumes

Furnace type: Electric vacuum furnace
Produced metal: melting of secondary refractory metals from scrap e.g. titanium
Gas collection and abatement: bag filter Wet scrubber
Remarks: Energy recovery may only be possible from the cooling water cycle

Furnace type: Electron beam furnace
Produced metal: Melting of Nb, Ta, Mo, W and Ti.
Gas collection and abatement: vacuum extraction condenser and scrubbing system
Remarks:

- High energy consumption
- Energy recovery may only be possible from the cooling water cycle
- Zr and Hf are also associated with radioactive metals (uranium, polonium and thorium) which can be present in residues

Furnace type: Electron beam furnace

Produced metal: Refining of V, Nb, Ta, Zr and Hf
Gas collection and abatement: vacuum extraction condenser and scrubbing system
Remarks:

- High energy consumption
- Energy recovery may only be possible from the cooling water cycle
- Zr and Hf are also associated with radioactive metals (uranium, polonium and thorium) which can be present in residues

Achieved environmental benefits

Energy saving

Applicability

The considered furnaces are in general all applicable to new and existing plants.

3.2.5 Steam systems

3.2.5.1 Distribution

Optimise steam distribution systems

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

The distribution system transports steam from the boiler to the various end-uses. Although distribution systems may appear to be passive, in reality, these systems regulate the delivery of steam and respond to changing temperatures and pressure requirements. Consequently, proper performance of the distribution system requires careful design practices and effective maintenance. The piping should be properly sized, supported, insulated, and configured with adequate flexibility. Pressure-regulating devices such as pressure-reducing valves and backpressure turbines should be configured to rovide a proper steam balance among the different steam headers. Additionally, the distribution system should be configured to allow adequate condensate drainage, which requires adequate drip leg capacity and proper steam trap selection.

Maintenance of the system is important, especially:

- to ensure that traps operate correctly
- that insulation is installed and maintained
- that l eaks are detected and dealt with sy stematically by planned maintenance. This is assisted by leaks being reported by operators and dealt with promptly. Leaks include air leaks on the suction side of pumps
- checking for and eliminating unused steam lines.

Achieved environmental benefits

Savings in energy from unnecessary losses.

Cross-media effects

No data submitted

Operational data

Steam piping transports steam from the boiler to the end-uses. Important characteristics of well designed steam system piping are that it is a dequately sized, configured, and supported. The installation of larger pipe diameters may be more expensive, but can create less pressure drop for a given flowrate. Additionally, larger pipe diameters help to reduce the noise associated with steam flow. As such, consideration should be given to the type of environment in which the steam piping will be located when selecting the pipe diameter. Important configuration issues are flexibility and drainage. With respect to flexibility, the piping (especially at equipment connections) needs to accommodate thermal reactions during system startups and shutdowns.

Additionally, piping should be equipped with as ufficient number of appropriately sized drip legs to promote effective condensate drainage. Additionally, the piping should be pitched properly to promote the drainage of condensate to these drip lines. Typically, these drainage points experience two different operating conditions, normal operation and startup; both load conditions should be considered at the initial design stage.

Applicability

All steam systems. Adequate sizing of pipework, minimising the number of tight bends, etc. Can best be dealt with at the design and installation stages (including significant repairs, changes and upgrading).

Economics

- proper sizing at the design stage has a good payback within the lifetime of the system
- maintenance measures (such as minimising leaks) also exhibit rapid payback.

Driving force for implementation

- cost savings
- health and safety

Example plants

Widely used

Isolate steam from unused lines

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

The di stribution system transports steam from the boiler to the various end-uses. Although distribution systems may appear to be passive, in reality, these systems regulate the delivery of steam and respond to changing temperatures and pressure requirements. Consequently, proper performance of the distribution system requires careful design practices and effective maintenance. The piping should be properly sized, supported, insulated, and configured with adequate flexibility. Pressure-regulating devices such as pressure-reducing valves and backpressure turbines should be configured to rovide a proper steam balance among the different steam headers. Additionally, the distribution system should be configured to allow adequate condensate drainage, which requires adequate drip leg capacity and proper steam trap selection.

Maintenance of the system is important, especially:

- to ensure that traps operate correctly

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- that insulation is installed and maintained
- that l eaks are detected and dealt with sy stematically by planned maintenance. This is assisted by leaks being reported by operators and dealt with promptly. Leaks include air leaks on the suction side of pumps
- checking for and eliminating unused steam lines.

Achieved environmental benefits

Minimises avoidable loss of steam and reduces energy loss from piping and equipment surfaces

Cross-media effects

No data submitted

Operational data

Steam piping transports steam from the boiler to the end-uses. Important characteristics of well designed steam system piping are that it is a dequately sized, configured, and supported. The installation of larger pipe diameters may be more expensive, but can create less pressure drop for a given flowrate. Additionally, larger pipe diameters help to reduce the noise associated with steam flow. As such, consideration should be given to the type of environment in which the steam piping will be located when selecting the pipe diameter. Important configuration issues are flexibility and drainage. With respect to flexibility, the piping (especially a te quipment connections) needs to accommodate thermal reactions during system startups and shutdowns.

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Applicability

All steam systems. Adequate sizing of pipework, minimising the number of tight bends, etc. Can best be dealt with at the design and installation stages (including significant repairs, changes and upgrading).

Economics

- proper sizing at the design stage has a good payback within the lifetime of the system
- maintenance measures (such as minimising leaks) also exhibit rapid payback.

Driving force for implementation

- cost savings
- health and safety

Example plants

Widely used

Insulation on steam pipes and condensate return pipes

BAT for steam systems is to optimise the energy efficiency

Brief technical description

Steam pipes and condensate return pipes that are not insulated are a constant source of heat loss which is easy to remedy. Insulating all heat surfaces is, in most cases, an easy measure to implement. In addition, localised damage to insulation can be readily repaired. Insulation might have been removed or not replaced during operation maintenance or repairs. Removable insulation covers for valves or other installations may be absent.

Wet or hardened insulation needs to be replaced. The cause of wet insulation can often be found in leaking pipes or tubes. The leaks should be repaired before the insulation is replaced.

Achieved environmental benefits

A reduction of energy losses through better insulation can also lead to a reduction in the use of water and the related savings on water treatment.

Cross-media effects

Increased use of insulating materials.

Operational data

No data submitted.

Applicability

As a baseline, all piping operating at temperatures above 200 °C and diameters of more than 200 mm should be insulated and good condition of this insulation should be checked on a periodic basis (e.g. prior to turnarounds via IR scans of piping systems). In addition, any surfaces that reach temperatures of higher than 50 ºC w here there is a risk of staff contact, should be insulated.

Economics

It can give rapid payback, but time depends on energy price, energy losses and insulation costs.

Driving force for implementation

Easy to achieve compared to other techniques. Health and safety.

Example plants

Widely used

Installation of removable insulating pads or valves and fittings

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

During maintenance operations, the insulation that covers pipes, valves, and fittings is often damaged or removed and not replaced.

The insulation of the different components in an installation often varies. In a modern boiler, the boiler itself is generally w ell insulated. On the other hand, the fittings, valves and other connections are usually not as well insulated. Re-usable and removable insulating pads a reavailable for surfaces that emit heat.

Achieved environmental benefits

Reduces energy loss from piping and equipment surfaces. The efficiency of this technique depends on the specific application, but the heat loss as a result of frequent breaches in insulation is often underestimated.

Proper installation of insulating covers may also reduce the noise.

Cross-media effects

None known

Operational data

Ensure that steam system piping, valves, fittings and vessels are well insulated.

Re-usable insulating pads are commonly used in industrial facilities for insulating flanges, valves, expansion joints, heat exchangers, pumps, turbines, tanks and other irregular surfaces. The pads are flexible and vibration resistant and can be used with equipment that is horizontally or vertically mounted or equipment that is difficult to access.

Applicability

Applicable for any high temperature piping or equipment that should be insulated to reduce heat loss, r educe e missions, and improve safety. As a general rule, any surface that reaches temperatures of greater than 50 °C where there is a risk of human contact should be insulated to protect personnel. Insulating pads can be easily removed for periodic inspection or maintenance, and replaced as needed. Insulating pads can also contain material to act as acoustic barriers to help control noise.

Special care must be taken when insulating steam traps. Different types of steam traps can only operate correctly if limited quantities of steam can condense or if a defined quantity of heat can be emitted (for instance, certain thermostatic and thermodynamic steam traps).

If theses team traps are over-insulated, this might impede their operation. It is therefore necessary to consult with the manufacturer or other expert before insulating.

Economics

It can give rapid payback, but time depends on energy, price and area to be insulated.

Driving force for implementation

- cost saving
- health and safety.

Example plants

Widely used

Implementation a control and repair programme for steam traps

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

Leaking steam traps lose significant quantities of steam, which result in large energy losses. Proper maintenance can reduce these losses in an efficient manner. In steam systems where the steam traps have not been inspected in the last three to five years, up to about 30 % of them may have failed allowing steam to escape. In systems with ar egularly scheduled maintenance programme, less than 5 % of the total number of traps should be leaking.

There are m any different types of steam traps and each type has its own characteristics and preconditions. Checks for escaping steam are based on acoustic, visual, electrical conductivity or thermal checks.

When replacing steam traps, changing to orifice venturi steam traps can be considered. Some studies suggest that under specific conditions, these traps result in lower steam losses and longer lifespans. However, the opinion between experts on the utilisation of orifice venturi steam traps is divided. In any case, this type of steam trap is a continuous leak, so it should only be used for very specific services (e.g. on reboilers, which always operate at a minimum 50 – 70% of their design duty).

Achieved environmental benefits

Reduces passage of live steam into the condensate system and promotes efficient operation of end-use heat transfer equipment.

Minimises avoidable loss of steam.

Operational data

Steam losses rapidly justify the setting up of an effective management and control system for all the steam traps in an installation.

Applicability

A programme to track down leaking steam traps and to determine whether steam traps need to be replaced is required for every steam system. Steam traps ften have a relatively short lifespan.

The frequency by which steam traps are checked depends on the size of the site, the rate of the steam flow, the operating pressure(s), the number and size of traps, and the age and condition of the system and the traps, as well as any existing planned maintenance. The cost be nefit of undertaking major inspections nd changing programmes needs to be balanced according to these factors. (Some sites may have 50 traps or fewer, all easily accessible, where others may have 10 000 traps.)

Some sources indicate that equipment with large steam traps (e.g. with steam flows of about 1 tonne of steam an hour or more), especially operating at high pressure, may be checked annually, and less critical ones on a rolling programme of 25 % of traps every year (i.e. every trap is checked at least once every 4 years). This is comparable to LDAR (leak detection and repair) programmes which are now being required in such installations by many governments.

In one example, w here trap maintenance was haphazard, up to 20 % of traps were de fective.

With annual follow-up, leaks can be reduced to 4 – 5 % of traps. If all traps were checked annually, there will be a slow decrease to about 3 % after 5 years (as older traps are replaced by newer models).

In all cases, when checking steam traps, it is good practice to also check by-pass valves. These are sometimes opened to avoid over-pressure in lines and damage (especially in tracer lines), where the steam trap is not able to evacuate all the condensate, and for operational reasons. It is generally more effective to rectify the original problem, make proper repairs, etc. (which may entail capital expenditure) than operate with poor energy efficiency in the system.

An automated control mechanism can be installed on each type of steam trap. Automatic steam trap controls are particularly applicable for:

- traps with high operating pressures, so any leakage rapidly accrues high energy losses
- traps whose operation is critical to operations and whose blockage will result in damage or production loss.

Economics

The costs for replacement are generally considerably less than the losses as a result of defective operation. Rapid payback depending on the scale of the leakage.

Driving force for implementation

- cost
- improved steam system efficiency.

Example plants

Widely used

3.2.5.2 Generation

Minimise boiler blowdown by improving water treatment.
Installation of automatic total dissolved solids control

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

Minimising the blowdown rate can substantially reduce energy losses as the temperature of the blowdown is directly related to that of the steam generated in the boiler.

As water vaporises in the boiler during steam generation, dissolved solids are left behind in the water, which in turn raises the concentration of dissolved solids in the boiler. The suspended solids may form sediments, which degrade heat transfer. Issolved solids promote foaming and carryover of boiler water into the steam.

In order to reduce the levels of suspended and total dissolved solids (TDS) to acceptable limits, two procedures are used, automatically or manually in either case:

- bottom blowdown is carried out to allow a good thermal exchange in the boiler. It is usually a manual procedure done for a few seconds every several hours
- surface or skimming blowdown is designed to remove the dissolved solids that concentrate near the liquid surface and it is often a continuous process.

The blowdown of salt residues to drain causes further losses accounting for between one and three per cent of the steam employed. On top of this, further costs may a lso be incurred for cooling the blowdown residue to the temperature prescribed by regulatory authorities.

In order to reduce the required amount of blowdown, there are several possibilities:

- the recovery of condensate. This condensate is already purified and thus does not contain any impurities, which will be concentrated inside the boiler. If half of the condensate can be recovered, the blowdown can be reduced by 50%

- depending on the quality of the feed-water, softeners, decarbonation and demineralisation might be required. Additionally, deaeration of the water and the addition of conditioning products are necessary. The level of blowdown is linked with the level of the more concentrated component present or added to the feed-water. In case of direct feed of the boiler, blowdown rates of 7 to 8% are possible; this can be reduced to 3% or less when water is pretreated
- the installation of automated blowdown control systems can also be considered, usually by monitoring conductivity. This can lead to an optimisation between reliability and energy loss. The blowdown rate will be controlled by the most concentrated component knowing the maximum concentration possible in the boiler (TAC max. of the boiler 38ºC; silica 130 mg/l; chloride <600 mg/l). For more details, see EN 12953 – 10
- flashing the blowdown at medium or low pressure is another way to valorise the energy which is available in the blowdown. This technique ap plies when the site has a steam network with pressures lower than the pressure at which steam is generated. This solution can be exergetically more favourable than just exchanging the heat in the blowdown via a heat exchanger.

Pressure degasification caused by vaporisation also results in further losses of between one and three per cent. CO_2 and oxygen are removed from the fresh water in the process (by applying slight excess pressure at a temperature of 103°C). This can be minimised by optimising the deaerator vent rate.

Achieved environmental benefits

Reduces the amount of total dissolved solids in the boiler water, which allows less blowdown and therefore less energy loss.

The amount of energy depends on the pressure in the boiler. The blowdown rate is expressed as a percentage of the total feed-water required. Thus, a 5 % blowdown rate means that 5 % of the boiler feed-water is lost through blowdown and the remaining 95 % is converted to steam. This immediately indicates that savings can be achieved by reducing blowdown frequency.

The amount of waste water will also be reduced if blowdown frequency is reduced. The or cooling water used for any cooling of this waste water will also be saved.

Cross-media effects

Discharges of treatment chemicals, chemicals used in deioniser regeneration, etc.

Operational data

The optimum blowdown rate is determined by various factors including the quality of the feed-water and the associated water treatment, the proportion of condensates re-used, the type of boiler and the operating conditions (flowrate, working pressure, type of fuel, etc.). Blowdown rates typically range between 4 and 8% of the amount of fresh water, but this can be as high as 10% if makeup water has a high content of solids. Blowdown rates for optimised boiler houses should be lower than 4%. Blowdown rates should be driven by the antifoaming and oxygen scavenger additives in the treated water rather than by dissolved salts.

Applicability

If blowdown is reduced below a critical level, the problems of foaming and scaling may return. The other measures in the description (recovery of condensate, water pre-treatment) may also be used to lower this critical value.

Insufficient blowdown may lead to a degradation of the installation. Excessive blowdown will result in a waste of energy.

A condensate return is usually standard in all cases except where steam is injected into the process. In this case, a reduction of blowdown by condensate return is not feasible.

Economics

Significant savings in energy, chemicals, feed-water and cooling can be achieved, and makes this viable in all cases.

Driving force for implementation

- economics
- plant reliability

Example plants

Widely used

Minimise boiler short cycling losses

BAT for steam systems is to optimise the energy efficiency

Brief technical description

Losses during short cycles occur every time a boiler is switched off for a short period of time.

The boiler cycle consists of a purge period, a post-purge, an idle period, a pre-purge and a return to firing. Part of the losses during the purge periods and idle period can be low in modern, well isolated boilers, but can increase rapidly in older boilers with inferior insulation.

Losses due to short term cycles for steam boilers can be magnified if the boilers can generate the required capacity in a very short period of time. This is the case if the installed capacity of the boiler is considerably larger than that generally needed. The steam demand for the process can change over time and should be reassessed periodically. Total steam demand may have been reduced through energy savings measures. Alternatively, boilers may have been installed with a view to a later expansion, which was never realised. A first point for attention is the type of boiler in the design phase of the installation. Fire tube boilers have considerably large thermal inertia, and considerable water content. They are equipped to deal with continuous steam demand and to meet large peak loads. Steam generators or water tube boilers in contrast can also deliver steam in larger capacities. Their relatively lower water content makes water pipe boilers more suitable for installations with strongly varying loads.

Short cycling can be avoided by installing multiple boilers with a smaller capacity instead of one boiler with a large capacity. As a result, both flexibility and reliability are increased. An automated control of the generation efficiency and of the marginal costs for steam generation in each boiler can direct a boiler management system. Thus, additional steam demand is provided by the boiler with the lowest marginal cost.

Another option is possible where there is a standby boiler. In this case, the boiler can be kept to temperature by circulating water from the other boiler directly through the standby boiler. This minimises the flue-gas losses for standby. The standby boiler should be well insulated and with a correct air valve for the burner.

Energy savings can be obtained by boiler isolation or boiler replacement.

Achieved environmental benefits

Optimises energy savings

Cross-media effects

None known

Operational data

Maintaining a boiler on standby at the right temperature will need a continuous supply of energy throughout the year, which coincides with approximately 8 % of the total capacity of the boiler.

The benefits of reliability and energy savings measures have to be determined.

Applicability

The negative impact of short cycling becomes clear when there is low usage of available boiler capacity for instance, less than 25%. In such cases, it is good practice to review whether to replace the boiler system.

Driving force for implementation

- cost savings
- better system performance

Optimise deaerator vent rate

BAT for steam systems is to optimise the energy efficiency

Brief technical description

Deaerators are mechanical devices that remove dissolved gases from boiler feed-water. Deaeration protects the steam system from the effects of corrosive gases. It accomplishes this by reducing the concentration of dissolved oxygen and carbon dioxide to a level where corrosion is minimised. A dissolved oxygen level of 5 parts per billion (ppb) or lower is needed to prevent corrosion in most high pressure (>13.79 barg) boilers. W hile oxygen concentrations of up to 43 ppb may be tolerated in low pressure boilers, equipment life is extended at little or no cost by limiting the oxygen concentration to 5 ppb. Dissolved carbon dioxide is essentially completely removed by the deaerator.

The design of an effective deaeration system depends upon the amount of gases to be removed and the final gas (O_2) concentration desired. This in turn depends upon the ratio of boiler feed-water makeup to returned condensate and the operating pressure of the deaerator.

Deaerators use steam to heat the water to the full saturation temperature corresponding to the steam pressure in the deaerator and to scrub out and carry away dissolved gases. Steam flow may be parallel, ross or counter to the water flow. The deaerator consists of a deaeration section, a storage tank, and a vent. In the deaeration section, steam bubbles through the water, both heating and agitating it. Steam is cooled by incoming water and condensed at the vent condenser. Non-condensable gases and some steam are released through the vent. However, this should be optimised to provide satisfactory stripping, with minimised steam loss.

Sudden increases in free or 'flash' steam can cause a spike in deaerator vessel pressure, resulting in re-oxygenation of the feed-water. A dedicated pressure regulating valve should be provided to maintain the deaerator at a constant pressure.

Achieved environmental benefits

Savings of unnecessary energy loss in steam venting.

Operational data

Steam provided to the deaerator provides physical stripping action and heats the mixture of returned condensate and boiler feed-water makeup to saturation temperature. Most of the steam will condense, but a small fraction (usually 5 to 14 %) must be vented to accommodate the stripping requirements. Normal design practice is to calculate the steam required for heating, and then make sure that the flow is sufficient for stripping as well. If the condensate return rate is high (>80 %) and the condensate pressure is high compared to the deaerator pressure, then very little steam is needed for heating, and provisions may be made for condensing the surplus flash steam.

The energy in the steam used for stripping may be recovered by condensing this steam and feeding it through a heat exchanger in the feed water stream entering the deaerator.

Deaerator steam requirements should be re-examined following the retrofit of any steam distribution system, condensate return, or heat recovery energy conservation measures.

Continuous dissolved oxygen monitoring devices can be installed to aid in identifying operating practices that result in poor oxygen removal.

The deaerator is designed to remove oxygen that is dissolved in the entering water, not in the entrained air. Sources of 'free air' include loose piping connections on the suction side of pumps and improper pump packing.

Applicability

Applicable to all sites with deaerators on steam systems. Optimisation is an ongoing maintenance measure.

Driving force for implementation

Cost savings in unnecessary venting of steam.

Example plants

Widely used

Preheat feed-water (including the use of economisers)

Preheat feed-water by using:

- waste heat, e.g. from a process
- economisers using combustion air
- deaerated feed-water to heat condensate
- condensing the steam used for stripping and heating the feed water to the deaerator via a heat exchanger

Brief technical description

The water from the deaerator being returned to the boiler generally has a temperature of approximately 105 °C. The water in the boiler at a higher pressure is at a higher temperature.

The steam boiler is fed with water to replace system losses and recycle condensate, etc. Heat recovery is possible by preheating the feed-water, thus reducing the steam boiler fuel requirements.

The preheating can be done in four ways:

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- using waste heat (e.g. from a process): feed-water can be preheated by available waste heat, e.g. using water/water heat exchangers
- using economisers: an economiser is a heat exchanger which reduces steam boiler fuel requirements by transferring heat from the lue-gas to the incoming feed-water
- using deaerated feed-water: in addition, the condensate can be preheated with deaerated feed-water before reaching the feed-water container. The feed-water from the condensate tank has a lower temperature than the deaerated feed-water from the feed-water container. Through a heat exchanger, the deaerated feed-water is cooled down further (the heat is transmitted to the feed-water from the condensate tank). As a result, the deaerated feed-water forwarded through the feed-water pump is cooler when it runs through the economiser. It thus increases its efficiency due to the larger difference in temperature and reduces the flue-gas temperature and flue-gas losses. Overall, this saves live steam, as the feed-water in the feed-water container is warmer and therefore less live steam is necessary for its deaeration
- installing a heat exchanger in the feed-water stream entering the deaerator and preheating this feed-water by condensing the steam used for stripping.

The overall efficiency can be increased through these measures, that is, less fuel energy input is required for a certain steam output.

Achieved environmental benefits

Recovers available heat from exhaust gases and transfers it back into the system by preheating feed-water.

The energy recovery which can be achieved depends on the temperature of the flue-gases (or that of the main process), the choice of surface and, to a large extent, on the steam pressure.

It is widely accepted that an economiser can increase steam production efficiency by 4%. The water supply needs to be controlled in order to achieve a continuous use of the economiser.

Cross-media effects

Possible disadvantages of these four possibilities are that more space is required and their availability for industrial facilities decreases with rising complexity.

Operational data

According to the manufacturer's specifications, economisers are commonly available with a rated output of 0.5 MW. Economisers designed with ribbed tubes are used for rated outputs of up to 2 MW, and equipped with finned tubes for outputs of over 2 MW. In the case of outputs over 2 MW, around 80 % of the large water tube bilers delivered are equipped with economisers, as they are even economical when operated in single shifts (at system loads of 60 - 70%).

The exhaust gas temperature typically exceeds the saturated steam temperature by around 70 °C.

The exhaust gas temperature for a standard industrial steam generator is about 180 °C. The lower limit of the flue-gas temperature is the flue-gases' acid dewpoint. The temperature depends on the fuel used and/or the fuel's sulphur content (and is around 160 °C for heavy fuel oil, 130 °C for light fuel oil, 100 °C for natural gas and 110 oC for solid waste). In boilers using heating oil, corrosion will occur more easily and part of the economiser has to be designed to be replaced. If the temperature of the exhaust gas drops significantly be ow the dewpoint, economisers might lead to corrosion, which usually occurs when there is significant sulphur content in the fuel.

Unless special steps are taken, sot builds up istacks below this temperature. As a consequence, economisers are frequently equipped with a bypass controller. This controller diverts a proportion of the exhaust gases around the economiser if the temperature of the gases in the stack drops too low.

Working on the principle that a 20 ºC reduction in the temperature of the exhaust gas increases efficiency by a round 1%, this means that, depending on the steam temperature and drop in temperature caused by the heat exchanger, efficiency can improve by up to 6 -7%. The temperature of the feed-water to be heated in the economiser is typically increased from 103 to around 140 °C.

Applicability

In some existing plants, feed-water preheating systems can only be integrated with difficulty. In practice, feed-water preheating with deaerated feed-water is applied only rarely.

In high output plants, feed-water preheating through an economiser is standard. In this context, however, it is possible to improve the efficiency of the economiser by up to 1% by increasing the temperature difference. Using waste heat from other processes is also feasible in most installations. There is also potential to use it in lower output plants.

Economics

The amount of energy savings potential by implementing economiser feed-water preheating depends on several conditions such as local system requirements, condition of the stack or flue-gas quality. The payback for a particular steam distribution system will depend on the operating hours, the actual fuel price and the location.

In practice, the possible savings from feed-water preheating amount to several per cent of the steam volume generated. Therefore, even in small boilers the energy savings can be in the range of several GWh per year. For example, with a 15 MW boiler, savings of roughly 5 GWh/yr, some EUR 60000/yr and about 1000 tonnes CO_2/yr can be attained. The savings are proportional to the size of the plant, which means that larger plants will see higher savings.

Boiler flue-gases are often rejected to the stack at temperatures of more than 100 to 150ºC higher than the temperature of the generated steam. Generally, boiler efficiency can be increased by 1% for every 40oC reduction in the flue-gas temperature. By recovering waste heat, an economiser can often reduce fuel requirements by 5 to 10% and pay for itself in less than 2 years.

Driving force for implementation

Reduction of energy costs and minimisation of CO_2 emissions.

Example plants

Widely used

Best practices

INSTALLING AN ECONOMISER

<u>Description</u>

A boiler generates 20 400 kg/h of 1 barg steam by burning natural gas. Condensate is returned to the boiler and mixed with makeup water to yield 47 °C feed-water. The stack temperature is measured a t 26 0 °C. The boiler operates 8400 h/ year a t a n e nergy c ost of USD 4.27/ GJ. By installing an economiser, the energy savings can be calculated as follows:

enthalpy values:

- for 1 barg saturated steam = 2780 kJ/kg
- for 47 °C feed-water = 198 kJ/kg.

Boiler thermal output = 20 400 kg/h x (2781 198) kJ/kg = 52.693 million kJ/h =14 640 kW.
The recoverable he at corresponding t o a s tack t emperature of 260 °C and a na tural gas-fired boiler load of 14 640 kW is read as~1350 kW.
Annual savings = 1350 kJ/s x USD 4.27/106 kJ x 8400 h/year x 3600 s/h = USD 174 318/year = EUR 197 800/year (USD 1 = EUR 1.1347, conversion date 1 January 2002).

PREHEATING FEED-WATER INCLUDING USING ECONOMISERS

Description

An economiser might be used for a gas-fired boiler with a production capacity of 5 t/h steam at 20 barg. The boiler produces steam with an output of 80 % and during 6500 hours per year. The gas will be purchased at a cost of EUR 5/GJ.

The economiser will be used to preheat the fresh boiler water before it flows to the degasser. Half of the condensate will be recovered, the other half will be supplemented with fresh water. This means the economiser can provide an improvement of 4.5%. The current use of the boiler is:

- [6500 h/yr x (2798.2 – 251.2) kJ/kg x 5 t/h x 5/GJ]/(0.80 x 1000) = EUR 517 359/yr

The annual operational cost is reduced with the installation of the economiser to:

- [6500 h/yr x (2798.2 – 251.2) kJ/kg x 5 t/h x 5/GJ]/(0.845 x 1000) = EUR 489 808/yr
- the savings thus amount to EUR 27 551/yr.

Prevention and removal of scale deposits on heat transfer surfaces (clean boiler heat transfer surfaces)

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Brief technical description

On generating boilers as well as in heat exchange tubes, a scale deposit might occur on heat transfer surfaces. This deposit occurs when soluble matter reacts in the boiler water to form a layer of material on the waterside of the boiler exchange tubes.

Scale creates a problem because it typically possesses at hermal conductivity with an order of magnitude less than the corresponding value for bare steel. When a deposit of a certain thickness and given composition is formed on the heat exchange surface, the heat transfer through surfaces is reduced as a function of the scale thickness. Even small deposits might thus serve as an effective heat insulator and consequently reduce heat transfer. The result is overheating of boiler tube metal, tube failures and loss of energy efficiency. By removing the deposit, operators can easily save on energy use and on the annual operating costs.

Fuel waste due to boiler scale may be 2 % for water-tube boilers and up to 5% in fire-tube boilers.

At boiler level, a regular removal of this scale deposit can produce substantial energy savings.

Achieved environmental benefits

Promotes effective heat transfer from the combustion gases to the steam

Reduced energy losses.

Cross-media effects

By treating feed-water to prevent scale deposits, the use of chemicals may increase.

Operational data

Removing the deposit will require the boiler to be out of use.

There are different ways of removing and preventing deposit formation:

- if pressure is reduced, the temperature will also reduce, which curtails scale deposits. This is one reason why steam pressure should be kept as low as possible
- the deposit can be removed during maintenance, both mechanically as well as with acid cleaning
- if scale formation returns too rapidly, the treatment of feed-water needs to be reviewed. A better purification or extra additives may be required.

An indirect indicator of scale or deposit formation is flue-gas temperature. If the flue-gas temperature rises (with boiler load and excess air held constant), the effect is likely to be due to the presence of scale.

Applicability

Whether scale deposits need to be removed can be ascertained by a simple visual inspection during maintenance. As a rule of thumb, maintenance several times per year may be effective for appliances at high pressure (50 bar). For appliances at low pressure (2 bar) annual maintenance is recommended.

It is possible to avoid deposits by improving the water quality (e.g. by switching to soft water or demineralised water). An acid treatment for deposit removal has to be carefully as sessed, particularly for high pressure steam boilers.

Economics

Depends on the method used, and other factors, such as raw feed-water chemistry, boiler type, etc. Payback in fuel savings, increased reliability of the steam system and increased operating life of the boiler system (giving savings on lost production time and capital costs) are all achievable.

Driving force for implementation

Increased reliability of the steam system and increased operating life of the boiler system.

Example plants

Widely used

3.2.5.3 Using coal and lignite

Double reheat and supercritical steam parameters

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

By applying ultra supercritical steam parameters to improve the efficiency, such as double reheat, and the most advanced high temperature materials, coal- and lignite-fired condensing power plants with a heat rate of 2.08 (48%) have been built using direct water cooling.

Achieved environmental benefits

Increased efficiency

Cross-media effects

None

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Operational data

Practised in new plants

Applicability

Possible in new plants

3.2.5.4 Using gaseous fuels

Expansion turbine to recover the energy content of pressurised gases

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

- Using expansion turbines to recover the energy content of the pressurised fuel gases
- Preheating the fuel gas by using waste heat from the boiler or gas turbine

Achieved environmental benefits

More efficient use of energy

Operational data

High

Applicability

Possible

3.3 Recovery

3.3.1 Combustion

Use of oxygen enrichment in combustion systems

The combustion/oxidation systems used in the production of non-ferrous metals often feature the use of tonnage oxygen directly or oxygen enrichment of air or in the furnace body. This enrichment is used to allow auto-thermal oxidation of sulphide based ores, to increase the capacity or melting rate of particular furnaces and to provide discrete oxygen rich areas in a furnace to allow complete combustion separately from a reducing zone.

Brief technical description

Oxygen can achieve the following improvements:

- The increase in the heat released in the furnace body allowing an increase in the capacity or melting rate. The ability to operate some processes auto-thermally and vary the extent of oxygen enrichment "on-line" to control the metallurgical process and prevent emissions.
- A significant reduction in the volume of process gases produced as the nitrogen content is reduced. This allows a significant reduction in the size of downstream ducts and abatement systems and prevents the loss of energy involved in heating the nitrogen.

- An increase in the concentration of sulphur dioxide (or other products) in the process gases allowing conversion and recovery processes to be more efficient without using special catalysts. The use of pure oxygen in a burner leads to a reduction of nitrogen partial pressure in the flame and therefore thermal NO_x formation may be reduced. This may not be the case with oxygen enrichment in or near the burner as the higher gas temperature may promote thermal NO_x formation. In the latter case oxygen can be added downstream from the burner to reduce this effect and maintain the improvement in melting rate.
- The production of tonnage oxygen on site is associated with the production of nitrogen gas separated from the air. This is used occasionally for inert gas requirements on site. Inert gases are used for abatement systems when pyrophoric materials are present (e.g. dry Cu concentrates), for de-gassing molten metal, for slag and dross cooling areas and fume control of tapping and pouring operations.
- Injection of oxygen at discrete points in a furnace downstream of the main burner allows temperature and oxidising conditions to be controlled in isolation from the main furnace operations. This allows the melting rate to be increased without an unacceptable increase in temperature. An example is the provision of an integral after-burning zone in a blast furnace.

Achieved environmental benefits

Energy saving

Example plants

Non Ferrous Metals Industries

3.3.2 Extracted air

Energy recovery from extracted air

There are limited options to substitute for PFOS and health and safety may be a particularly important factor. Where PFOS is used, it is BAT to minimise the use by controlling the air emissions of the hazardous fumes.

Brief technical description

The exhaust air is passed through a heat exchanger. The capital investment and operating costs are very high. Savings from energy recovery are only a fraction of these costs, a feasibility study prior to installation including economic considerations is essential to ensure sound investment.

Achieved environmental benefits

Energy recovery.

Operational data

Attention needs to be paid to energy efficiency in all installations using air extraction.

Applicability

This energy saving measure is limited to installations of large size and/or with large volumes of warm air being extracted.

Example plants

Surface treatment of metals plants

3.3.3 Non-ferrous metal

Heat and energy recovery

Energy recovery before or after abatement is applicable in the majority of cases but local circumstances are important, for example, where there is no outlet for the recovered energy. The BAT conclusions for energy recovery are:

- Production of steam and electricity from the heat raised in waste heat boilers.
- The use of the heat of reaction to smelt or roast concentrates or melt scrap metals in a converter.
- The use of hot process gases to dry feed materials.
- Pre-heating of a furnace charge using the energy content of furnace gases or hot gases from another source.
- The use of recuperative burners or the pre-heating of combustion air.
- The use as a fuel gas of CO produced.
- The heating of leach liquors from hot process gases or liquors.
- The use of plastic contents in some raw materials as a fuel, provided that good quality plastic cannot be recovered and VOCs and dioxins are not emitted.
- The use of low-mass refractories where practicable.

Brief technical description

Energy and heat recovery is practised extensively during the production and casting of non-ferrous metals. Pyrometallurgical processes are highly heat intensive and the process gases contain a lot of heat energy. As a consequence recuperative burners, heat exchangers and boilers are used to recover this heat. Steam or electricity can be generated for use on or off site and process or fuel gases can be pre-heated. The technique used to recover heat varies from site to site. It is governed by a number of factors such as the potential uses for heat and energy on or near the site, the scale of operation and the potential for gases or their constituents to foul or coat heat exchangers.

The following examples are typical and constitute techniques to consider for use in the processes to produce non-ferrous metals The techniques described can be incorporated into many existing processes:

- The hot gases produced during the smelting or roasting of sulphide ores are almost passed through steam raising boilers. The steam produced can be used to produce electricity and/or for heating requirements. An example of this in where a copper smelter produces 25% of its electrical requirements (10.5 MVA) from the steam produced by the waste heat boiler of a flash furnace. In addition to electricity generation, steam is used as process steam, in the concentrate dryer and residual waste heat is used to pre-heat the combustion air.
- Other pyrometallurgical processes are also strongly exothermic, particularly when oxygen enrichment of combustion air is used. Many processes use the excess heat that is produced during the smelting or conversion stages to melt secondary materials without the use of additional fuel. For example the heat given off in the Pierce-Smith converter is used to melt anode scrap. In this case the scrap material is used for process cooling and the additions are carefully controlled, this avoids the need for cooling the converter by

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other means at various times of the cycle. Many other converters can use scrap additions for cooling and those that are not able are subject to process developments to allow it.

- The use of oxygen enriched air or oxygen in the burners reduces energy consumption by allowing autogenic smelting or the complete combustion of carbonaceous material. Waste gas volumes are significantly reduced allowing smaller fans etc to be used.
- Furnace lining material can also influence the energy balance of a melting operation. In this case Low Mass refractories are reported to have a beneficial effect by reducing the thermal conductivity and storage in an installation. his factor must be balanced with the durability of the furnace lining and metal infiltration into the lining and may not be applicable in all cases.
- Separate drying of concentrates at low temperatures reduces the energy requirements. This is due to the energy required to super heat the steam within a smelter and the significant increase in the overall gas volume, which increases fan size.
- The production of sulphuric acid from the sulphur dioxide emitted from roasting and smelting stages is an exothermic process and involves a number of gas cooling stages. The heat generated in the gases during conversion and the heat contained in the acid produced can be used to generate steam and /or hot water.
- Heat is recovered by using the hot gases from melting stages to pre-heat the furnace charge. In a similar way the fuel gas and combustion air can be pre-heated or a recuperative burner used in the furnace. Thermal efficiency is improved in these cases. For example, nearly all cathode/copper scrap melting shaft furnaces are natural gas fired, the design offers an thermal efficiency (fuel utilisation) of 58% to 60%, depending on diameter and height of the furnace. Gas consumption is approximately 330 kWh/tonne of metal. The efficiency of a shaft furnace is high, principally because of charge preheating within the furnace. There can be sufficient residual heat in the off-gas to be recovered and re-used to heat combustion air and gas. The heat recovery arrangement requires the diversion of the furnace stack gases through a suitably sized heat exchanger, transfer fan and ductwork. The heat recovered is approximately 4% to 6% of the furnace fuel consumption.
- Cooling prior to a bag filter installation is an important technique as it provides temperature protection for the filter and allows a wider choice of fabric. It is sometimes possible to recover heat at this stage. For example in a typical arrangement used by a shaft furnace to melt metal, gases from the top of the furnace are ducted to the first of two heat exchangers that produces preheated furnace combustion air. The temperature of the gases after this heat exchanger can be between 200 and 450 oC. The second heat exchanger reduces the gas temperature to 130 oC before the bag filter. The heat exchangers are normally followed by a cyclone, which removes larger particles and acts as a spark arrester.
- Carbon monoxide produced in an electric or blast furnace is collected and burnt as a fuel for several different processes or to produce steam or other energy. Significant quantities of the gas can be produced and examples exist where a major proportion of the energy used by an installation is produced from the CO collected from an electric arc furnace installation. In other cases the CO formed in an electric furnace burns in the furnace and provides part of the heat required for the melting process.
- The re-circulation of contaminated waste gas back through an oxy-fuel burner has resulted in significant energy savings. The burner recovers the waste heat in the gas,

uses the energy content of the contaminants and removes them. Such a process can also reduce nitrogen oxides.

- The use of the heat content of process gases or steam to raise the temperature of leaching liquors is practised frequently. In some cases a portion of the gas flow can be diverted to a scrubber to recover heat into the water, which is then used for leaching purposes. The cooled gas is then returned to the main flow for further abatement.
- During the smelting of electronic scrap or battery scrap in metallurgical vessels the heat content of the plastic content is used to melt the metal content and other additional scrap and slag forming components.

The advantage of preheating the combustion air used in burners is well documented. If an air preheat of 400 °C is used there is an increase in flame temperature of 200 °C, while if the preheat is 500°C the flame temperature increases by 300 °C. This increase in flame temperature results in a higher melting efficiency and a reduction in energy consumption.

The alternative to preheating the combustion air is to preheat the material charged to the furnace. Theory shows that 8% energy savings can be obtained for every 100 °C preheat and in practice it is claimed that preheating to 400 °C leads to 25% energy savings while a preheat of 500 °C leads to a 30% energy savings. Pre-heating is practised in a variety processes for example the pre-heating of the furnace charge using the hot furnace off-gases during the production of ferro-chrome.

Heat and energy recovery is therefore an important factor in this industry and reflects the high proportion of costs that energy represents. Many techniques for energy recovery are relatively easy to retrofit but there are occasionally some problems of deposition of metal compounds in heat exchangers. Good design is based on a sound knowledge of the compounds released and their behaviour at various temperatures. Heat exchanger cleaning mechanisms are also used to maintain thermal efficiency.

Whilst these savings are examples of individual components of installations they are critically dependant upon the site and process specific conditions including economics.

Achieved environmental benefits

Energy recovery

Cross-media effects

The environmental cost of producing the energy required for processes and abatement is another important cross-media effect.

Example plants

Non Ferrous Metals Industries

Best practices

MINIMISATION OF THE EMISSIONS OF VOCS

Description

Use of low shear mixer for the solvent/aqueous mixture to optimise droplet size and minimise contact with air. Covered mixer and separate, covered settlement zone reduces emissions of VOC to air and carryover in aqueous phase. Use of low shear and variable speed pumping reduces energy consumption of the system.

Achieved environmental benefits

Prevention of VOC emissions

Cross-media effects

Positive effect by prevention of VOC emissions, reduction of energy use.

Operational data: Status of development

Concentration of VOC in occupational air < 5 ppm (< 30 mg/Nm^3 kerosene was used as solvent.

Applicability

All solvent extraction processes.

Economics

Not available but the process operates viably in several installations.

ENERGY BALANCE OF THE CONTIMELT PROCESS

Description

The energy balance of the Contimelt process, uses the rising, hot gases in a shaft furnace to pre-heat the charge.

Primary lead smelting

Brief technical description

The lead smelting processes to consider are:

- For mixed lead and zinc concentrates after sintering - the Imperial smelting furnace incorporating a splash condenser and New Jersey distillation column for zinc and cadmium purification and separation. Sintering stages should have good gas collection.
- For lead concentrates and some secondary raw materials - the blast furnace and the electric furnace after sintering or roasting or smelting of the concentrates. The direct smelting processes that use the Kaldo, ISA Smelt/Ausmelt, QSL or Kivcet processes.
- For mixed copper and lead concentrates - the electric furnace after roasting the concentrate in a fluidised bed roaster.

The abatement system to consider for primary smelting processes is dust removal and the removal of other metals followed by the recovery of sulphur dioxide. This is usually achieved by conversion to sulphuric acid in a double contact process with four or more passes, sometimes a caesium-doped catalyst is used. Conversion of part of the SO2 into liquid SO2 can be practised, with the balance being converted into sulphuric acid. The use of a single contact plant or WSA process is a technique to consider for weak sulphur dioxide gas streams.

The gases are cooled (with heat/energy recovery) and cleaned before conversion. A combination of coolers and hot electrostatic precipitators or a combination of scrubbers (radial or jet) and wet EPs are used.

Steel belt, up-draught or fully enclosed down-draft sintering processes are techniques to be considered. Steel belt sintering has several advantages for certain metal groups and can minimise gas volumes, reduce fugitive emissions and recover heat.

Achieved environmental benefits

Recovery of energy

Cross-media effects

Good gas collection and abatement systems and energy recovery applied to these processes offer advantages in energy efficiency, cost, throughput and ease of retrofitting.

Operational data

Gases from the sintering, roasting and direct smelting processes should be treated to remove dust and volatile metals, to recover heat or energy and the sulphur dioxide recovered or converted to sulphuric acid depending on local markets for sulphur dioxide.

Driving force for implementation

Processes to produce lead, zinc and cadmium (+ Sb, Bi, In, Ge, Ga, As, Se, Te)

Example plants

Non Ferrous Metals Industries

Secondary lead smelters - usage of an afterburner

The range of secondary materials and the variation in metal content and degree of contamination has lead to the development of a range of smelters for secondary materials. The blast furnace, the ISA Smelt furnace, the TBRC, the electric furnace and the rotary furnace are used for a wide range of materials are techniques to consider in the determination of BAT.

Brief technical description

Gases from secondary smelters contain some sulphur dioxide dependent on the source of the material. In particular the desulphurisation of battery paste may be needed unless paste is treated separately in a primary smelter or the sulphur can be fixed in a lead/iron matte or in the slag using a sodium based flux or other fluxes that can perform the same function. If the sulphur is not fixed a scrubber system may be needed. The gases can contain significant quantities of the more volatile metals such as antimony and cadmium etc. The abatement stages for secondary smelting involve gas cooling (with heat/energy recovery), coarse particle separation if necessary and fabric filtration. Sulphur dioxide removal and after-burning may be needed depending on the composition of the furnace gases (e.g. VOCs and dioxins). The collected dusts are recycled to recover metals.

In several instances there may be significant concentrations of organic material (including dioxins) depending on the raw material used. For example EAF dust will have a high dioxin content and whole battery feed (or incomplete separation) will provide a significant load of organic carbon and chlorinated plastic material. After burning or carbon adsorption and high efficiency dust removal may be needed in these cases.

Achieved environmental benefits

Recovery of energy from the off gases

Example plants

Non Ferrous Metals Industries

Best practices

USE OF AN AFTERBURNER

Description

Use of afterburner, cooling system and fabric filter to remove VOC, metals and dust from a furnace off gas. The example used is part of a lead acid battery recovery system that uses the pyrolysis products of the plastic content as fuel in the afterburner. The abatement system incorporates an afterburner to destroy VOCs.

Achieved environmental benefits

Destruction VOCs and recovery of energy from the off gases. Removal of dust and metals from the off gas allows the filter dust to be returned to the furnace.

Cross-media effects

Positive effect reducing emissions, use of organic content as fuel. Potentially negative by loss of plastic and energy cost of replacement.

Operational data: Status of development

The off-gas amounts to 65000 Nm^3/h. Emissions as dust, carbon monoxide and sulphur dioxide are monitored continuously. Calcium hydroxide additive can be injected into the off-gas channel, to prevent sulphur dioxide emissions peaks. The fabric filter dust has a lead content of up to 65 wt-% and can be recycled back to the smelting furnace as input material after chlorine removal. In order to achieve this, the filter dust is treated externally in a hydrometallurgical process to produce lead carbonate. The lead carbonate is returned and fed as raw material to the shaft furnace.

Applicability

Most furnaces with high organic loading.

Economics

Not available but data for a similar system is in the annex on costs. Several plants are operating viably.

Driving force for implementation

Processes to produce lead, zinc and cadmium (+ Sb, Bi, In, Ge, Ga, As, Se, Te)

3.3.4 Steam systems

Collect and return condensate to the boiler for re-use (optimise condensate recovery)

BAT for steam systems is to optimise the energy efficiency by using collect and return condensate to the boiler for re-use(optimise condensate recovery).

Brief technical description

Where heat is applied to a process via a heat exchanger, the steam surrenders energy as heat as it condenses to hot water. This water is lost, or (usually) collected and returned to the boiler. Re-using condensate has four objectives:

- re-using the energy contained in the hot condensate
    - saving the cost of the (raw) top-up water
    - saving the cost of boiler water treatment (the condensate has to be treated)
    - saving the cost of waste water discharge (where applicable).

Condensate is collected at atmospheric and negative pressures. The condensate may originate from steam in appliances at a much higher pressure.

Achieved environmental benefits

Recovers the thermal energy in the condensate and reduces the amount of makeup water added to the system, saving energy and chemicals treatment. Where this condensate is returned to atmospheric pressure, flash steam is spontaneously created. This can also be recovered.

The re-use of condensate also results in a reduction in chemicals for water treatment. The quantity of water used and discharged is also reduced.

Cross-media effects

No data submitted

Operational data

Deaeration is necessary in the case of negative pressure systems.

Applicability

The technique is not applicable in cases where the recovered condensate is polluted or if the condensate is not recoverable because the steam has been injected into a process.

With respect to new designs, a good practice is to segregate the condensates into potentially polluted a nd clean condensate streams. Clean condensates are those coming from sources which, in principle, will never be polluted (for instance, coming from reboilers where steam pressure is higher than process pressure, so that in the case of leaking tubes, steam goes into the process rather than process components into the steam side). Potentially polluted condensates are condensates which could be polluted in the case of an incident (e.g. tube rupture on reboilers where process-side pressure is higher than steam-side pressure). Clean condensates can be recovered without further precautions. Potentially polluted condensates can be recovered except in the case of pollution (e.g. leak from a reboiler) which is detected by online monitoring, e.g. TOC meter.

Economics

The recovery of condensate has significant benefits and should be considered in all applicable cases, except where the amount of condensate is low (e.g. where steam is added into the process).

Driving force for implementation

No data submitted

Example plants

Generally applied

Recover energy from boiler blowdown

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

Energy can be recovered from boiler blowdown by using a heat exchanger to preheat boiler make-up water. Any boiler with continuous blowdown exceeding 4% of the steam rate is a good candidate for the introduction of blowdown waste heat recovery. Larger energy savings occur with high pressure boilers.

Alternatively, flashing the blowdown at medium or low pressure is another way to valorise the energy which is available.

Achieved environmental benefits

Transfers the available energy in a blowdown stream back into the system, thereby reducing energy loss. By reducing the blowdown temperature, it is easier to comply with environmental regulations requiring waste water to be discharged below a certain temperature.

Cross-media effects

None known

Economics

The efficiency of such a technique usually results in costs recovery within a few years.

Driving force for implementation

Cost savings

Re-use of flash-steam

BAT for steam systems is to optimise the energy efficiency.

Brief technical description

Flash steam is formed when the condensate at high pressure is expanded. Once the condensate is at a lower pressure, part of the condensate will vaporise again and form flash steam. Flash steam contains both the purified water and a large part of the available energy, which is still present in the condensate.

Energy recovery can be achieved through heat exchange with make-up water. If the blowdown water is brought to a lower pressure in a flash tank beforehand, then steam will be formed at a lower pressure. This flash steam can be moved directly to the degasser and can thus be mixed with the fresh make-up water. The flash steam does not contain any dissolved salts and the steam represents a large portion of the energy in the blowdown.

Flash steam does, however, occupy a much larger volume than condensate. The return pipes must be able to deal with this without pressure increases. Otherwise, the resulting backpressure may hamper the proper functioning of steam traps and other components upstream.

In the boilerhouse, the flash steam, like the condensate, can be used to heat the fresh feed-water in the degasser. Other possibilities include the use of the flash steam for air heating.

Outside the boilerhouse, flash steam can be used to heat components to under 100 °C. In practice, there are steam uses at the pressure of 1 barg. Flash steam can thus be injected into these pipes. Flash steam can also be used to preheat air, etc.

Low pressure process steam requirements are usually met by throttling high pressure steam, but a portion of the process r equirements can be achieved at low cost by flashing high pressure condensate. Flashing is particularly attractive when it is not economically feasible to return the high pressure condensate to the boiler.

Achieved environmental benefits

Exploits the available energy in the returning condensate. The benefits are case dependent. At a pressure of 1 bar the condensate has a temperature of 100 °C and an enthalpy of 419 kJ/kg. If t he flash steam or the steam post evaporation is recovered, then the total energy content depends on the workload of the installation.

Cross-media effects

Where flash steam is produced from pressurised condensate, the temperature (and energy content) of the condensate returning to the boiler is lowered. Where an economiser is fitted, this has the potential advantage that the economiser can then recover more energy from the exhaust stack into the return/feed-water stream, and the boiler efficiency will improve. This is the most energy efficient combination. However, there must be a use for the low pressure (LP) steam from flashing, taking into account that LP steam (from all sources) can only be moved limited distances. In many cases (such as in refineries and hemical plants) there i sa surplus of LP steam, and there is often no use for the steam from flashing. In such cases, the best option is to return the condensate to the deaerator, as flashing steam to the atmosphere is a waste of energy.

To avoid condensate problems, condensate can be collected locally in a specific unit or activity and pumped back to the deaerator. The installation of either option depends on the cost-benefit of installing the necessary pipework and other equipment.

Operational data

Use high pressure condensate to make low pressure steam. The re-use of flash steam is possible in many cases, often for heating to under 100 °C. There are a number of possibilities.

Collection of the flash steam in the condensate pipes. During the lifespan of the installation, various components may be added into the same lines, and the condensate return pipe may become too small for the quantity of condensate to be recovered. In most cases, this condensate is r ecovered at atmospheric pressure, therefore the major part of the pipe is filled with flash steam. If there is an increase in condensate discharge, the pressure in these pipes may rise to over 1 barg. This can lead to problems upstream and may hamper the proper functioning of the steam traps, etc.

Flash steam can be discharged to a flash tank installed at a suitable point in the return pipe run. The flash steam can then be used for local preheating or heating at less than 100 °C. At the same time, the pressure in the condensate return pipe will be reduced to normal, avoiding the upgrading of the condensate return network.

When reviewing an existing network, an option to be considered is to return the condensate at a lower pressure. This will generate more flash steam and the temperature will also decrease to under 100 °C.

When using team, for example for heating at less than 100 °C, it is possible that the real pressure in the heating coil, following adjustment, decreases to under 1 bar. This may result in suction of the condensate into the coil, and flooding it. This can be a voided by recovering condensate at low pressure. More flash steam is generated as a result of the low pressure and more energy is ecovered from the condensate. The components working at these lower temperatures can be switched to an individual network. However, additional pumps need to be installed to maintain this low pressure and to remove any air leaking i nto the pipes from the outside.

Applicability

This technique applies when the site has a steam network with pressures lower than the pressure at which steam is generated. Then, re-using flash steam can be exergetically more favourable than just exchanging the heat in the blowdown via a heat exchanger.

In theory, any energy use at a lower temperature can be a possible use for flash steam instead of fresh steam and there will be a range of opportunities on investigation, although implementation is not always easy. It is widely applicable in the petrochemical industry.

Economics

The recovery of flash steam saves on fresh top-up water and its treatment, although the main cost savings are in energy. The recovery of flash steam leads to much greater energy savings than with the simple collection of liquid condensate.

Driving force for implementation

- cost saving
- use of low pressure steam.