ENVIRONMENT
AGENCY

Process Guidance

Iron and Steel Making Processes

Processes Subject to Integrated Pollution Control

IPC Guidance Note
Series 2 (S2)
Metal Industry Sector

S2 2.01:   Iron and Steel Making Processes

Prepared by the Environment Agency 1999

Enquiries about the contents of this publication should be made to:

Executive Summary

This IPC Guidance Note is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations[1] made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to processes involved in the production of iron and steel. It supersedes Her Majesty's Inspectorate of Pollution's Chief Inspector's Guidance Notes IPR 2/1 and IPR 2/3 published by HMSO in 1994. Reference is also made to techniques which will be relevant to the proposed Integrated Pollution and Prevention (IPPC) regulations.

It will be used by Agency staff, in conjunction with other relevant guidance[2], in assessing operators' proposals relating to their Authorisations under EPA90. This Note should be used in conjunction with separate guidance on monitoring[3] and dispersion modelling methodology[4], together with the assessment principles for determining best available techniques not entailing excessive cost (BATNEEC) and best practicable environmental option (BPEO)[5] to provide a framework for a consistent approach to the regulation of this class of processes regulated under IPC.

The processes covered by this Note are found in Section 2.1 of the Regulations[1]. Other related processes prescribed for IPC are covered by IPC Guidance Notes S2 1.01 (Combustion Processes), S2 1.06 (Carbonisation Processes) and S2 1.12 (Reheat or Heat Treatment Furnaces).

This Note provides brief descriptions of selected processes, best available techniques for pollution prevention and control, and the levels of release achievable by their use. A brief overview of some of the main economic influences on the iron and steel industry is also included.

Contents

3   Best available techniques for controlling releases

List of Figures

1 Introduction

1.1 Scope and status of Guidance Note

This IPC Guidance Note supersedes Chief Inspector's Guidance Notes IPR 2/1 and 2/3, issued by Her Majesty's Inspectorate of Pollution and published by HMSO in 1994. It is issued by the Environment Agency as one of a series of guidance notes for processes prescribed for Integrated Pollution Control (IPC) in Regulations[1] made under Section 2 of the Environmental Protection Act 1990 (EPA90). It is a guide on techniques and standards relevant to the processes covered by the Note.

It will be used by Agency staff, in conjunction with other relevant guidance[2] in assessing operators' proposals relating to their Authorisations under EPA90. This Note should be used together with separate guidance on monitoring[3], dispersion methodology[4], and assessment principles for determining best available techniques not entailing excessive cost (BATNEEC) and the best practicable environmental option (BPEO)[5] to provide a framework for a consistent approach to the regulation of this class of IPC process.

This Note, which represents the state of understanding at the time of writing, includes:

O   descriptions of the principal processes covered by the Note;

O   the prescribed substances and other substances that can cause harm and are most likely to be released from the processes;

O   guidance on best available techniques (BATs) for the control of releases;

O   benchmark achievable release levels;

e   other environmental standards relevant to the process;

O   information on the economic influences of the iron and steel industry and notional cost information on typical pollution control techniques; and

O   preliminary comment on issues that are likely to be relevant in the context of the introduction of Integrated Pollution Prevention and Control (IPPC) legislation.

An operator should keep up to date with the best available techniques relevant to each regulated process. This Note may not therefore be cited in an attempt to delay the introduction of improved available techniques and, except where specifically stated to the contrary, nothing contained herein should be considered prescriptive.

The concepts of BATNEEC and BPEO expressed in the EPA90 and associated Regulations are site-specific. This Note cannot take into account such site-specific considerations. Thus, while operators' proposals should be judged against the benchmark release levels given in this Note, the benchmarks should not be applied as uniform release limits. They are indicative, but not prescriptive, for new processes, which are expected to use modern techniques for the prevention, minimisation and abatement of releases.

Where other release levels are proposed for a specific case, comparing them and the benchmark release levels will indicate the degree of technical and economic justification required to be provided by the operator. Conditions in Authorisations that relate to permitted releases should ensure that all factors, including those which are site-specific, have been taken into account, and that the legal requirements to use BATNEEC and BPEO are fully satisfied.

Compliance with statutory environmental quality standards or objectives, and with agreed international obligations relating to permitted releases or environmental standards, is mandatory. No discretion is permitted without formal Environment Agency policy approval.

1.2 New processes

This Note provides guidance on the releases achievable by, and techniques applicable to, new processes.

1.3 Existing processes

Existing processes should have been upgraded taking into account the criteria included in Articles 4, 12 and 13 of the European Community Directive on the Combating of Air Pollution from Industrial Plants, known as the Air Framework Directive (84/360/EEC)[6]. Article 13 requires the following points to be taken into account:

O   the plant's technical characteristics;

O   its rate of utilisation and remaining life;

O   the nature and volume of polluting emissions from it; and

O   the desirability of not entailing excessive costs for the plant concerned, having regard in particular to the economic situation of undertakings belonging to the category in question.

Most existing processes should have completed their improvement programmes and, subject to the above points, should be achieving the benchmark release levels given in Section 4 or should be closely approaching them. Where this is not so, a timetable for further improving or decommissioning the process should be required.

1.4 Processes covered by this Note

This Note covers processes for the manufacture of iron and steel. These include primary and secondary iron and steel

making, casting and rolling processes.

Related processes excluded from this note, but covered by other IPC Guidance Notes, include:

- metallurgical coke production   (S2 1.06 Rev)

- reheat or heat treatment furnaces   (S2 1.12)

- combustion processes   (S2 1.01)

- ferrous foundry processes   (IPR 2/3)
                                          (S2 2.02)

The primary processes covered by this Note are sinter production, pelletising, blast furnace iron making, desulphurisation, basic oxygen and electric arc steel making, slag handling, casting and rolling. Sections on pickling, machine scarfing and oxygen lancing have also been included since, although they are not specifically prescribed in the Regulations, they are part of the steel making and rolling processes. (Note: acid pickling is also dealt with in IPC guidance Note S2 4.03.)

Where other prescribed processes are carried on in conjunction with the primary process, reference should be made to the relevant Chief Inspector's Guidance Notes (CIGNs) or IPC Guidance Notes (IPCGNs) and, where appropriate, the Secretary of State's Guidance for Local Authority Air Pollution Control of the ancillary processes, insofar as they have potential for releases to the environment.

In the context of this Note, the term 'process' includes the activities from receipt of raw materials via production of intermediates to dispatch of finished products.

1.5 Reference conditions used throughout this Note

The reference conditions of substances in releases to air from point sources are: temperature 273 K (0°C), pressure 101.3 kPa (1 atmosphere), no correction for water vapour or oxygen.

These reference conditions relate to the benchmark release levels given in this Note and care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. The Authorisation may employ different reference conditions if they are more suitable for the process in question.

For conversion of measured values to reference conditions, see Technical Guidance Note M2[3] for more information.

Releases may be expressed in terms of mg/m³, g/h, g/te (product) or g/MJ, as appropriate.

1.6 Standards and obligations

1.6.1 Air quality standards

Statutory Instrument 1989 No. 317, *Clean Air, The Air Quality Standards Regulations 1989*[7] gives limit values in air for the following substances:

- sulphur dioxide;

- suspended particulates;

- lead; and

- nitrogen dioxide.

Any emission from the process should not result in a breach of the appropriate air quality standard beyond the site boundary

1.6.2 Air quality objectives

Statutory Instrument 1997 No 3043, *Environmental Protection, The Air Quality Regulations 1997*[8] gives air quality objectives to be achieved by 2005 for:

- benzene;

- 1,3-butadiene;

- carbon monoxide;

- lead;

- nitrogen dioxide;

- PM_{10} (particulate < 10 (μm); and

- sulphur dioxide.

1.6.3 The UNECE Convention on Long-Range Transboundary Air Pollution

Under this Convention[9], a requirement further to reduce SO_2 emissions from all sources has been agreed. The second Sulphur Protocol (Oslo, 1994) obliges the UK to reduce SO_2 emissions by 80% (based on 1980 levels) by 2010. Negotiations are now under way which could lead to a requirement further to reduce emissions of NO_x and volatile organic compounds (VOCs).

1.6.4 Volatile organic compounds

Reducing Emissions of VOCs and Levels of Ground Level Ozone: A UK Strategy[10] was published by the Department of the Environment in October 1993. It sets out how the Government expects to meet its obligations under the UNECE VOCs Protocol to reduce its emissions by 30% (based on 1988 levels) by 1999, including the reductions projected for the major industrial sectors. A 45% reduction is forecast for the iron and steel sector.

An EC Directive on the *Limitation of Emissions of VOCs due to the Use of Organic Solvents in Certain Activities and Installations*[11] (the 'Solvents Directive') was adopted on 11 March 1999.

1.6.5 Water quality standards

Statutory Instrument (1989) No 2286[13], *The Surface Waters (Dangerous Substances Classification) Regulations* gives annual mean concentration limit values for certain substances in receiving waters.

1.6.6 Groundwater protection

The principles, powers and responsibilities for groundwater protection in England and Wales, together with the Agency's policies in this regard, are outlined in the Agency's document *Policy and Practice for the Protection of Groundwater (PPPG)*[13]. This outlines the concepts of vulnerability and risk and the likely acceptability from the Agency's viewpoint of certain activities within groundwater protection zones.

The EC Directive on the *Protection of Groundwater against Pollution Caused by Certain Dangerous Substances (80/68/EEC)* imposes an obligation on Member States to prevent the introduction into groundwater of List I substances and to limit the introduction of List II substances so as to prevent pollution of groundwater. List I and List II substances are described in Appendix 1 of the PPPG. The Directive is at present implemented by, *inter alia*:

- Part I of the Environmental Protection Act 1990, which requires Authorisation of IPC processes;

- Part II of that Act, which requires the management of controlled wastes;

- Regulation 15 of the Waste Management Licensing Regulations 1994, which requires the Agency to observe the provisions of the Groundwater Directive when issuing waste management licences; and

- Part II of the Water Resources Act 1991, which makes it an offence to discharge polluting matter to controlled waters, except in accordance with a Consent issued by the Agency.

The Government has introduced the new Groundwater Regulations 1998[14] to provide additional protection and complete the transposition of the Groundwater Directive. In addition to those processes controlled for IPC, these Regulations are intended to relate primarily to activities where List I and II substances are either deliberately discharged, or where there is a risk of discharge occurring, for example, as a result of spillages or leaks. The Regulations provide for prior investigation of the potential effects of discharges on groundwater; the Authorisation of disposal or tipping to land and Consents to discharge to groundwater; the serving of Notices by the Agency to prohibit activities or to apply conditions; the recognition of the importance of Codes of Practice; and provisions for cost recovery by the Agency. Two key aspects of the Groundwater Directive are the need for the following:

- **Prior investigation** of the potential effect on groundwater of on-site disposal activities or discharges to groundwater. Such investigations will vary from case to

case, but the Agency is likely to require a map of the proposed disposal area; a description of the underlying geology, hydrogeology and soil type, including the depth of saturated zone and quality of groundwater; the proximity of the site to any surface waters and abstraction points, and the relationship between ground- and surface waters; the composition and volume of waste to be disposed of; and the rate of planned disposal.

- **Requisite surveillance.** This will also vary from case to case, but will include monitoring of groundwater quality and ensuring the necessary precautions to prevent groundwater pollution are being undertaken.

The Directive states that, subject to certain conditions, the discharges of List I substances to groundwater may be authorised if the groundwater is 'permanently unsuitable for other uses'. Advice must be sought from the Agency where this is being considered as a justification for such discharges.

The Agency is obliged to take account of these requirements for IPC processes and, where there is an activity that represents a potential risk to groundwater, may request further investigations.

1.6.7 COMAH

The Control of Major Accident Hazards (COMAH) Regulations[15] are due to replace the current CIMAH regulations in the near future as the main mechanism to incorporate the requirements of the 'Seveso 2' Agreement into UK legislation. This will extend the scope of CIMAH, which placed a duty on sites to identify major accident hazards, and increases the emphasis of the environment.

Under the COMAH Regulations, the Environment Agency and the Health and Safety Executive are jointly responsible as the Competent Authority.

1.6.8 Waste Oil Directive 1975

Where waste oil is combusted as a fuel, Agency staff should ensure that the requirements of the Waste Oil Directive (75/439/EEC) are met.

1.6.9 Integrated Pollution Prevention and Control (IPPC)

European Directive 96/61/EC requires implementation of Integrated Pollution Prevention and Control (IPPC) in Member States. In the UK this is being implemented through the Pollution Prevention and Control Regulations. This will apply to a wide range of industry sectors, including all those covered by the IPC regime.

New and modified processes will require regulation under IPPC from 1 November 1999. Regulation for other existing processes will be phased in between this date and 2007.

IPPC sets out to achieve integrated prevention and control of pollution and, in doing so, to achieve a high level of protection of the environment taken as a whole. The regime has many

similarities to the IPC regime in requiring operators to take preventive measures to minimise pollution using best available techniques. However, there are a number of key differences, which include the following:

- The regime is concerned with installations, rather than processes.

- Energy efficiency and noise are covered.

- Accident prevention and mitigation are covered.

- An initial survey of the site to assess contamination of land and groundwater is required.

- Provision must be made for returning the site to a satisfactory state after closure.

Although this Note provides guidance on IPC, it is recognised that consideration may need to be given to IPPC, particularly in case of changes to existing processes. Some guidance has therefore also been included on energy and noise matters. Where this has been done, the text appears inside a box.

2 Processes, potential release routes and specialised techniques for controlling releases

Processes covered by this Note may be found in Section 2.1 of the Regulations[1].

The significant processes in this subsector are briefly described and the release routes of pollutants from them are identified. The control techniques, are considered to be BAT for the processes are either listed by reference to Section 3, which deals with general techniques, or, where they are special to the subsector concerned, they are specifically described below. The release levels achievable by the use of techniques are given in Section 4 for each group of related processes as benchmarks. These benchmarks should not be applied as uniform release limits.

A summary of releases to the environment commonly associated with the processes described are listed in Table 2.1 at the end of this section.

2.1 Process routes

Crude steel is produced by various process routes, which use as feedstocks molten pig iron, cold pig iron, directly reduced iron (DRI) or steel scrap. Molten pig iron is made in a blast furnace or by one of the newer smelting reduction processes (e.g. COREX process).

Molten pig iron ('hot metal') is normally used in conjunction with the basic oxygen process to produce crude steel but may also be used as part of the metallic charge to an electric arc furnace. The more usual charge material for an electric arc furnace is steel scrap, often supplemented with cold pig iron or DRI, which, in the case of overseas plants, may comprise over 80% of the furnace charge. DRI is occasionally used in the basic oxygen process as a scrap substitute and coolant. Hence, depending on the economic and technical conditions, hot metal, cold pig iron, steel scrap, DRI and products of direct smelting processes may be employed in various proportions as the feedstock in both the basic oxygen processes and the electric arc furnace.

The majority of crude steel made in the UK is produced by the blast furnace/basic oxygen steel making process route. (BF/BOS) Plants which operate this process route normally also include the associated upstream and downstream processes and are known as integrated plants. Electric arc furnace (EAF) based plants are referred to as non-integrated plants.

Because steel derived from DRI or HBI (hot briquetted iron) is only produced at a limited number of plants in the EU, none of which are in the UK, and as there are currently no smelting reduction processes of a commercial scale in the EU, these process routes are not described in detail, but are referred to as alternative technologies. Alternative or emerging technologies are referenced in this Note in order to provide guidance to Agency staff when considering applications for new or replacement plant. Further guidance on available technologies

and reference plants may be obtained from the European IPPC BAT Reference (BREF) Notes(16) concerning the production of iron and steel.

In an **integrated iron and steel works**, ores containing a high percentage of iron oxides, together with coke and fluxes, are charged to a blast furnace to produce molten iron, slag and blast furnace gas. The molten iron, which is known as pig iron or hot metal, contains about 4% carbon that has been absorbed from the coke. Much of this carbon must be removed, along with other undesirable elements, to produce steel, which typically contains less than 1% carbon. Alloying materials may then be added to give the steel the required properties.

An integrated iron and steel works comprises several separately identifiable processes, which are carried out as sequential operations on a single site, to convert iron ores and other raw materials into semi-finished steel products, such as slab, bloom or billet, and a variety of finished products, including plate, sections, bars, rod, hot and cold rolled sheet and coil, together with various types of coated flat products. The main processes can be categorised as follows:

- raw materials handling;
- ore preparation and agglomeration;
- coke making and by-product treatment;
- iron production;
- steel making;
- casting; and
- rolling and finishing.

A non-integrated EAF steel works is generally on a smaller scale than the integrated plant and the main processes can usually be split into the following categories:

- raw materials handling;
- steel making;
- casting; and
- rolling and finishing.

As explained in Section 1, this Note does not cover coke production, reheat furnaces or other combustion processes. The main process operations covered by the descriptions in Section 2.1 of the Regulations[1] and included herein are:

- loading, unloading and handling of bulk raw materials;
- blending and mixing of raw materials;

- sintering of iron ore;

- pelletising of iron ore;

- production of molten iron by the blast furnace route;

- ladle desulphurisation of molten iron;

- production and refining of steel using the basic oxygen process;

- production of steel using the electric arc process;

- ladle treatment of steel and other secondary steel making practices;

- treatment and handling of iron and steel making slags;

- ingot and continuous casting;

- machine scarfing;

- rolling and pickling; and

- skull burning.

These operations are described in detail in the BAT Review Reports on Pollution Control DoE/HMIP/RR/93/022 and 066.

An overview of the process routes indicating inputs and waste streams is given in Figure 2.1.

2.2 Raw material handling

The storage and flow of raw materials for a typical integrated steelworks is shown schematically in Figure 2.2.

Integrated steel works use iron ores from a variety of sources, which are mainly imported by bulk carrier. Where the ore terminal is not immediately adjacent to the steel works, road and/or rail transfer may be used. The materials are stored in the primary stockyard, together with coke, limestone and other fluxes. Coal is normally stored in a separate stockyard from other raw materials, since the inclusion of ore or flux in the charge to the coking oven could damage the oven refractory. The stockyards traditionally have permeable base surfaces, usually constituted from the material being stored. The stockpiles are formed and reclaimed using specially designed plant and the bulk materials are normally transferred by belt conveyors.

The main scrap storage areas for both integrated and non-integrated plants are traditionally outside in large uncovered compounds on unpaved ground. Some scrap sorting is carried out to reduce the risk of including hazardous or non-ferrous contaminants and the Applicant should take account of problems that may arise from the accidental inclusion of radioactive materials in externally supplied scrap metal. Scrap generated within the processes is recycled and where necessary may be cut into manageable sizes by oxygen lancing. The scrap

may be loaded into charging baskets or boxes in the scrapyard or may be transferred for short-term temporary storage in the scrap bay inside the melting shop. In the case of EAF shops, the scrap may be preheated prior to charging into the furnace.

Other raw materials, including fluxes in lump and powder form, carbon, alloying additions, deoxidants and refractories, are normally stored under cover. Following delivery, handling should be kept to a minimum and, where appropriate, dust extraction equipment should be used. Powdered materials may be stored in sealed silos and conveyed pneumatically or kept dry and·handled in sealed bags.

2.2.1 Potential release routes from raw material handling

Releases to air

Emissions to air can comprise fine particulate metallic or non-metallic matter.

Releases to water

If not controlled, deposition of the fine particulate matter, particularly on paved areas and roofs, may result in pick-up during heavy rainfall and run-off to sewer, surface water drains or watercourses.

There is potential risk of release of oil or chemicals from storage areas for purchased merchant scrap.

Releases to land

Potential risks of contamination of land can arise from storage of bulk materials and purchased scrap.

2.2.2 Control of releases arising from material handling

Control of releases to air

General techniques

In general terms, BAT for the prevention of dust releases during handling of bulk raw materials is the appropriate combination of:

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

- installing wind barriers or using natural terrain to provide shelter;

- controlling the moisture content of the material delivered;

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

- the use of dust suppression water sprays, with additives such as latex, where appropriate;

- rigorous maintenance standards for equipment;

Figure 2.1 *Overview of integrated works process routes*

PROCESS INPUTS		PROCESS WASTE MATERIAL

PROCESS INPUTS

Coal

□

Fluxes
Ore fines
Coke fines
Flue dust
Waste material

Pellets
Iron ore
Sinter
Coke
Limestone
Slag

Mg, Ca, C, CaO
Carrier Gas
Hot metal

Oxygen
Hot metal
Scrap
Lime
Fluorspar
Coke

Liquid steel
Alloys

Liquid steel
Alloys &
powders

Coke ovens

Coke   Fluxes   Iron ore

Return fines
Sinter plant

Injectants

Blast furnaces

Hot metal
desulphurisation

Transfer ladle   Torpedo ladle

Mixer

Basic oxygen furnace

CAS-OB   Ladle   Vacuum   Ladle stirring
          furnace   degasser   alloy injection

Continuous casting

Ingot or   Scarfing
casting

Rolling mills

PROCESS WASTE MATERIAL

Dust, CO, H_2S
Tar, Phenol
Ammonia liquor
SO_x, NO_x, Cyanide
BOD, Susp. Solids

Dust

Flue gases
Dust, SO_x, NO_x,
Sulphides
Fluorides

Flue gases
Sludge, Phenol
Dust, Sulphides
Cyanides, NO_x
H_2S, Slag

Flue dust
Fume
Slag

Fume
Slag

Sludge
Basic slag
Flue dust
(high iron content)
CO, Zn, pH
Fume

Fume
H_2, CO_2, CO
Mn, Zn, Fluoride
Slag

Scale
Slag
Scrap
Oil

SO_x, NO_x
Scale
Oil

7

Figure 2.2 *Typical integrated works materials flowchart*
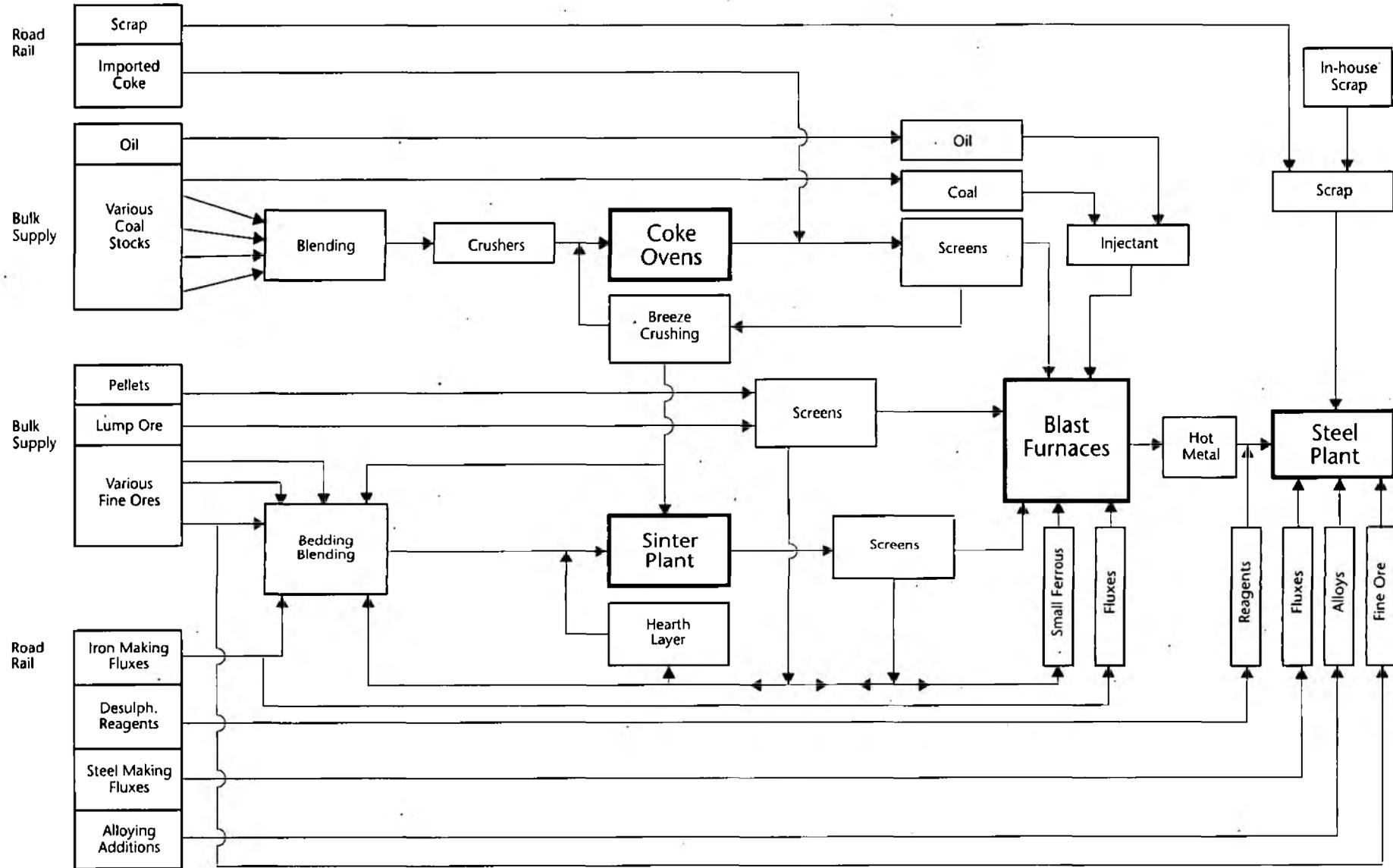
- high standards of housekeeping, in particular the cleaning and damping of roads;

- use of mobile and stationary vacuum cleaning equipment;

- the provision of enclosed, if not sealed, transportation systems; and

- dust suppression or dust extraction and bag filter cleaning plant to abate sources of dust generation.

The following are normally considered to be the BAT for material delivery, storage and reclamation activities:

- unloading hoppers for dusty materials should either be totally enclosed in a building equipped with filtered air extraction or the hoppers should be fitted with dust baffles and the unloading grids should be coupled to a dust extraction and cleaning system;

- dust suppression may be appropriate, if it can be demonstrated to be effective;

- storage bins should be fitted with filter units to control dust; and

- reclamation from bins should be via totally enclosed devices.

Where fuel and raw materials are delivered by sea, self-discharge ships, or enclosed continuous unloaders, will minimise dust releases. Where such facilities are not available, dust generated by grab-type ship unloaders can normally be controlled by ensuring adequate moisture content of the material as delivered, by minimising drop heights and by using water sprays or atomised mist at the mouth of the ship unloader hopper when necessary.

Conveying systems
Conveyor systems at remote parts of a site can be prone to poor maintenance and housekeeping. Agency staff should ensure that regular inspections are made and good maintenance records kept of all conveying systems. Totally enclosed conveying systems are now available.

However, as long as the provisions listed above are adhered to, traditional troughed belt conveying systems, that have good wind shielding are normally adequate for bulk handling in new or existing plant.

In order to minimise spillage, normal good engineering practice includes:

- conservatively selected conveyor belt widths and speeds;

- controlling sag between carrying idlers by correct selection of belt tension and idler pitch;

- anti-run-back devices fitted to inclined conveyors, both for safety reasons and to prevent spillage;

- belt motion indicators fitted and interlocked with the control system to ensure that belt slippage does not lead to material build up and spillages;

- correct operation of the head end scraper or other cleaning device to avoid material adhering to the belt return strand, leading to misalignment and spillage;

- chain speed indicators fitted on elevators, since at low speeds the buckets can become overfilled, leading to spillage - where dust is likely to cause a problem the best option is normally to enclose the elevator fully and extract dust to a bag filter; and

- minimising material drop heights at conveyor transfer points.

If the bulk materials are not dusty or provided the moisture content of the material is sufficient, dust generation at junction houses and other transfer points may not be a significant problem. Any dust generated can be captured by bag filter plants and recycled back to the conveying system. Where dust suppression spray systems are used, either instead of or in addition to extraction, chemical additives can be employed to reduce the surface tension, thereby enhancing the efficacy of the sprays.

Fine materials, such as powdered lime or pulverised coal, are normally transported by pneumatic conveying systems, with the discharge points, such as tankers and bunkers, being sealed and vented, as appropriate, through filters.

Powdered carbon and lime should be stored in sealed silos and conveyed pneumatically or stored and transferred in sealed bags. Lime and calcium carbide should be kept dry.

Miscellaneous techniques
Where the material being conveyed may lead to dust releases, transfer points, vibrating screens, crushers, hoppers and the like can be totally enclosed and extracted to a bag filter plant.

Central or local vacuum cleaning systems are preferable to washing down for removal of spillages, since the effects are restricted to one medium and recycling of spilt material is simplified.

In order to prevent the spread of dust, windbreaks can be created by natural terrain, banks of earth or planting of long grass and evergreen trees in open areas. This not only has aesthetic benefits, but such vegetation is able to capture and absorb dust without suffering long-term harm. The technique of hydro-seeding can rapidly establish grass or other appropriate vegetation on waste tips, slag heaps or other apparently infertile ground.

Points of access from the public highways should be minimised and wheel-cleaning equipment employed where necessary to prevent the carry-over of mud and dust on to public roads. Site

roads should be surfaced with slag, concrete or tarmac to minimise the generation of dust clouds and vehicles should be restricted to these designated routes by fences, ditches or banks of recycled slag.

Control of releases to water

Areas for handling and storage of purchased scrap are potential sources of contaminated effluent due to leaching of oil, chemicals and metal oxides by rain water run-off. Depending on the risk and extent of scrap contamination and the duration of storage, the scrap compound should have an impermeable surface with an appropriate drainage system, including an interceptor trap prior to discharge.

Agency staff should consider the arrangements made for monitoring the quality of the water collected and discharged from the storage areas for scrap and bulk materials and whether such discharges are in the vicinity of potentially vulnerable receptors.

Control of releases to land

Applicants should be requested to demonstrate that the potential risks of contamination of land by deposition of dust, leachate or run-off water are not significant.

2.2.3 Noise issues (IPPC)

Raw material operations may produce significant impact-derived noise, particularly where scrap handling takes place in the open air. Where practicable, the height from which scrap is dropped by cranes should be minimised.

Another common source of noise is the movement and operation of heavy mobile equipment. Such vehicles and equipment should comply with the appropriate standards.

2.3 Blending/mixing

This activity only refers to the integrated steel making process.

Iron ore is stocked in the primary stockyard. Blending is carried out in the secondary stockyard and is necessary to maintain a consistent quality of feedstock for the sinter plant and blast furnaces. Direct charge materials for the blast furnaces (e.g. rubble and pellets) are recovered from the primary yard and screened, with the oversize being conveyed to the blast furnace bunkers and the undersize to the blended fine ore bed for incorporation in the sinter mix.

2.3.1 Potential release routes from blending/mixing

Releases to air

Fine particulate matter may be released to air if not controlled effectively.

Releases to water

Run-off of rain water from all open areas, but in particular

from coal and raw materials stocking areas, will contain suspended solids.

2.3.2 Control of releases arising from blending/mixing

Control of releases to air

As for raw materials handling (Section 2.2.2).

Control of releases to water

As for raw materials handling (Section 2.2.2).

Control of releases to land

Run-off water should be intercepted and the suspended solids removed by settlement or other techniques. Since the solubility of the chemical species in the majority of the coal and raw materials is small, base linings and leachate capture from stockpiles have not been traditionally used. However, as a precaution, Agency staff should obtain confirmation that leachate and rain water run-off from outdoor stockpiles of bulk materials are not potential sources of unacceptable groundwater pollution.

2.4 Sintering

The sinter plant is used to process iron ore fines and various recycled materials, which are too small to be fed directly into the blast furnace. The sintering process agglomerates the fine material into a clinker-like aggregate, with a size range that is acceptable to the blast furnace. The use of sinter in the blast furnace improves the permeability, homogeneity and chemical composition of the charge, thereby increasing the productivity and consistency of operation and improving the energy efficiency.

In modern sinter plants (see Figure 2.3) the iron ore fines, fluxes and revert materials are deposited in predetermined and weighed proportions on to a fines bed in a chevron pattern, to give the required chemical composition for the sinter feed. Using special machinery and conveyors, the blended bed is reclaimed and transferred to bunkers. Weighed amounts of the blended fines, recirculated sinter fines, crushed coke breeze (to assist ignition and the propagation of the flame front during the sintering process) and burned lime (to improve micro-pelletisation) are passed to a mixing and balling drum (where water is added) to optimise the permeability of the sintering mix.

Sintering is carried out on a continuous travelling grate ('the strand') consisting of a number of individual pallets. These pallets have heat-resistant side plates, with heat-resistant grate bars spanning the strand. The pallets travel over a series of suction chambers (wind boxes), incorporating butterfly valves, so that the volume of air drawn by the main sinter fan(s) can be varied along the length of the strand. This allows the speed at which the flame front is pulled through the sinter mix to be controlled. Beneath each wind box is a dust hopper, which collects the coarse dust drawn through the pallets. After collection, this material is recirculated.

The grate bars on the pallets are protected from the peak temperature of the flame front by a 3-4 cm deep layer of closely sized (15-25 mm), recirculated sinter (hearth layer), which does not contain coke breeze. The hearth layer also helps to reduce the quantity of fine material drawn through the pallets by the suction of the main fan(s).

A roll feeder places the sinter mix from the conditioning drums on to the hearth layer of the sinter strand to a controlled depth, dependent on fan power and plant production required. The surface of the bed is ignited under a gas- or oil-fired radiant-hood ignition furnace, producing a flame front, which is drawn downwards through the mix by the suction of the main fan(s) as the bed travels along the strand. Bed depth, strand speed and fan suction are normally controlled to finish sintering (i.e. achieve burn-through) at the penultimate wind box. The agglomerated sinter leaving the strand is broken on a spiked crusher and fed to a circular updraught deep bed cooler. The sinter is discharged from the cooler at about 60°C and crushed to a size range of 5 mm to 50 mm. The product is then screened to remove the undersize sinter and the fraction used as hearth layer, before conveying the oversize material to the blast furnace bunkers.

2.4.1 Potential release routes from sintering

Releases to air

The emissions to air from the sinter plant can represent a major proportion of the overall authorised emissions from an integrated steel works. (See Table 3.2 of Section 3.)

Particulate matter (heavy metal and iron oxides), sulphur oxides, nitrogen oxides, hydrogen chloride, hydrogen fluoride, carbon monoxide and carbon dioxide are usually released. Additionally, trace amounts of organohalogen compounds such as polychlorinated dibenzo dioxins/furans (PCDD/Fs), polyaromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) may be emitted at the exhaust stack.

2.4.2 Control of releases arising from sintering

The quality of raw materials can significantly affect the releases from the sinter plant. Specifically, emissions of SO_x and organohalogens can be controlled by selective purchasing of raw materials and fuel.

Control of releases to air

Two gas cleaning systems are normally provided on sinter plants, one for the flue gases and one for the dust extraction systems. Where practicable, the non-metallic dust, the iron oxide dust and the heavy-metal-containing dust and fume should be separated, in order to aid recycling. The flue gas abatement system also has to contend with SO_x emissions and high humidity.

Dedusting of the off-gases from the crushing and screening operations is also commonplace and usually involves electrostatic precipitation techniques.

Primary flue gas releases
A dry cyclone on its own would not be adequate for cleaning

Figure 2.3 *Sinter plant showing main emission points*

Iron ore bedding system
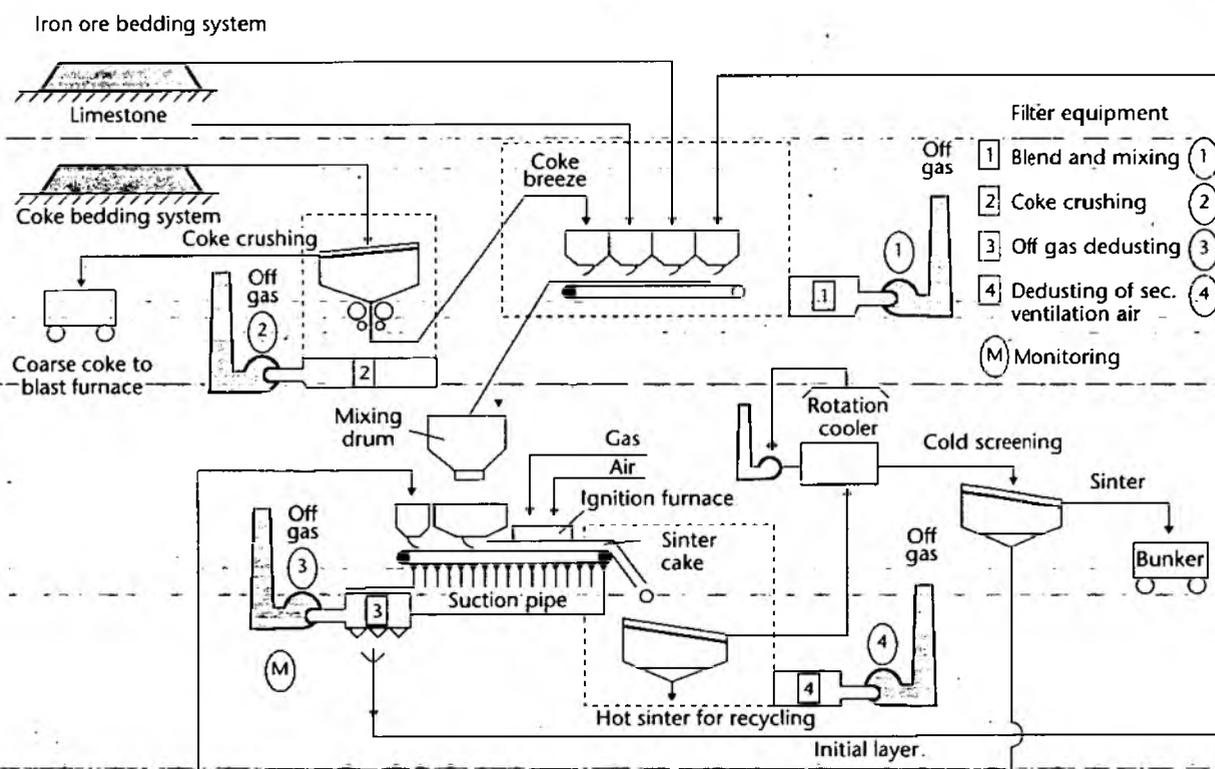
of the primary flue gases. Bag filters have not traditionally been used for primary fume cleaning because of the abrasive nature of the dust and frequently occurring high temperatures. Wet scrubbing systems with an appropriately designed water treatment plant could achieve the abatement objectives but tend to be expensive and introduce the risk of water pollution.

Hence, electrostatic precipitators (EPs) are almost universally used for primary flue gas treatment. However, recent developments at some plants have reportedly successfully introduced either fine wet scrubbing systems or bag filters, as a final fume cleaning stage after the EP, with good results. The EPs collect the dry dust and achieve the required dust separation, with coarse dust falling out in the first stages and heavy metals and fine fume in the later stages of the precipitator. Problems caused by the deposition of alkali metal chlorides on the plates can be partially overcome by careful selection of raw materials and reverts. Newly developed techniques are available for on-line cleaning of deposits from the electrodes, which enable the precipitator plant to be operated at a higher level of efficiency, although increased maintenance levels will be required due to the additional moving parts. Other overseas developments, of which Agency staff should be aware are the return of a proportion of the off-gases to the ignition hood, which has the effect of reducing the dust emissions and minimising the gases released to the atmosphere. Some overseas sinter plants are fitted with flue gas desulphurisation equipment. However, increased energy consumption and BPEO considerations associated with solid and/or liquid waste streams should be taken into account when considering such abatement techniques.

The performance of an electrostatic precipitator (EP) depends largely on the resistivity of the dust particles. Operation of the plant with a high sinter basicity can result in an increase in resistivity and a fall-off in the efficiency of the EP. Low dew point and high exhaust gas temperature are also detrimental to performance. EP performance may be enhanced by determining and applying the optimum degree of moisture or SO_3 preconditioning of the exhaust gases for the particular combination of material and abatement plant. Other enhancements include the use of higher, or pulsed, voltages. Careful attention must be paid to maintenance, corrosion, rapping and electrical performance. Older EPs may benefit from an assessment of the airflows and improved baffling.

Recycling oily mill scale to the sinter plant can cause 'glow fires' on EP electrodes and should therefore be controlled. Furthermore, recycling of oily scale and sludges can result in the generation of dioxins in the sinter plant off-gases; due to contamination with chlorinated hydrocarbons. Agency staff should therefore ensure that provisions have been made to control the release levels of such species.

For an existing plant, even with well run EPs, it is unlikely that the releases will be less than 70 to 100 mg/m³, which is still visible and, in the longer term, unacceptable for such a near-continuous operation. Since considerable emissions of dust can occur during start-up and shut-down, the number of stoppages, particularly unplanned ones, should be minimised.

Since much of the sulphur ends up in the sinter, it is also theoretically possible to control the SO_x by recycling the combustion gases to the combustion hood, thereby absorbing more of the sulphur into the sinter. However, this then passes to the blast furnace, where it will be released in a less acceptable way during slagging, unless the slag is granulated. Agency staff should be satisfied that authorised process operators address this issue.

NO_x releases from sinter plants can be significant and techniques to reduce these emissions should be considered. This may include adopting low NO_x burners or implementing waste gas recirculation measures, where practicable to do so.

Fluorine emissions primarily depend on the fluorine content of the ore used and the basicity of the sinter feed. Increased basicity of the feed has led to significantly lower fluorine emissions.

High hydrocarbon emissions mainly occur as a result of processing oily residues, such as mill scale and sludge. Most steel works try to keep the oil content of the feed material below 0.1%, in order to avoid problems at the EP and to minimise emissions; although the addition of slaked lime can reportedly reduce emissions of hydrocarbons. These additions can also reduce emissions of acid gases.

Trace amounts of PCDD/F, PCB and PAH emissions have all recently been linked to emissions from sinter plants. Although data are scarce, non-steady-state operation, together with oils and other hydrocarbons in the sinter feed, appear to be one of the contributory causes. Agency staff should ensure that operators seek to minimise emissions through appropriate control of the raw material and the process operation. Effective dedusting equipment and the use of gas recirculation measures will also minimise these emissions. Further details of such techniques are available in the IPPC BREF Note for iron and steel processes[16].

Secondary atmospheric releases
For cleaning of secondary releases to air from the cooler and other parts of the sinter plant, the EP has been traditionally considered to be the most appropriate abatement plant, for similar reasons to the primary flue gas. Some existing plants can achieve particulate emission levels of around 30 mg/m³ and these levels are unlikely to be significantly improved upon.

A system that is used in some overseas plants is 'on strand cooling'. With this system, the sinter strand is extended beyond the point at which sintering finishes and an updraught current of cold air is blown through the sintered bed on this additional length of strand. This preheated air is then ducted to the earlier wind boxes of the strand, where sintering is taking place. The system is designed to avoid the need for a separate cooler and at the same time to reduce the energy requirement. A similar system is employed in straight grate pelletising plants (see Section 2.5).

Control of releases to water

The cooling water system in a sinter plant is normally recirculated in a closed-loop circuit, which minimises water

losses. In plants where wet waste gas treatment is used, the effluent should be treated by precipitation and neutralisation. All discharges from the site must comply with the authorised conditions.

Control of releases to land

Most solid wastes arising from sinter plant operations are recycled within the plant. However, where sludge is produced by wet gas cleaning systems, this is usually disposed of by landfill.

2.4.3 Energy conservation measures (IPPC)

Where possible and economic, the waste heat energy of the flue gas should be recovered to preheat the process air for sintering, as in the 'on strand cooling design'.

Sensible heat from the exhaust gas of the cooler can potentially be used in boilers, to preheat combustion air or to preheat the 'green' feed.

2.4.4 Noise issues (IPPC)

The dominant noise sources from sinter plant activities are generally regarded as the sinter cooler and strand dedusting. New plant should be selected to comply with the appropriate noise regulations. Where necessary, noise abatement measures should be applied to existing plants.

2.5 Pelletising

From an environmental viewpoint, a pelletising plant is similar to a sinter plant, although, because of the process route, less dust is created. At present, there are no pellet plants at UK steel works and it is unlikely that any will be built in the foreseeable future.

Iron oxide pellets are small indurated balls of iron ore, typically 10-16 mm-diameter. The pellets are made from iron ore concentrates that are considered to be below the optimum size for sintering and will form readily into a 'green ball'. The size range of the ore is normally the result of beneficiation at the mine to improve the iron content of the ore and to remove undesirable impurities.

Where the concentrates delivered are not suitable for pelletising, grinding may be carried out at the pelletising plant. The pelletising plant typically consists of dewatering and/or drying, grinding, pre-wetting, balling, induration, cooling and screening processes.

The induration kilns may be of the travelling-grate design the grate-kiln or the vertical-shaft type. The travelling-grate design is derived from the sinter plant and consists of a series of heat-resistant pallets travelling over a series of wind boxes, where drying, preheating, induration and cooling are sequentially effected by updraught and downdraught airflows.

In the grate-kiln design, drying and preheating are carried out on a moving straight grate, induration takes place in a rotary kiln and cooling on a circular cooler. Shaft kilns are not very common and, although more energy efficient than the other designs, are more difficult to control and are unsuited to pelletising haematite materials.

The pelletising plant will typically receive high iron content ore concentrates, which will, if necessary, be dried and ground to a fine powder in a ball mill. Additives such as pellet fines, mill scale, steel plant slag, limestone and binders (such as olivine, slaked lime and bentonite) will also be dry ground and proportioned on to the concentrate gathering conveyor. The blend will then be homogenised in a mixer.

Production of a 'green' pellet takes place in a balling drum or on an inclined rotating disc ('flying saucer'). Under- and oversized pellets are screened off and recirculated. The green pellets are then dried, heated and indurated to provide mechanical strength, before cooling and screening for despatch.

The first section of the process is devoted to drying and preheating the green pellets to avoid disintegration during firing. This is followed by the indurating section, where a gas- or oil-fired furnace is used. The last part of the process is the cooling section, where the pellets are cooled and the hot air recirculated to the earlier part of the process. The recirculation of hot gases is essential to maintain the energy efficiency of the process. After cooling, broken and undersize pellets are removed by screening. Undersize or broken pellets are crushed and recycled, while the oversize pellets are forwarded to the blast furnace.

2.5.1 Potential release routes from pelletising

Releases to air

The main releases to air from pelletising operations are:

O particulate matter from grinding;

O NO_x emissions from induration and drying;

O SO_2 emissions from induration; and

O HCl and HF emissions from induration.

Releases to water

Where wet waste gas treatment processes are used, waste water containing suspended solids will be generated.

Releases to land

Particulate matter is collected at the gas cleaning plants and also arises from the screening and handling operations.

2.5.2 Control of releases arising from pelletising

Control of releases to air

Emissions of particulate matter, which mainly consist of iron oxide, can be abated using electrostatic precipitators, bag filters or wet scrubbing techniques. Dry abatement techniques are preferred.

NO_x emissions are most effectively controlled by reducing the peak temperature in the burners and restricting the quantity of excess oxygen in the combustion air. To date, there are no de-NO_x systems installed at any commercial pelletising plant.

Emissions of SO_x depend on the level of sulphur in the ore, additives and fuel used. The use of low-sulphur raw materials and the use of abatement techniques should be considered.

HF and HCl emissions originate from fluorine and chlorine compounds contained in the raw materials. This should be minimised or abated, as necessary.

Control of releases to water

Whenever a scrubber is used to remove contaminants, a waste-water flow is created, which is treated in a recirculating water system. This water system may require a large bleed due to the presence of HF.

Control of releases to land

All solid wastes created at the pelletising plant can be recycled in the iron and steel making process.

2.5.3 Energy conservation measures (IPPC)

Sensible heat from the off gas is normally re-used efficiently to preheat combustion air for the induration process or used in the drying operations. The economic viability of the travelling-grate and the grate-kiln processes are dependent on the energy efficiency obtained from the recirculation of the hot gases.

2.6 Blast furnace iron making

The function of the blast furnace is to reduce solid iron oxides to molten iron, principally by carbon monoxide reduction. The blast furnace is the major source of molten pig iron ('hot metal') in the world and individual furnaces are capable of producing in excess of 10,000 t/day.

The blast furnace is a tall, shaft-type furnace, with a vertical stack over a crucible-shaped hearth (Figure 2.4). It is completely lined with refractories and extensively equipped with copper or cast iron inserts, which are cooled either by forced water circulation or by evaporative steam cooling. Near-boiler-quality water is used for cooling and the closed circuit cooling systems are usually equipped with air-cooled heat exchangers. The outside of the hearth or well of the furnace may be cooled by cast iron coolers or external sprays and the underside of the hearth by forced-draught air or water cooling.

The iron-bearing feedstock materials and the coke are charged through a gas-tight, double valve system into the top of the furnace and pressurised air heated to 900-1350°C ('hot blast') is blown in through water-cooled nozzles ('tuyeres') round the periphery of the furnace just above the hearth. Coal (pulverised or granulated), oil or natural gas, together with oxygen, may be injected with the hot blast to reduce the consumption of coke and to increase the output of the furnace. The hot blast blown into the furnace through the tuyeres is heated in regenerative refractory-filled 'hot blast stoves', which are fired with blast furnace gas (usually enriched to achieve high blast temperatures).

The furnace may be equipped for 'high top pressure' (HTP) operation of 1 to 2 atmospheres, to further improve the efficiency and output. As the gases exit the top of the furnace, this pressure may be utilised to generate electricity via a back-pressure turbine ('expander'). The waste gas is cleaned in a dry cyclone-type dust catcher to remove coarse material and in a two-stage venturi scrubber, which regulates the furnace HTP.

A pressure relief system, often referred to as the 'bleeder valves', is used to limit the effects of excess pressure excursions due to occasional slippages of the burden inside the furnace.

The iron-bearing materials (rubble ore, sinter and/or pellets), coke and perhaps some fluxes, are normally supplied by belt conveyor to the blast furnace bunkers. These raw materials are screened and weighed out of the bunkers in the required proportions and charged in a pre-planned order into the top of the blast furnace. Whilst transport of the burden to the top of more modern furnaces is usually by inclined belt conveyor, older furnaces may still employ a twin skip hoist system. The material is charged more or less continuously into the top of the furnace through the gas seal arrangement, which in many modern furnaces is pressurised (purged) with nitrogen.

Combustion of the coke in the furnace charge provides the heat necessary to melt the iron and slag and the gas produced (mainly carbon monoxide) reduces the iron oxides to metallic iron. The top gas leaving the blast furnace contains carbon monoxide, carbon dioxide, nitrogen and hydrogen and, after cleaning and cooling, the gas is used throughout the works as a fuel. Gas cleaning is usually a two-stage process, with the coarse grit being removed in a cyclone, followed by a wet scrubber, which removes the fine particulates, sulphur compounds, ammonia and cyanide.

The reduced molten iron and slag percolate through the unburned coke in the lower part of the furnace and accumulate in the furnace hearth, from where they are periodically tapped off via refractory-lined channels or 'runners'. The hot metal is discharged into transfer ladles or 'torpedo vessels' for transport to the steel plant, while the slag may be sent to slag cooling pits, pelletisers or a granulation plant.

Figure 2.4 *Typical blast furnace*
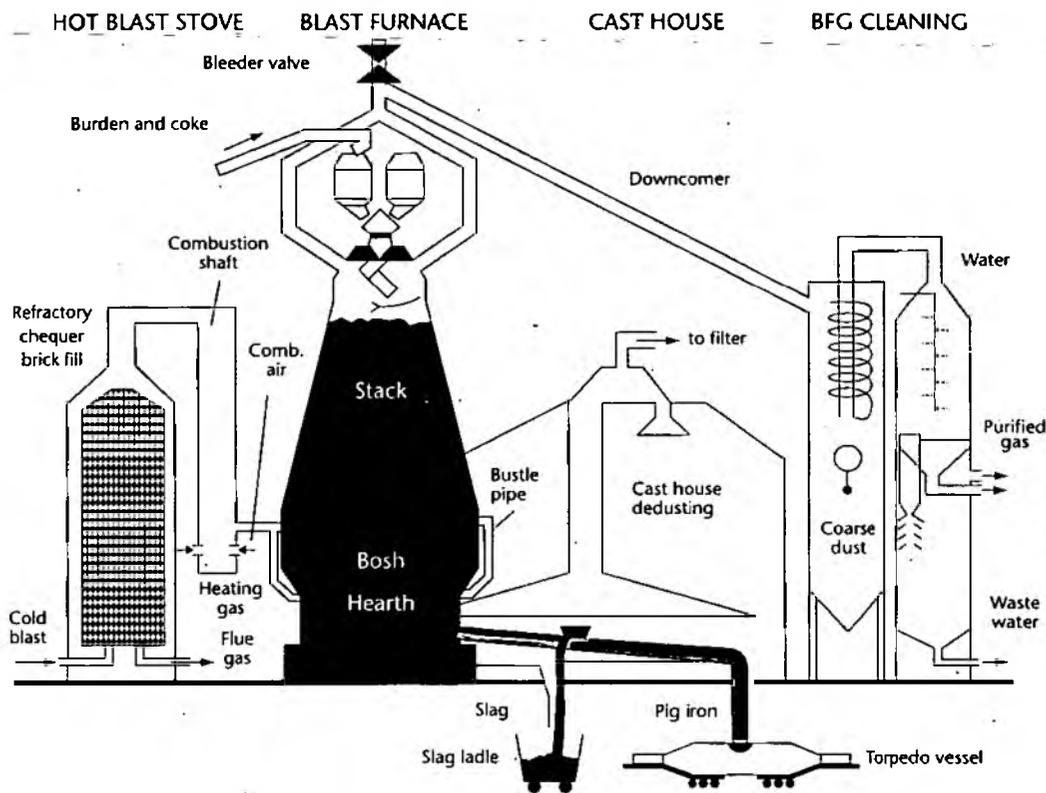
2.6.1 Potential release routes from blast furnace iron making

Releases to air

The raw gas leaving the blast furnace contains particulate matter (mainly iron oxides, heavy metals and carbon), carbon monoxide, carbon dioxide, nitrogen, hydrogen, zinc fume, sulphur compounds, ammonia, cyanide compounds, hydrocarbons and PAH.

Cleaned blast furnace gas can be used throughout the steel works as a source of energy. Since virtually all the blast furnace gas is captured and cleaned to a high standard, there are no significant primary releases to air from the blast furnace, apart from random brief periods of temporary gas and dust pollution released from the bleeder valve at the top of the furnace in the event of a burden slip. However, indirect emissions will occur when blast furnace gas is combusted in the stoves, boiler plant and other facilities.

A quantity of gas is vented during charging, but it is not normally practicable to abate this release with the current generation of UK blast furnaces. Proposals for any new or substantially changed plant should include the capture of these releases.

Secondary emissions to air during casthouse operations are mainly particulate matter, where hot metal and slag are in contact with ambient oxygen. A small amount of SO_2 may also be emitted from the slag during cooling, whilst VOCs and PAH may be released from the runner systems where tar-based binders are still used.

The cooling of molten slag generates diffuse H_2S and SO_2 emissions, which can vary in quantity depending on the slag processing techniques used and the sulphur content of the coke used in the blast furnace.

The emissions from the hot blast stoves are mainly combustion off-gases. The SO_x emitted is minimal. NO_x is minimised in the stoves by controlling oxygen levels; although this is for engineering rather than environmental reasons, as the quantities of NO_x are small.

Releases to water

Large quantities of clean water are used to cool the furnace structure, tuyeres and other equipment by means of closed recirculating cooling water system(s).

Relatively small amounts of water are released from such circuits, except under exceptional circumstances, which occur extremely rarely, when the circuit may be drained for major reconstruction/repair, such as relining of the blast furnace or inspection/cleaning of water sumps.

Large volumes of water are also used for cleaning and cooling of the CO-rich furnace gas, which is used as a fuel. This recirculating water circuit becomes heavily contaminated with suspended solids and a variety of dissolved species, including alkaline salts, cyanide, zinc, lead and fluoride and, to a lesser extent, other compounds such as ammonia and phenol.

Water is released from the furnace gas cleaning system in the sludge underflow from clarifiers/thickeners and may also be discharged as a blow-down to control the level of dissolved solids in the cooling circuit.

Apart from discharges arising from the gas cleaning water system, other effluents may be created by demineralisation or water softening plants, which may be used to provide make-up to the clean closed water circuits.

Releases to land

The coarse dust from the dry 'dust catcher' is normally recycled to the sinter plant. The finer sludge from the blast furnace gas cleaning system may contain significant levels of heavy metals and alkali metal chlorides, which may preclude recycling.

Where this sludge has to be landfilled, consideration should be given to the potential risk of groundwater pollution. In many plants abroad, the sludge is dewatered to produce a cake with about 20% moisture content, which is then disposed of to landfill or recycled.

A blast furnace gas cleaning process that produces a dry solid waste and has no liquid effluent stream would not only simplify recycling but would also probably represent the BPEO. For this reason, any further developments in dry gas cleaning techniques should be carefully considered.

As in all the other parts of a steel works which handle molten metal, waste refractories are generated when ladles, runners and process equipment are relined. On extremely rare occasions at very prolonged intervals, blast furnaces and stoves are completely relined with refractory. Such major events are normally planned years in advance.

2.6.2 Control of releases arising from blast furnace iron making

Control of releases to air

Primary releases

Operators should make efforts to minimise the level of sulphur input to the blast furnace in order to reduce emissions downstream in the process. Approximately 90% of the sulphur normally comes from the coke and so input levels are dependent on the availability and cost of low-sulphur coals.

The primary gas is normally cleaned by passing it through an expansion vessel (cyclone-type dust catcher) and a multi-stage wet scrubbing system (venturi or cone scrubber), which removes iron-rich dust containing alkali metal chlorides, heavy metals and PAH. Although in the past EPs were used in this application, they are now rarely used. However, since EPs have some advantages in avoiding potential releases to water, modern EP plant may be considered for new installations. For existing installations, which use wet abatement technology, BATNEEC will mainly be concerned with maximising the use of the iron-rich sludge, and minimising aqueous releases.

Practices should exist to prevent or minimise the release of the CO-rich blast furnace gas to atmosphere.

Operating parameters must be controlled to minimise the risk of burden slippage within the blast furnace, which can result in significant emissions of furnace gas to atmosphere. Authorisations should require that such releases are recorded. Gas generated in the blast furnace that cannot be utilised as a fuel should be flared via a suitably designed flare stack. This should provide smokeless combustion at all times and the satisfactory dispersion of combustion products and heat. Flaring of gas from the blast furnace system will normally only be carried out when the production of gas is greater than can be used and insufficient gas storage capacity is available.

Secondary releases

In the casthouse, secondary releases comprise large quantities of dust, fume and sulphurous gases. These are evolved during tapping of the furnace, the transfer of hot metal and slag through the runners, and where the former falls into the transfer or mixer ladle. These secondary releases can be effectively controlled by suppression techniques or local extraction systems at the tapping and ladle filling locations.

An abatement technique, which reportedly has been used successfully at several overseas plants, is the use of inert gas blanketing in the tapping area and over the hot metal runners. This technique can be effective in reducing oxidation and fume generation, although trials in the UK using nitrogen gas were found to be only 80% as effective as casthouse ventilation. This technique relies on the availability of a low-cost inert gas and may be impracticable to introduce onto some existing plants. Another issue to be considered is the high noise level due to the high rate that inert gas is injected into an area. Agency staff should be aware of these techniques and monitor their development.

The operation of fume extraction systems may be optimised under computer control, to open and close dampers and to regulate variable-speed extraction fans to minimise energy consumption. Such control systems may be justifiable on both environmental and economic grounds.

The use of tar-free runner linings has been shown to reduce PAH and VOCs significantly.

Within the stockhouse, all the screens and conveyor systems should be enclosed and connected to a dust extraction system. Dust suppression water sprays may also be employed. Since the different screens do not operate simultaneously, the installation of shut-off dampers in the extraction ducting to control the volume of air being drawn through the system can often be justified by the energy savings. Either an EP or a bag filter can achieve the release levels in Table 4.1 for the casthouse and stockhouse. However, fabric filters will achieve lower emission levels and would therefore normally be preferred for both new installations and retrofitting to existing plant.

Stand-by blast furnaces

A stand-by blast furnace, which is used only once every few years for limited periods of typically around 3 months, should not be authorised unless a satisfactory plan of improvements is in place to ensure that there is no greater effect on the local

environment during its operation or from the associated slagging activities, than during operation of the main blast furnace(s). As a minimum, the fume from the tapping operation should be captured or suppressed. Since such stand-by plants are invariably old, an assessment needs to be made of the risk of plant failure.

Control of releases to water

The recirculating water used for cleaning and cooling of the blast furnace gas becomes contaminated with suspended solids and a range of dissolved species, including alkaline salts, cyanide, zinc, lead and fluoride and, to a lesser extent, other compounds such as ammonia and phenol.

The suspended solids in the recirculating water are removed by settlement in devices such as clarifiers, often with the aid of flocculation. The sludge removed from the clarification process is typically either settled in a lagoon or thickened and dewatered by rotary vacuum filters or other types of mechanical filter. The zinc, lead and fluoride content of the waste water must be controlled to acceptable levels by conventional precipitation techniques, whilst compounds such as cyanides, phenol and ammonia must be controlled by oxidation.

The manner in which the final discharges of waste water from the 'dirty' recirculating water system of the blast furnace(s) are treated and re-used or disposed of will be strongly influenced by the facilities available to discharge effluent and the economics of alternative methods of utilising low-grade water.

Control of releases to land

Blast furnace slag is normally re-used for various purposes, including on-site road make-up and sale as a road stone or to the cement industry. (Section 2.12 deals with slag utilisation in greater detail.)

Dry grit and dust captured in the initial stage of gas cleaning will normally be sufficiently free of tramp elements such as zinc and lead to be recycled to the sinter plant. Wet sludge from the venturi scrubber system is usually disposed of to landfill because of the presence of zinc and lead. However, hydrocyclone techniques have been successful in segregating this sludge into high (fine) and low (coarse) tramp metal content. Consequently, it may be practicable to recycle the low-impurity fraction of the gas cleaning sludge to the sinter plant, thereby reducing the total quantity of waste sludge sent to landfill.

Waste refractory is normally disposed of by landfilling. Opportunities to utilise waste refractory materials should be considered by the operator.

2.6.3 Noise issues (IPPC)

At plants without noise reduction measures, sound levels of 122 dB(A) can arise.

Apart from the blowing plant, which forms part of the works power station, the normal main sources of noise associated with the blast furnace are the regular pressurisation and depressurisation of the hot blast stoves and the fans serving the casthouse ventilation and cooling water systems. During abnormal conditions caused by slippage of the burden, temporary high noise levels can arise due to brief intermittent blow-off of blast furnace gas through the 'bleeder' valve at the top of the furnace.

2.6.4 Energy conservation measures (IPPC)

As blast furnace gas typically contains 20-28% CO and 1-5% hydrogen, the gas is a valuable fuel. Hence, it is normal to recover, clean and store blast furnace gas for subsequent use as a fuel, often mixed with coke oven gas and/or BOS gas or natural gas to provide a fuel of a suitable constant calorific value.

If the blast furnace operates with high top pressure, a turbine generator (top gas expander) can be used to recover energy as the gas depressurises.

Hot blast stoves are normally fired with enriched BF gas and the energy consumption can be optimised by using fuel/air preheating, efficient burners, computer control and rapid oxygen measurement to control combustion conditions. Most modern stoves are completely computer-controlled.

Reducing agents such as pulverised or granulated coal and, less frequently, oil or natural gas are commonly injected into the blast furnace as a part replacement for the more expensive coke. The resulting reduction in the consumption of coke reduces the overall pollution and energy demand of the steel works. (However, coal injection can lead to increased dust content of the BF off-gas.) The endothermic decomposition of these injectants has to be compensated in the furnace by either higher hot blast temperatures or oxygen enrichment of the blast air. Recently, several iron and steel companies in Europe have run trials of injecting plastic waste to reduce the coke demand. This technique is still being developed and is not yet considered to be BAT.

2.6.5 Utilisation of surplus hot metal

Pig casting of iron

In the past, a traditional method of processing molten iron that was surplus to immediate requirements, was by casting pigs in an automatic casting machine. At the present time, pig casting is mainly used to produce modest quantities of cold pig iron for sale to electric arc furnaces and foundries, since it is costly to maintain a large casting machine on stand-by which, in any case, would be incapable of disposing of the 400-600 tonnes of molten iron in a large transfer ladle or torpedo vessel.

A pig casting machine comprises moulds, cast from haematite iron, fitted to an inclined endless belt. The moulds pass under a spout, where they are filled with molten iron from the transfer ladle. After being filled with molten iron, the moulds are sprayed with water until they reach the head of the belt where the solidified 'pigs' are normally discharged into a steel wagon. When filled, the wagon may be placed under a water quencher for cooling. As the empty moulds return in the inverted position on the underside of the belt, they are sprayed with a lime slurry to stop the pigs sticking to the moulds. There are normally two parallel belts fed from the same ladle by means of a divided spout. Pigs typically weigh about 50 kg and the pouring rate is typically about 1 t/min, which is the reason that pig casting machines are of little use for emptying a large transfer ladle or torpedo.

Some oxide fume is generated during transfer of iron through the runner and as the iron fills the moulds. Steam arises from spray cooling along the length of the belts and from quenching of the hot pigs after discharge.

There is little if any particulate matter in these emissions of steam. The machine normally stands on a concrete base surrounded by a retaining wall, so that all excess water and lime slurry is captured, filtered and recirculated. Iron chips and iron shot recovered from the feed end of the machine are added to the cold pig stockyard.

Plating of iron

'Plating out' of hot metal into open pits (also known as 'ponding' or 'puddling') is carried out as a short-term measure and its use is dictated by the large scale of modern iron production. Fume generation can be minimised by pouring the iron in 50 mm thick layers on top of already chilled iron. Since the beds are normally allowed to air cool, there are no process water releases, although there may be some run-off of rain water if the beds become completely cold.

When iron is plated out, the drop in temperature can cause the precipitation and emission of iron graphite (kish). This problem also occurs in the steel making shop, when pouring iron to charge the BOS vessel. Avoidance of excessive hot metal temperatures can help to reduce the amount of kish generated.

Iron granulation

Granulation of molten iron can be used as an alternative process to ponding or pig casting. In the granulation process, molten iron is poured from a ladle at a strictly controlled rate into a high volume stream of fast-flowing water. The iron is immediately quenched and granulated and carried off in the water stream to a settling pond, from where it is removed by a mechanical grab. The process water is recirculated through a cooling tower. Fume generation during the process is minimised by the slow, controlled rate of pour necessary to carry out the operation in safety, although a substantial quantity of steam is released.

2.6.6 Alternative iron making processes

There are a range of alternative methods of producing iron, other than the traditional blast furnace. The primary

environmental benefit of using such alternative processes is that they avoid the need for coke and, in most cases, sintered material. This eliminates two traditional processes with significant pollution problems. The alternative iron making processes can be broadly categorised into two groups. The first group of processes, which are generically termed 'direct reduction' processes, are usually natural-gas-based. In 1997 installed direct reduction production capacity accounted for approximately 5% of world raw steel production. The capacity of individual direct reduction units is expanding rapidly. The economic viability of direct reduction processes generally depends on favourable local factors, such as cheap natural gas.

Releases from the gas-based direct reduction plant are generally low; with particulate releases to air after abatement in the order of 10 mg/m³. Cleaning of the process gas is normally based on wet technology, leading to an aqueous waste stream; although this can be minimised by good water management practices.

The second group of new alternative methods of producing iron comprises 'smelting processes' which use coal directly as a reducing agent. A number of processes are under development, one of which, the COREX process, is in commercial operation. This process is a combination of two separate processes, comprising the direct reduction of iron ore in an upper shaft furnace and the generation of the reducing gas, from coal, in the smelter gasifier unit. The environmental releases from a COREX unit are broadly comparable with those from a blast furnace, but with the major environmental advantage that the need for coke ovens and the associated emissions is eliminated.

To date, steel produced by such alternative iron making methods would not be competitive in the UK with steel produced by the blast furnace route. However, the low capital cost per annual tonne of product makes the DRI process route attractive in parts of the world that do not already have blast furnace technology and where energy costs are relatively low.

Since economic influences and process technologies change with time, any proposal for new iron making capacity within the UK must be justified against the range of alternative processes available.

2.7 Hot metal mixing

The hot metal from the blast furnace can be temporarily stored in large insulated torpedo or transfer ladles, which can hold sufficient hot metal for a number of charges to the BOS converters. At one UK steel plant, the hot metal is transferred to a very large mixer vessel, which is heated using gas burners to enable the hot metal to be held for longer periods to match the BOS production demands.

2.7.1 Potential release routes from hot metal mixing

Releases to air

The main releases are fume, generated during pouring and any combustion off-gases from the mixer furnaces. The pouring operations produce large volumes of iron oxide fume and kish.

2.7.2 Control of releases arising from hot metal mixing

Control of releases to air

The fume and kish given off during the transfer of hot metal into the hot metal mixers and particularly when pouring from the mixers and torpedo ladles into the BOS charging ladles should be captured and filtered. When pouring the metal, fume generation can be reduced by minimising the pouring distance and pouring rate. As mentioned previously, trials have taken place using either nitrogen or CO_2 as a fume suppressant during pouring and other hot metal transfer operations. Such techniques can reduce the generation of fume (iron oxide), but does not prevent the formation of kish. Agency staff should be aware of the potential application of such techniques. Releases of combustion gases can be minimised through selection and optimisation of appropriate burners and combustion control systems.

2.7.3 Energy conservation measures (IPPC)

Where practicable, lids should be placed on ladles whilst transporting hot metal around the site. This will help reduce thermal losses and is particularly important where delays may be incurred.

2.8 Iron desulphurisation

The molten iron from the blast furnace contains undesirable amounts of carbon, manganese, silicon, sulphur, phosphorus and minor quantities of other elements, which are reduced or removed in the steel making process. However, sulphur in hot metal is more effectively removed in a separate process carried out in the ladle prior to transfer to the steel making vessel. An early method of desulphurisation involved pouring the molten metal into a transfer ladle containing a quantity of soda ash or a mixture of soda ash, coke and magnesium. It is now common practice to deep-inject the reactants, comprising salt-covered magnesium granules or calcium carbide, into the ladle using a refractory lance and inert carrier gas. The resulting high-sulphur slag is skimmed off the surface of the metal with a mechanical rake or 'rabble'.

2.8.1 Potential release routes from desulphurisation

Releases to air

The main releases during iron desulphurisation operations are of fume.

Releases to land

Slag is produced during the desulphurisation process.

2.8.2 Control of releases arising from desulphurisation

Control of releases to air

The gas and fume emissions from the desulphurisation process, the skimming station and the decanting station should all be collected effectively and dedusted in either a fabric filter or EP. The recovered dust is not usually suitable for recycling.

Control of releases to land

Slag arising from iron desulphurisation operations generally contains high levels of sulphur and has poor mechanical properties. Consequently, this slag is not suitable for most slag recycling uses and is usually either landfilled on the site or used for the construction of noise barriers and other low-specification projects.

2.8.3 Energy conservation measures (IPPC)

Energy consumption can be minimised by variable speed fans and fitting control dampers to the fume extraction ducting to balance the volume of air extracted when process units which are connected to the system are not in operation.

2.8.4 Emerging techniques

Several 'foaming' techniques are already available for pre-treatment of iron. The benefit of foaming techniques is that particulate matter can be absorbed into the foam.

The displacement of air by inert gas above the molten metal during pre-treatment reduces the production of metal oxides and fume. Industrial-scale tests have used nitrogen and CO_2 to shroud the transfer of molten metal between vessels, though potentially the use of nitrogen might increase the emissions of NO_x.

2.9 Basic oxygen steel making

The basic oxygen converter consists of a large open topped steel vessel, which is lined with basic refractories, and is mounted in a trunnion ring assembly. The vessel is capable of rotation through 360°. Above the vessel is a large water-cooled duct connected to a gas cleaning plant, which evacuates, cools and cleans the hot waste gases from the vessel before discharge. The BOS vessel is charged with up to 30% steel scrap, with the balance as hot metal.

There are two basic technologies employed. In the original concept of the process (the LD converter) oxygen was blown at supersonic velocity through a water-cooled lance on to the surface of the molten iron, burning the carbon and oxidising the metalloids into the slag. In a later development of the process (known generically as Q-BOP), oxygen and other gases were injected through a tuyere in the bottom of the vessel, giving various metallurgical advantages. In due course the two technologies were combined and currently there are a number of combination processes, where the possible injectants include nitrogen, argon, flux and fuel gases.

At the start of the steel making cycle, the converter is tilted to the charging side at an angle of approximately 45° and charged with pre-weighed scrap from a scrap 'box'. Up to 30% of the charge weight can be scrap, depending on the quality of iron

being used. The molten hot metal is then poured on to the cold scrap and the vessel returned to the vertical position. Flux-forming material, such as lime, is fed into the vessel from a chute located above the converter. A water-cooled oxygen lance is lowered to a fixed position above the liquid metal charge and high-pressure oxygen is blown onto the surface at supersonic speed. Almost all of the energy released in the blowing process originates from the hot metal. 40% is in the form of thermal energy and 60% is in the form of chemical energy contained in the carbon and other elements in the iron. During the blowing process, some of these elements react with the oxygen to release heat. At the same time, carbon burns to form carbon monoxide and carbon dioxide. Some of the iron is oxidised and is entrained in the flue gas as dust particles. When the steel composition and temperature are correct, the vessel is tilted to the tapping side of the shop and the steel tapped into the casting ladle. After tapping the steel, the slag is drained off by pouring from the mouth of the vessel into a slag pot, which is used to transfer the slag to cooling pits. After solidification, the slag is removed for crushing, recovery of metallics and disposal or use as a secondary material.

2.9.1 Potential release routes from basic oxygen steel making

Releases to air

The main releases to air from the BOS steel making process are particulate matter (mainly containing metal oxides) and CO, with relatively small amounts of sulphur oxides and nitrogen oxides. Additionally, very small amounts of PCDD/F and PAH are emitted.

Significant quantities of NO_x oxides can be released at the ladle preheating and heating facilities.

Releases to water

Clean water is used in recirculating 'indirect' cooling systems serving various items of equipment such as the oxygen lance, primary fume extraction hood and associated hot gas ducting. Water can be discharged as blow-down if parts of the circuit are evaporatively cooled, but since most plants use closed circuit fin/fan cooling, releases of waste water are normally negligible from such circuits. (However, significant volumes of water can be discharged, if the system is completely drained for maintenance.)

More recently, some plants also employ evaporative air mist cooling of the cone of the converter vessel. This should not create releases of waste water if the system is operating correctly.

The recirculating 'direct' contact water used to clean and cool the primary fume extracted from the converters becomes heavily contaminated with suspended solids and dissolved solids, which include alkaline salts, lead and zinc compounds, cyanide and fluoride. The concentration of dissolved solids in the gas cleaning water can vary widely, depending to a large extent on the operation of the furnace and the amount of water discharged as blow-down from the recirculating system.

Demineralisation or water softening plants are often used to treat the make up water to the indirect cooling systems. Such treatment facilities, which may be centralised or serve individual process plants, give rise to a variety of waste water qualities, including acidic, alkaline and saline effluents.

Releases to land

The main releases to land are sludge from primary fume cleaning systems, dry dust from secondary fume cleaning and slag.

Waste refractory is generated when ladles and converters are relined.

2.9.2 Control of releases arising from basic oxygen steel making

Control of releases to air

Primary fume emissions
The blowing operations in the converter create an off-gas that is rich in CO (around 70%). This potential source of energy should be captured during the parts of the blowing cycle when the composition of the off-gas is suitable. In older plants, it is common to combust the off-gas with air at the mouth of the converter vessel and, in some instances, recover heat in the form of steam in the fume ducting system. When unburned off-gas must be released to atmosphere, it should be flared to combust the carbon monoxide and the design of the flare stack should ensure clean combustion at all times.

Emissions of PCDD/F and PAH can be limited by controlling the quality of scrap and other additions, and ensuring the dust control equipment is properly operated and maintained.

Secondary releases
Whilst the majority of the primary fume is extracted directly from the BOS vessel, some fume may escape through the lance hole or from the annular gap between the fume hood and mouth of the converter. The control of the fume escaping from such sources requires the use of secondary control techniques.

Secondary releases of fume to the building through the lance hole of the fume duct can be reduced by shielding the hole with inert gas or steam.

Secondary releases of fume emitted during charging and tapping processes, and escaping from the primary fume extraction system, will occur. This needs to be captured and abated. The design of these systems, which will be retrofits on existing plant, will depend on local conditions. Local hoods, or an enclosure ('doghouse') should be used, with any hood system as close to the converter as possible. The secondary fume collected is extracted to a bag filter plant.

However, charging is carried out by pouring hot metal from a ladle suspended on an overhead crane, so that local extraction hoods rarely manage to capture all the fume. Because of this, sealing of the building roof and extraction to a bag filter plant is normally required for both new and existing installations. The roof extraction system also captures various other fugitive

releases, including those escaping from the local extraction hoods at the hot metal pouring stations. However, it is not practicable to rely on roof extraction alone to capture such releases.

The bunkers that hold the flux additions are located in the roof space. The small releases from such sources can be fed into the roof extraction system.

Either a bag filter or an EP should be able to meet the benchmark release levels suggested in Table 4.1. Whilst the former abatement technique will result in the lowest particulate releases, the latter might enable more selective recycling of the dust.

Control of releases to water

The main releases to water arise from the recirculating water system of the primary fume cleaning and cooling circuit.

Where wet fume abatement techniques are employed, the resulting dry process water is treated to remove the suspended solids and cool the water, prior to recirculation. Particulate removal typically involves two stages of separation: primary settlement to remove coarse particles, followed by settlement of finer particles in equipment such as clarifiers or settlement tanks. Flocculation additives are usually employed to improve sedimentation. After discharge from the clarifier, settled sludge may be subject to further treatment in a thickener, followed by dewatering in such equipment as rotary vacuum filters, filter presses, tube presses or centrifuges.

In cases where the clarifier underflow is discharged to settlement lagoons, the lagoons are periodically excavated and the sludge allowed to drain prior to disposal. Where the concentration of tramp elements such as zinc and lead are sufficiently low, this material may be recycled to the iron making process route. Otherwise, the material is disposed of to landfill. Recovery of tramp elements from the sludge is not usually economic.

Throughout the world there has been increased effort to recycle the dust recovered from BOS gas cleaning systems and various techniques have been developed to recycle these materials to the sinter plant, blast furnace or BOS plant.

The waste water discharged from the recirculating water circuit of the gas cleaning system may be re-used in other parts of the steel works for low-grade duties such as quenching or, alternatively, disposed of as an effluent. The effluent treatment and disposal arrangements are normally site-specific but, prior to discharge from the site, all such effluents must comply with the Authorisation conditions.

The capacity and costs of final effluent treatment will be strongly influenced by the Consent conditions and the effectiveness of the water management regime within the steel works. Agency staff should seek evidence of a structured approach to minimising the consumption of water and volume of effluent discharged.

Control of releases to land

Slag arising from BOS operations is crushed to recover the metallic content and the residue slag material is utilised where economic outlets are available or stockpiled at the steel works site. (See Section 2.12 for further details.)

There is potential to recycle the sludge from the gas cleaning plant to recover the Fe units and this material is recycled to either the blast furnace or sinter plant in many facilities throughout the world. The presence of zinc and other tramp elements can cause difficulties with the operation of the BF or affect the chemistry of the hot metal by altering the sinter chemistry. Steps can be taken to increase recycling by control of scrap quality charged to the BOS plant and by separation of the coarse and fine particulate recovered from the primary fume cleaning system. The coarse grit is more suitable for recycling, as it contains less of the volatile tramp components. Agency staff should ask operators for proposals to recycle this material.

Waste refractory is normally disposed of by landfilling. However, the amount of waste refractory previously generated within BOS plants has been reduced by modern refractory gunning techniques, improved refractories, air mist cooling of the converter cone and operational practices such as 'slag washing' and 'slag splashing' to protect the converter linings.

2.9.3 Noise issues (IPPC)

Apart from brief intermittent percussive noise whilst charging scrap to the converter, the main sources of noise associated with a BOS plant are the supersonic jet of oxygen blown through the lance inside the converter vessel and the fans of the primary and secondary fume extraction systems.

Suppressed combustion skirts and 'doghouse' enclosures around the converter vessels attenuate the noise from the oxygen lance significantly. Noise from other sources, such as fans, can be controlled by appropriate selection of equipment and, where necessary, noise attenuation measures.

2.9.4 Energy conservation measures (IPPC)

Energy can be recovered from the off-gas released from the BOS process using one of two systems:

- Combustion of BOS gas in the gas duct, with recovery of sensible heat in a waste heat boiler.

- Suppression of BOS gas combustion and storage of the off-gas generated during appropriate parts of the blowing cycle for subsequent use as a fuel.

  Recovery of BOS gas using suppressed combustion techniques usually involves lowering a skirt over the converter mouth during oxygen blowing. This prevents ambient air entering the flue gas duct, thus suppressing the combustion of carbon monoxide.

The use of suppressed combustion to permit gas recovery is considered BAT. This technique not only provides a substitute for purchased fuels, it reduces the volume of exhaust gas and hence reduces the capacity of the waste gas treatment system and the energy consumed. A further benefit is that the iron fume is entrained as Fe_3O_4 rather than Fe_2O_3 and is therefore easier to recover.

2.9.5 Emerging techniques

Dust from the BOS plant and other fine by-product materials containing high levels of Fe may be pressed in a 'hot' or 'cold' briquetting machine to produce briquettes, which can be charged back to the BOS furnace in place of scrap as a coolant.

Depending on the characteristics of the feedstocks, zinc-rich dusts can be produced during cleaning of BOS and blast furnace off-gases. Although in theory pyrometallurgical and

hydrometallurgical processes are technically developed to permit the recovery of zinc from waste dusts, the commercial application of such techniques to these materials is not at present economic.

2.10 Electric arc steel making

Melting of ferrous materials that have low or zero iron oxide content, such as steel scrap, is usually performed in electric arc furnaces (EAFs), which play an important role in the recycling of ferrous materials recovered by the scrap metal industry. A schematic diagram of the EAF steel making process is shown in Figure 2.5. The main applications for EAFs are bulk steel melting for mini-mill strip and plate, bulk steel ingots for forging and batch melting for foundries.

The electric arc furnace consists of a steel shell lined with refractory or comprises water-cooled panels, which can be tilted to pour the molten steel through the furnace tap hole. The electrode(s) for input of electric power pass through the roof of the furnace, which can be slewed aside for charging the scrap feedstock. The roof also contains a 'fourth hole' through which the gaseous by-products of the steel making reactions are discharged from the furnace to the fume cleaning plant. Electric arc furnaces have capacities ranging from a few tonnes up to 200 t or more. Most of the existing electric arc furnaces are powered by alternating current (AC furnaces) and have three electrodes, but direct current furnaces (DC furnaces) are becoming more common, particularly in regions where electrical supplies are poor. The latter furnaces have a single electrode in the roof and a second electrode embedded in the hearth. DC arc furnaces tend to be used where the capacity of the electrical supply systems is marginal for using conventional AC furnaces. Generally, DC arc furnaces produce significantly less electrical 'flicker' and are considerably quieter than the equivalent AC electric arc furnaces.

Figure 2.5 *Electric arc furnace steel making process*
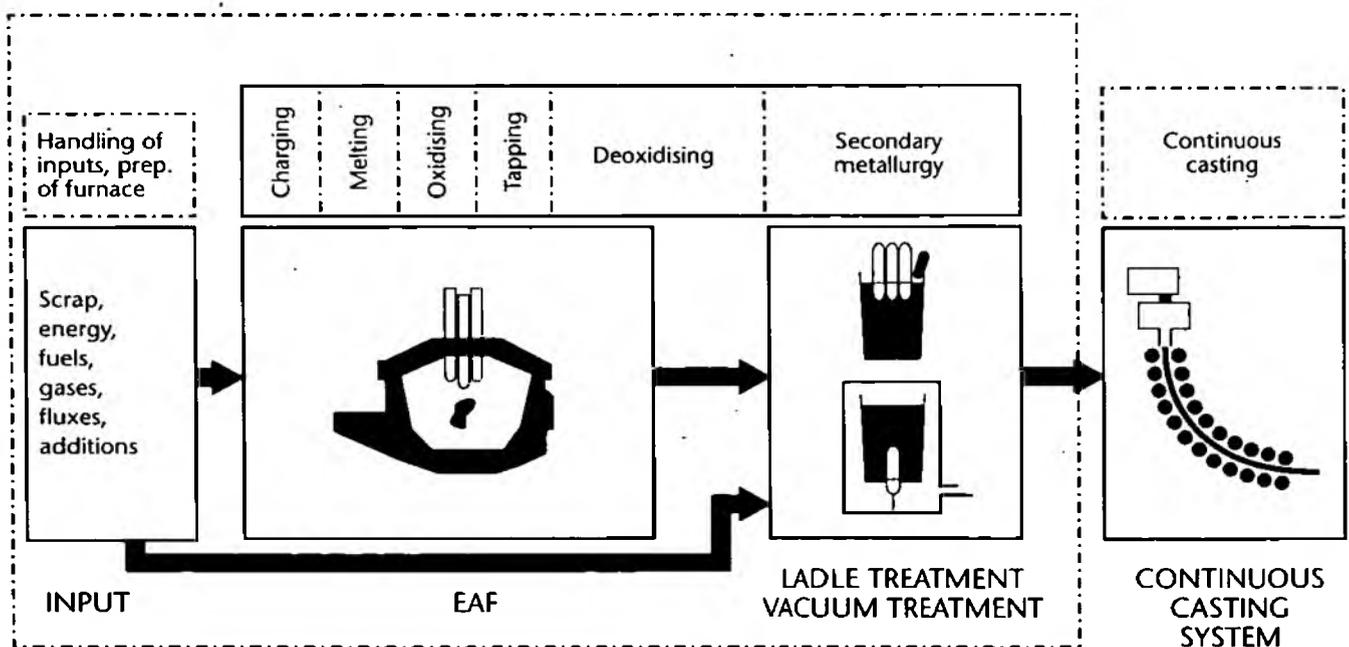
In Europe, the main feedstock for the EAF is post-consumer ferrous scrap, supplied by merchants in the waste management sector, supplemented by internal recirculating scrap arising within the steel works. However, in countries where natural gas is cheap and little scrap is available or where 'low residual' steel is necessary,.DRI may form the major constituent of the EAF charge.

Charging

The scrap is loaded into baskets, together with lime (sometimes with dolomite in addition), which is used as a flux for slag formation. Lump coal or coke is also charged at some plants as a recarburiser. In a conventional furnace, the electrodes are raised up through the furnace roof, which is then swung away from the furnace body to allow the scrap to be charged. Typically, about 60% of the scrap is charged with the first scrap basket. The roof is then closed and the electrodes lowered to within 20-30 mm above the scrap before striking an arc. After the initial charge has melted, the charging process is repeated by adding the remainder of the scrap using one or more further baskets.

Melting and refining

During the initial period of melting, the maximum power is not applied in order to minimise damage to the furnace walls and roof from radiation, whilst allowing the electrodes to bore into the solid scrap. Once the arcs have become shielded by the surrounding scrap, the power can be increased to finish the melting. Oxy-fuel burners are often positioned in the side walls or on the slag door to heat up cold spots and even out melting during the melting stage of the project. The auxiliary fuel is normally natural gas, although oil and coal can also be employed. Oxygen, fuel gas or air may also be supplied to the liquid steel through specific nozzles located in the bottom or side wall of the EAF.

Oxygen is injected into the molten bath through a lance for decarburisation of the melt and removal of other unwanted elements such as phosphorus, silicon and sulphur. A separate burner or lance is used to achieve 'post-combustion' of carbon monoxide. This results in a marked increase in the generation of gas and fume, which comprise CO and CO_2 gases, extremely fine iron oxide particulate and other oxidation products. Argon is injected through porous plugs for stirring.

Oxygen lancing also results in oxidation of the iron in the charge, leading to an increase in the bath temperature due to the exothermic oxidation reactions. The iron oxide reverts to the slag and may be recovered by injection of carbon through a separate lance into the slag to reduce it back to metallic iron. Although the reduction reactions are endothermic, the generation of CO and CO_2 creates a foaming slag, which covers the electrode tips and increases the thermal efficiency of the furnace by stabilising the arcs and reducing radiation losses.

Argon or other inert gases may be injected into the melt, usually through tuyeres and porous plugs, to provide bath agitation and temperature balancing. The slag-metal equilibrium can also be improved by this technique.

Steel and slag tapping

Slag is removed at the end of the heating, prior to tapping, and may also need to be removed during refining. This involves raising the electrodes and tilting the furnace backwards towards the slagging door, to allow the slag to run off or be raked into a slag pot or tipped on to the ground below the furnace. The resulting dust and fume generation can be partly suppressed by water sprays, providing the appropriate safety precautions are observed. To tap the furnace, the electrodes are raised, allowing the furnace to be tilted, and the tap hole is opened to allow the discharge of molten steel into the ladle.

A technique known as 'hot heel' tapping is frequently used in bulk steel making, which involves leaving up to 20% of the steel with some of the slag in the hearth, in an attempt to produce a slag-free tap and speed up the tap-to-tap cycle time. However, it is still necessary to remove slag from the furnace prior to tapping.

In plants without secondary steel making facilities, alloying and other additions are often made to the steel ladle before or, more commonly, during tapping the molten steel from the furnace. Such additions can noticeably increase the fume produced during tapping.

Secondary metallurgy

The use of secondary metallurgical techniques is now commonplace for EAF steel manufacture. These techniques are described in Section 2.11.

Furnace and ladle lining repairs

Maintenance of the hearth refractories, particularly at the slag line, is normally carried out immediately after tapping by using refractory gunning techniques. Such repairs to the furnace result in some release of fume. Relining of furnaces and ladles involves wrecking the old linings, which are contaminated with slag, and disposal of the resultant waste to landfill or recycling off-site. The wrecking operation, which is normally carried out using pneumatic or hydraulic machinery, can produce large quantities of dust. The dust can be suppressed by using water sprays.

2.10.1 Potential release routes from electric arc steel making

Releases to air

The production of steel using the EAF process route may produce large quantities of fume (metal oxides of predominantly iron, with zinc, lead and other oxides, including trace oxides of cadmium), together with CO, CO_2 and traces of PCDD/F, PAH, PCB, HF, HCl, benzene and other hydrocarbons.

The use of oxy-fuel burners or oxygen lances can increase the quantity of dust emissions.

SO_x and NO_x emissions do not normally require special consideration.

Releases to water

Water cooling of the furnace shell, roof, fume ducting electrode arms and transformers normally involves closed-circuit cooling systems, which minimise releases to water.

Releases to land

The main solid wastes produced by the EAF steel making process are slag and dust. The dust normally contains significant quantities of iron, zinc and lead oxides and may also contain detectable levels of PCDD/F and PCBs.

Waste refractories are generated when ladles and arc furnaces are relined.

2.10.2 Control of releases arising from electric arc steel making

Control of releases to air

The essential requirement is for primary fume control. Furnaces of 30 tonnes or more capacity should employ direct extraction of primary fume through a 'fourth hole' in the furnace roof ('second hole' on DC arc furnaces). The primary fume off-take should allow the entry of induced air to ensure complete combustion of any CO released from the furnace. Smaller furnaces of less than 30 tonnes capacity may have side-draught hoods for primary fume control, though this abatement technique should be replaced by direct extraction where practicable. Partial enclosures or canopies located at likely areas of fume escape can be mounted on, and move with, the furnace roof. Such areas are typically around the electrode ports, the roof ring seal, over the slagging door and above the tapping spout.

The primary fume is extracted from the furnace through a water-cooled elbow and duct by the exhaust fan(s) of the abatement plant. The fume may be cooled by a forced draught cooler, unless dilution air from a roof canopy is used to reduce the temperature to a satisfactory level for the abatement plant, which is generally a fabric filter. Combustion air enters at the 'slip gap' between the furnace elbow and the water-cooled ducting, which combusts CO and allows the furnace to tilt.

For a new furnace, the fume control system should be included in the design and the provision of a furnace enclosure, often referred to as a 'doghouse' should be considered, together with traditional primary fume abatement plant. Although a furnace enclosure usually provides effective noise abatement and fume containment during the operation of the furnace, the design should also include control of local fume escape during charging and tapping. This is particularly important if the furnace enclosure has doors for crane access. The potential benefits of an enclosure apply to both large- and small-capacity furnaces.

The design of a new or upgraded fume control system for an existing furnace or for the installation of a new arc furnace within an existing plant will be strongly influenced by the layout and overall situation within the plant. In these circumstances, a modified roof capture system for fume control

can be considered, possibly involving extension of hoods in the roof space and further sealing of the building roof. If such changes are contemplated, the existing fume cleaning system and fan capacity will need to be reviewed. In the case of furnaces below 20 tonnes capacity, canopy hoods above the furnace and side extraction ducts have commonly been used for collection of primary and secondary fume. However, 'fourth hole' extraction is known to be installed on furnaces with as little as 3 tonnes capacity and should therefore be considered for all EAFs.

Fabric filters are considered to be BAT for both primary and secondary fume cleaning, although EPs may be used if they are capable of achieving the benchmark release emission levels listed in Table 4.1.

Emissions of benzene and other hydrocarbons have been linked to the addition of coal, which degasses before being burnt. Minimising the use of coal can limit the emission of such hydrocarbons.

PCDD/F, PCB and PAH emissions are largely related to the presence of non-metallic material such as oils and materials containing chlorine in the scrap. It has been reported that emissions of these species can increase where scrap preheating techniques are used and can be reduced by:

⊖ controlling scrap quality to minimise oil contamination;

● post combustion and rapid cooling of the exhaust gases to below 250°C; and

○ minimising dust emissions.

Research has indicated that discharge exhaust gas temperatures below 75°C result in PCDD/F releases below 1 ng I-TEQ / Nm^3. Further details are contained in the EU iron and steel BREF Note[16].

Control of emissions during charging, tapping and slag handling

With existing plant, secondary emissions during charging, tapping and slagging should be collected by hoods connected to an extraction and filtration system. The use of local fume enclosures can reduce emissions from these operations. Where this is not practicable, consideration should be given to extraction by canopies located in the roof space of the melting shop.

For large furnaces with eccentric bottom tapping, transfer cars should be used to position the tapping ladles and, where utilised, slag pots. The operation should be well enclosed with a local extraction system installed under the furnace where practicable. The fume from these hoods should be ducted into the primary extraction system.

Secondary dust and fume is reduced by discharging slag into slag pots, rather than on to the ground.

Control of releases to water

The use of closed-circuit water cooling systems, which recycle

the water, are considered BAT for cooling EAF steel making equipment.

Control of releases to land

The production of slag can be minimised through effective process optimisation and the use of high-quality raw materials.

Slag from EAF steel production is normally crushed to recover the metallic content and the residual slag can be sold as a road aggregate or used on-site to build roads or noise barriers. (See Section 2.12 for further details.)

Dust captured by the bag filter plant of the fume cleaning system has traditionally been landfilled or in some cases sold to primary zinc smelters to recover zinc. A number of techniques are currently available at differing levels of technical and commercial development to recycle fume cleaning dust back to the arc furnace or extract the constituent metals of iron and zinc from the dust for recycling. Further details are given in Section 2.10.5.

Waste refractory is normally disposed of by landfilling. Opportunities to utilise such material should be considered by the operator.

2.10.3 Noise issues (IPPC)

Inside an EAF shop, noise levels as high as 133 dB(A) can occur. The main potential sources of boundary noise are the operation of the EAF, high-velocity oxy-fuel burners, scrap handling and fume extraction equipment.

The selection of equipment such as fans and appropriate use of noise attenuation cladding and barriers can help reduce this noise. Where practicable, arc furnace enclosures ('doghouses') can reduce noise levels significantly. If necessary, acoustically insulated buildings can be employed

2.10.4 Energy conservation measures (IPPC)

Reduced tap-to-tap time
Energy consumption can be reduced by optimising the furnace operation. Some of the most important techniques to achieve this include:

- Computer control

- Ultra high power (UHP) operation

- Post-combustion

- Water-cooled side walls and roof

- Foaming slag practice

- Oxy-fuel burners and oxygen lancing

- Slag-free tapping furnace design, such as EBT, OBT or furnace slide gate

- Ladle or secondary metallurgy

- Optimum control of the fume collection system

- Scrap preheating

Most of the above techniques achieve reductions in energy consumption by shortening the tap-to-tap cycle time of the EAF, even though some of the techniques, such as water cooling, increase thermal losses from the shell and roof of the furnace.

Scrap preheating
Scrap preheating can be used to reduce energy consumption and tap-to-tap time by utilising part of the sensible heat in the furnace off gas. The 'shaft furnace' and 'CONSTEEL' process are two technologies that incorporate scrap preheating, which are commercially available.

The shaft furnace, which is now an established process, allows part of the scrap to be preheated by charging it through a vertical shaft that is integral with the furnace roof. It is only applicable where consistently light scrap can be used, e.g. frag scrap. The scrap is preheated by the process exhaust gas, which reduces the electrical power input during melting and the productivity of the furnace. In the conventional shaft furnace, the initial basket of scrap is charged directly into the furnace shell, which can be moved from its normal position under the fixed roof to permit charging. The furnace is repositioned quickly under the roof and a short period of melting takes place using electric arc power and the oxy-fuel side wall burners. The remainder of the scrap is then charged into the shaft, which is closed prior to recommencement of melting. During melting, the height of the scrap in the shaft falls as the scrap enters the molten bath. A further development is the 'finger shaft furnace', which allows the scrap to be held in the shaft during refining, thus increasing the degree of preheating and recovery of energy from the exhaust gas. Currently, this development is only installed at a limited number of applications and should not at present be considered BAT.

A further variation is the double shaft furnace, which consists of two identical furnace shells, serviced by a single set of electrode arms.

Furnace off-gases passing up the shaft and preheating the scrap can lose up to 25% of the dust load due to contact with the scrap feedstock. Extraction of the off-gases is from one side of the top of the shaft and the gases may be passed to a combustion chamber to burn off any combustible substances. In such cases, the direct energy benefit of using a shaft furnace is lost, though energy is still saved through reduced tap-to-tap times.

The CONSTEEL process, which at present is considered to be an emerging technique, continuously feeds scrap via a horizontal conveyor system into the arc furnace. The conveyor runs in a refractory-lined tunnel, in which furnace

off-gas preheats the scrap to between 300 and 400°C. Additional preheating up to about 900°C can be achieved by fuel burners along the side of the feed tunnel. With this arrangement, the roof of the arc furnace does not need to open, since scrap enters through the side of the furnace.

Agency staff should be aware that scrap preheating may result in the creation of dioxins and other partial combustion products from scrap, that is contaminated with paint, plastics, cutting oil and lubricants. This can result from the relatively low temperatures produced in the preheated charge and consequently post-combustion techniques may need to be considered. Similar conditions may also occur in a conventional arc furnace during charging or during the initial stages of melting.

2.10.5 Developing processes

Re-use of EAF waste products
Several EAF operators in the UK have experimented with recycling EAF dust and mill scale from the casting and rolling processes to the furnace.

Several techniques have been employed, including direct injection and briquetting of these by-products. The aims of the trials are to establish a technique to reduce the total quantity of solid waste, recover additional iron units and increase the concentration of non-ferrous elements in the dust, thus increasing its suitability for recycling. Empirical evidence indicates that zinc concentrations of 30-35% in the EAF dust can be achieved, without adversely affecting the quality of the steel produced or the operation of the furnace.

Zinc recovery from EAF dust
EAF dusts arising from scrap-based operations usually contain relatively high quantities of zinc oxide. A number of techniques for treating the dust and recovering the zinc, including the use of plasma/DC furnaces, rotary kilns, or hydrometallurgical processes, are technically developed and are used at different locations throughout the world. Some of the processes, such as the Waelz kiln process, are well established, but unless there are regulatory incentives, the economic viability of plants processing dust from carbon steel production has yet to be demonstrated. Zinc enrichment up to 30% has been reported without detrimental effect on steel quality, and filter dust with this level of zinc may be suitable for reprocessing in a zinc smelter or special treatment plant to recover zinc. (Plants processing dust and scale from stainless steel production to recover ferro-alloys are likely to be more viable than the treatment of such materials from carbon steel production, particularly if sufficient quantities are available. However, economic viability is site specific.)

Control of PCDD/F by injection of lignite/carbon
Research suggests that it may be possible to control organic micro-pollutants in the furnace exhaust gases, especially PCDD/F, by injecting activated carbon or lignite powder into the off-gas stream. Further details are contained in the EU BREF Note on iron and steel making[16].

2.11 Secondary steel making

'Secondary steel making' covers the processes and treatment of molten steel after tapping of the primary steel making furnace (BOS or EAF) up to the point of casting. Secondary steel making is typically carried out at ladle treatment stations in order to:

O reduce the sulphur and carbon in the steel;

O deoxidise the steel;

O adjust the chemical composition in other ways;

O homogenise or mix the steel;

O adjust the temperature for downstream casting operations;

O remove undesirable gases such as hydrogen and nitrogen; and

O remove non-metallic inclusions.

A ladle treatment station also acts as a buffer, to enable easier 'sequencing' of ladles at the continuous casting plant.

The ladle of molten steel is usually transferred between stations using an overhead crane or ladle transfer car. There is a range of treatment techniques available, but ladle treatment stations in bulk steel production plants usually involve either a vacuum generating system or arc heating or a combination of both. Other treatment stations employ inert gas, wire feed or powder injection equipment. The range of these processes is shown in Figure 2.6.

Ladle furnace processes
A ladle furnace is similar in principle to an arc furnace, except that the electrodes heat the molten steel in the ladle.

Alloying and micro-alloying agents used in secondary steel making include: aluminium, manganese, silicon, magnesium, calcium, cerium, molybdenum, tungsten, nickel, vanadium, chromium, lead, boron, titanium and niobium. Additives are usually introduced either as ferro-alloys or elementally.

Pneumatic injection systems are also used for certain refining processes, using argon or nitrogen as a carrier gas and a refractory-clad lance for subsurface injection of the reagents into the melt. The types of reagents used include:

O lime and lime-fluorspar mixtures to remove sulphur and phosphorus;

O calcium carbide and calcium silicide powders to remove sulphur and modify the sulphide inclusions;

O micro-alloy powders to improve the mechanical properties of the finished products; and

O injection of lead shot to produce steel with good machinability.

Figure 2.6 *Secondary steel making*

CAS = Compositional Adjustment by Sealed Argon Bubbling

CAS.OB = CAS plus Oxygen Blowing
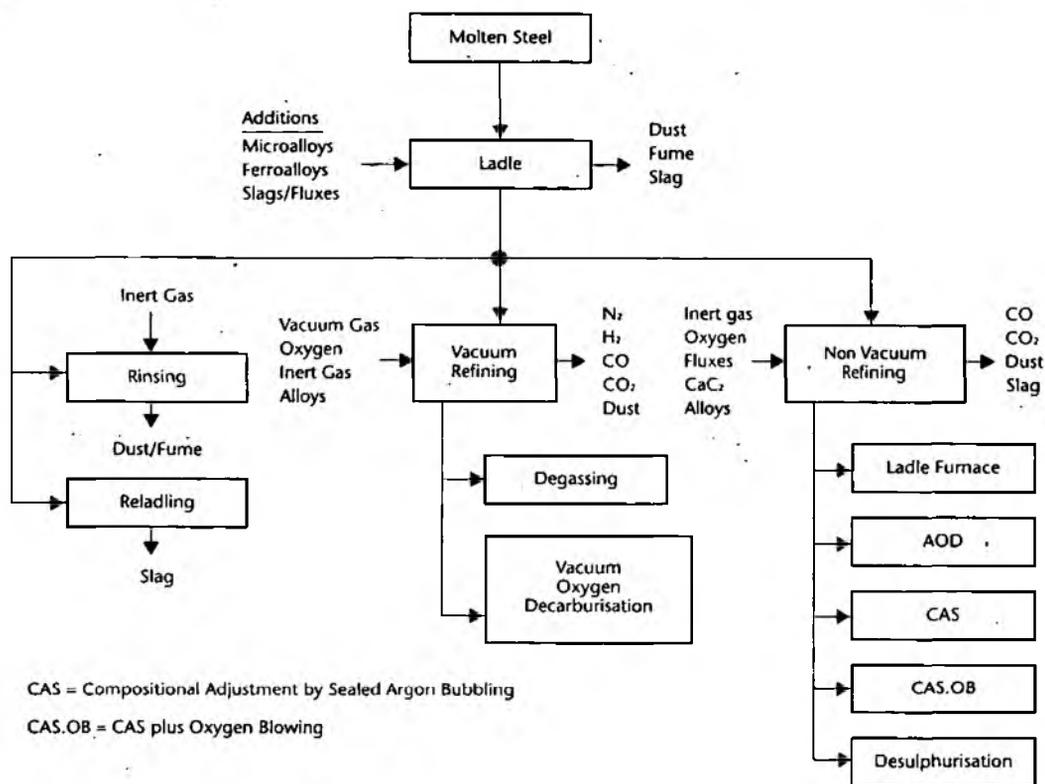
These latter operations are normally carried out at a dedicated lead addition station or at the ladle furnace station. The attention of Agency staff is drawn to the potential fume generation of this process and the special precautions necessary.

Vacuum treatments

Secondary steel refining can involve placing the ladle inside a vacuum degassing facility (e.g. RH or DH degasser) to remove dissolved hydrogen and nitrogen. Oxygen is removed using solid deoxidants, with some of the oxides floating out during degassing.

Vacuum oxygen decarburising (VOD), which is used for alloy steel production, involves injecting oxygen through a lance into a ladle of molten steel under vacuum conditions in a sealed vessel to oxidise the carbon to low levels. Carbon can be reduced to very low levels in this batch process.

Vacuum arc degassing (VAD) is a process in which a ladle furnace is operated under vacuum conditions, thus providing a facility to heat, degas, add alloys and treat the slag in a closely controlled environment.

Non-vacuum treatments

The argon-oxygen decarburisation (AOD) process is used for decarburising low-carbon stainless steel and nickel alloys and is carried out in a converter vessel, similar in design to a BOS vessel. Initial melting is carried out in an electric arc furnace. The melt is then transferred by ladle and poured into the AOD converter, where the argon-oxygen gas mixture is injected into

the bath through tuyeres. The refined stainless steel and slag are tapped off by rotating the converter. High-temperature off-gas, containing a significant quantity of carbon monoxide, is generated.

There are variants to the conventional AOD process, such as the CLU (Creusot Loire-Uddeholm) furnace, where steam is injected as a partial substitute for argon during part of the steel making cycle.

Induction melting

Induction melting in air is used in the manufacture of a wide range of alloys and ferro master alloys. The process, which is operated on a batch basis, consists of a tilting refractory-lined crucible or rammed monolithic lining, surrounded by a water-cooled, electric induction heating coil. Additions are made and a slag produced to remove unwanted impurities. The charge normally comprises recycled scrap, remelt ingot, alloying additions and fluxes. The process is primarily a melting and alloying operation and is only capable of carrying out limited refining.

Vacuum induction melting

The vacuum induction melting (VIM) unit consists of a vacuum chamber containing the furnace, with facilities for making alloy additions and casting.

Induction melting under vacuum is used in the manufacture of complex super-alloys and nickel-based alloys. If required, such alloys can be subsequently refined by electroslag remelting or

vacuum arc remelting processes, or a combination of both, to achieve the required metallurgical and mechanical properties.

Vacuum induction melting can also be used to manufacture nickel/cobalt master alloys without further refining. The entire operation, including melting, making additions, sampling, tapping and casting, is carried out under vacuum, and produces either ingots for hot working or electrodes for remelting.

Vacuum arc remelting
In this process, a steel ingot electrode is continuously remelted by means of a DC arc passing between a water-cooled copper mould and the ingot under a vacuum of around 0.15 mbar or below. The electrode melts and falls as droplets into the mould, where it solidifies. No slag is involved. The controlled slow solidification improves the directional structure of the re-cast ingot and increased purity is achieved.

Electroslag remelting
This process involves remelting an ingot into a water-cooled copper mould at atmospheric pressure. The melting process is by AC or DC resistance heating of a liquid synthetic slag held between an electrode and the surface of the ingot to be remelted. The slag comprises a mixture of mainly fluorspar, with some lime and alumina. As the alloy melts, droplets fall through the slag and collect as a pool in the bottom of the mould. Reactions between the slag and the metal enable the metal to be refined, with particularly good removal of oxide particles and non-metallic inclusions.

Ferrous alloy powder/shot production
The water atomisation method of manufacturing ferrous powder/shot involves charging raw materials into an induction or arc furnace for melting to the required specification. The resulting molten metal is poured into an atomiser, where it is blasted with high-pressure water. This forms an aqueous slurry of powder/shot, which is allowed to settle in a collection tank. The product is dried, blended and sieved.

The gas atomisation method of ferrous powder production involves the melting of a charge of raw materials in either an induction furnace at atmospheric pressure or a vacuum induction furnace. The resulting molten metal is atomised into fine droplets by supersonic jets of nitrogen or argon gas. At the bottom of the atomising tower, solidified powder and gas are extracted to a gas separator, where the bulk of the powder drops into a collector. Any fine particles are removed from the process gas by cyclone. The powders are then blended and sieved.

Ferro master alloy production
Manufacture of ferro-boron is achieved by the carbon reduction of boric oxide using an open-top DC electric arc furnace. The ferrous material is charged to the furnace via a vibrating feeder. The molten metal is cast into small ingots.

Ferro-titanium is manufactured by melting ferrous and titanium scrap in an induction furnace at atmospheric pressure. The attention of Agency staff is drawn to the potential fume generation of this process.

2.11.1 Potential release routes from secondary steel making

Releases to air
Secondary metallurgical techniques can produce large quantities of metallic fume.

Releases to water
Liquid ring pumps and steam ejectors are a possible source of water contamination when using vacuum treatment processes.

Releases to land
Relatively small quantities of slag and dust are produced. Waste refractory is generated when ladles and other equipment handling molten metal are relined.

2.11.2 Control of releases arising from secondary steel making

Control of releases to air

Ladle treatment (non-vacuum)
Collection of fume generated by a ladle furnace is achieved by a refractory-lined or water-cooled hood incorporated into the roof of the furnace. The fume is ducted to a fabric filter, which may be separate or common to the fume cleaning system of the EAF(s). Where decarburisation is undertaken in the ladle, high fume temperature will be experienced and fume cooling should be included to protect the downstream fabric filter plant.

The control of fume emissions during steel desulphurisation is achieved by a specially designed hood or lid placed over the ladle, with extraction to a dedicated bag filter system. Appropriate means should be provided to prevent release of dust to air during the transfer and storage of reagent powders. Fabric filters are considered to be BAT for the treatment of emissions to atmosphere from non-vacuum secondary steel refining plants. It is important that the hood is well designed and the extraction volume is adequate for the application.

In the argon-oxygen decarburisation (AOD) process, an extraction hood, which can be water-cooled or refractory-lined, captures fume at the mouth of the converter vessel. The fume generated, together with induced air, is extracted through the hood. The excess air combusts the CO arising from the process and also provides some cooling by dilution. The fume temperature is reduced by heat losses to the water-cooled ductwork of the fume extraction system. However, in order to protect the bag filter plant, further air dilution or a heat exchanger will normally be required.

Ladle treatment (vacuum)
Fumes or gases arising from the VOD or VAD processes should be extracted via an indirect cooler into the vacuum system, which acts as a wet scrubber. The cleaned fume is then exhausted to atmosphere by a stack. BAT for vacuum generating equipment utilised in bulk vacuum secondary refining is either multi-stage steam ejectors or a combination of ejectors and water ring pumps. These systems are the most effective method for achieving the required operating vacuum and minimising emissions to air and water.

The vacuum oxygen decarburisation (VOD) process may require the installation of a burner system in the stack, in order to avoid the discharge of higher levels of CO.

Electroslag remelting
An effective capture system for removal of particulate matter from the fume generated during electroslag remelting should be installed and ducted to a fabric filter. Filter bags should be pre-coated with lime to capture HF, which is generated from the calcium fluoride present in the slag.

Special alloy processes
Induction melting equipment and DC furnaces for manufacturing ferro-alloys should incorporate a movable hood linked to a fume extraction duct and bag filter system.

In the case of production of ferro-alloy powders by gas atomisation, a gas/powder separator should be followed by a suitably designed cyclone collector for final capture of small particles. Particulate matter emitted during the processing of alloy powders should be collected by a hood and captured by a fabric filter. Pyrophoric powders may need to be vented through a wet scrubber or irrigated cyclone or other safe system.

Control of releases to land

Most slag from secondary metallurgy is processed for iron recovery and is then landfilled. Waste refractories are normally landfilled.

2.12 Slag handling and processing

Ironmaking slag
In modern blast furnace operation, around 300-350 kg of slag is produced for every tonne of iron. The molten slag may be processed in a number of ways, depending on market demands for the by-product materials and slag processing facilities available.

Substantial amounts of slag are tapped directly into pits where, after air and water cooling, it is crushed for use as aggregate in road and rail construction, as a sewage bed filtration medium and as back-fill material.

Lower quantities of slag are processed into granulate. In this process the slag tapped from the furnace is poured on to a jet of water to granulate the molten slag, which falls into a tank where cooling continues. The granulate is dewatered and the process water cooled in a recirculating cooling system. The resulting product, which has a high moisture content, is dried and subsequently ground for use mainly as a pozzolanic cement for concrete.

Expanded or pelletised slag is produced by pouring molten slag on to a water-sprayed revolving drum, which is designed to throw the semi-molten slag into the air for sufficient time to allow it to form a pellet. This process uses less water than slag granulation and produces a product that can be used for fire-resistant wall panels, insulating bricks and structural infill.

A number of dry or semi-dry slag processing techniques are under development but are not yet commercially proven.

BOS slag
Slag from the BOS process is usually poured directly into slag pots and transported to the slag processing area using purpose-built heavy-duty mobile carriers or poured into slag pits and removed using excavators and trucks. After crushing and processing to recover steel entrained in the slag, the material is less useful than blast furnace slag because of its chemical composition and mechanical characteristics. Some BOS slag is recycled to the blast furnace and the sinter plant to recover the lime and combined iron, and limited markets have been developed to use the material in road making after 'weathering', and in agriculture as a liming agent and soil conditioner. BOS and secondary steel making slags that cannot be utilised in such markets are landfilled.

EAF steel making slag
Slag is poured from the furnace either into pots or on to the ground below the furnace. When slag pots are used, these are normally transported by road on purpose-built heavy-duty mobile carriers to a slag tipping area. The molten slag is normally cooled with water sprays and, after solidification, the slag is recovered by an excavator, prior to crushing, screening and magnetic separation to recover scrap metal for recycling and slag for sale.

Some EAF slags may contain a high proportion of lime. EAF slags are usually 'weathered' in the open air for a period of at least a few months to hydrate the free lime before use as roadstone or other construction material.

2.12.1 Potential release routes from slag handling and processing

Releases to air

Significant quantities of fume can be released during handling of the various types of slag. This can occur during the tipping of molten slag, and the breaking and crushing of solidified slag. The main pollutants are dust, fume and, in the case of blast furnace slag, also SO_2 and H_2S.

Releases to water

The recirculating water of granulation plants for blast furnace slag becomes strongly alkaline and contaminated with suspended solids and a range of dissolved species.

Releases to land

Slag that can not be processed for re-use or commercial applications is disposed of to landfill.

2.12.2 Control of releases arising from slag handling

Control of releases to air

Iron making slag handling and processing
Slag granulation processes are generally preferable to traditional slag cooling methods from the environmental viewpoint, because the process can be enclosed, the gases can be dispersed

more effectively via a stack, less water is consumed and more of the sulphur remains in the slag rather than being emitted. Gas cleaning and dedusting systems can be retrofitted to slag granulation equipment, which is not completely enclosed.

Pelletisation is a crude form of granulation, with a lower water-to-slag ratio, which can be more effectively controlled than traditional slag pit cooling from the environmental viewpoint. There are significantly fewer examples of slag pelletisation processes than modern slag granulation plants, which are used throughout the world.

It is an important BPEO consideration that each of the three types of blast furnace slag has distinct properties, which have commercial value in different market sectors. In order to maximise recycling, all three types of slag are required in quantities that are largely driven by market demand. However, because of the environmental benefits, granulation processes are considered BAT for new slag treatment facilities, and operators should be encouraged to convert existing slag pit processes to the maximum extent permitted by the market capacity.

There are developments towards a dry air-cooled granulated slag process (i.e. granulation in air, with no water-cooling). Since a dry granulating process could offer environmental benefits, this development should be kept under review by Agency staff.

While hot, the sulphur in the blast furnace slag reacts with air to release SO_2. When water is added, H_2S is produced by the reaction of water on hot CaS and MnS. It appears that controlling the pH of the cooling water to between 7.5 and 9.5 may inhibit this reaction, which can be particularly significant in slag pit cooling. There is, however, a general shortage of knowledge on the quantities of pollutants emitted from slag pit cooling and of the methods that will most effectively control such emissions. Since slag pit cooling will continue to be used for some time, operators should be encouraged to investigate and recommend improved methods of pollution control.

Water used for quenching should be free from substances such as ammonia, which may give rise to odorous or toxic fumes. This must be taken into account when developing the overall water treatment and recycling strategy (see Section 3.4).

BOS slag handling
Different types of slag arise during the BOS steel making process. The largest amount, known as primary BOS slag, is produced in the converters. Smaller quantities of other slags, with different properties, are produced during the hot metal pre-treatment and secondary steel making processes.

EAF steel making slag handling
In circumstances where traditional tipping and excavation of solidified slag take place within the steel plant building or in the open air, operators should use appropriate techniques to minimise the emission of fume and dust and the impact of such emissions.

Where tipping of molten EAF slag and excavation of solidified slag take place outside the steel plant building, there may be merit in the provision of a purpose-built building enclosure to contain the particulate emissions associated with these activities.

Control of releases to water

Where water-cooled blast furnace slag pit methods cannot be replaced by alternative technology such as slag granulation, the water used should be collected and recycled. Whilst this can be difficult due to the 'cement-like' characteristics of the solids, operators should be encouraged to establish the appropriate technology as quickly as possible.

Apart from contamination by suspended solids, the water used for slag processing can become strongly alkaline by solution of the free lime. Depending on the source of the slag, the process water can also become contaminated with a range of other dissolved species, including ammonia, cyanide and hydrogen sulphide in the case of blast furnaces.

The waste water from blast furnace slag processing should be treated by pH correction, settlement and oxidation, where necessary, to destroy cyanide.

Control of releases to land

Slags from iron and steel making are regarded as by-products that have potential commercial value. The actual value and degree of commercial exploitation strongly influenced by the market for each secondary product/by-product and economic instruments of Government policy, such as the Landfill Tax. Agency staff should encourage the utilisation of such by-product materials, where practicable.

There is a good market for blast furnace slag products in the UK and blast furnace slag is imported.

The ability to recycle a proportion of the BOS slag to the blast furnace is limited by the presence of elements such as phosphorus. Since all the phosphorus charged to the blast furnace is reduced into the hot metal, the phosphorus content

of the iron would progressively increase if too much phosphorus-rich BOS slag is recycled to the blast furnace. (This could jeopardise the specified chemical composition of certain steels.)

Whilst the metallic Fe entrained within the BOS slag is recovered by crushing, followed by magnetic separation, continued effort should be made to route the remaining residual slag away from disposal by landfill. Potential alternative routes include the use of BOS slag as a fertiliser additive or soil conditioner and use as a construction material, after aging to hydrate any free lime.

Depending on chemical analysis, EAF slag can be recycled as a civil engineering aggregate or roadstone, after an appropriate period of weathering, or used as an additive by the cement industry.

2.12.3 Emerging technology

The development of dry slag granulation plant should be kept under review.

For new plant, the so-called 'slagless steel making' processes may be considered. This involves pre-treatment of the blast furnace hot metal to remove silicon and phosphorus, prior to decarburisation in the BOS converter.

2.13 Continuous casting

The continuous casting process produces semi-finished products, such as slabs, blooms and billets. It has generally replaced the production stages of ingot casting, soaking pits and primary rolling mills, with resulting improvement in yield, energy consumption and operating costs. Molten steel is fed at a controlled rate into a water-cooled copper mould of appropriate cross-section. As the molten steel cools and forms a solid outer skin, it is drawn from the mould and is cooled by secondary water sprays, prior to discharge onto a roller table, where it is cut to the required length. Depending on the cross-section of the product, continuous casting machines normally have from one to eight strands. The cast product is normally of square or rectangular section, though 'dog-bone' shapes can be cast for rolling heavy section beams and round blooms are cast for manufacturing seamless tubes.

The molten steel is fed from the casting ladle into a tundish that acts as a reservoir to provide a constant ferrostatic head and as a distributor for multi-strand casting machines. Shroud tubes or inert gas shielding may be used between the ladle and tundish, and between the tundish and mould to limit the contact of the stream of molten metal with air. The steel begins to solidify in the copper mould, forming a shell, with a molten core. To prevent the solidified shell sticking to the mould, mould lubricant powder is added and the mould is oscillated in the direction of casting at a speed greater than the casting speed. After the point where solidification is complete, the strand is cut to the required length using automatic oxy-gas cutters. In the case of stainless steel, iron powder injection is employed for oxygen cutting.

2.13.1 Potential release routes from continuous casting

Releases to air

Small amounts of metal fume are released during the continuous casting operation.

Releases to water

The primary cooling water for the moulds and caster machinery is supplied by a closed circuit, which uses high-quality water. There are normally no releases to water from this circuit, apart from blow-down in the case of evaporative cooling systems and during major maintenance, when the cooling system may be drained. There may also be leaks from the system, at rotating joints, etc.
Releases to water from the recirculating cooling and treatment plant of the secondary spray cooling circuit comprise solids, in the form of scale, and oil/grease.

Releases to land

Scale is produced during the casting process, which is normally recovered for recycling.

Waste refractory material is generated when tundishes are relined and submerged entry shrouds/nozzles are replaced.

2.13.2 Control of releases arising from continuous casting

Control of releases to air

To enhance the quality of the finished product, the streams of molten steel between the ladle and tundish and between the tundish and mould are normally shielded from contact with air. This shielding has the added benefit of reducing fume generation.

The oxy-gas cutting equipment used when cutting stainless steel is fed with iron powder. This produces sufficient brown fume to justify fitting fume extraction and abatement equipment.

Leaded steels
When casting leaded steels or when making lead additions, the top of the ladle should be enclosed by a close-fitting canopy hood, with extraction to a fabric filter dedicated to treating lead-bearing fume. Careful consideration of injection plant design is required to minimise the risk of releasing lead fume. Tundishes should be covered and fume extraction provided for the tundish and the surrounding area. When an inert gas shield is provided, the vented gas should also be collected by the fume extraction system. Fume collection should also be provided around the mould area.

If oxygen lancing is used to clear the ladle nozzle, the fume should be confined and extracted, together with the other lead-bearing fumes.

Ladle cleaning, wrecking and repairing areas should be provided with dust control and collection equipment.

When cutting leaded steels, oxy-propane cutters should be fitted with a travelling enclosure to extract fume into the lead extraction system. All dust and fume within a leaded steel casting-area should be captured by a dedicated bag filter unit. Collected lead fume should be kept in sealed and marked containers and disposed of to a lead refinery for recycling or other safe disposal route authorised by the Agency.

Control of releases to water

The 'closed' cooling circuit normally has a primary circuit rejecting heat to a heat exchanger, and a secondary circuit, which cools the heat exchanger and rejects heat to atmosphere. The secondary circuit has a purge to control the concentration of dissolved solids as the water is evaporated.

The purge can be minimised by using good-quality make-up water and by attention to water treatment to minimise fouling and corrosion. Care should be taken to ensure that any additives such as biocides and scale/corrosion inhibitors are

minimised and that control systems and operational practices are designed to minimise the risk of accidental releases of such chemicals.

The recirculating 'open' cooling water circuit becomes heavily contaminated with the scale removed during casting. The water can also become contaminated with tramp hydraulic oil, · lubricating oil and grease escaping from the process equipment. The spray cooling water is discharged from the machine into a scale pit, which captures the heavier scale and then passes to a clarification system for settling the finer particles of scale, which can be contaminated with tramp oil. The spray water is commonly polished by sand filtration prior to or after cooling in an evaporative cooling tower. Sand filtration helps to ensure low levels of particulate and oil contamination to achieve satisfactory prolonged operation of the secondary spray nozzles of the casting machine.

If sand filters are employed, equipment to recover the backwash water should also be installed.

The bleed from the open circuit to control the level of dissolved solids should be taken from downstream of the sand filtration plant to minimise the discharge of suspended solids and any oil/grease contamination.

Effective oil separation and removal is essential at both the scale pit and, more importantly, the clarification system of the open cooling circuit. Operating management should adopt appropriate procedures to monitor oil consumption and control leakage from the continuous casting plant.

Control of releases to land

Scale is removed from the open cooling circuit at various points, including the scale pit, sedimentation tanks, clarifiers and from the backwash recovery system of the sand filtration plant.

This scale is normally relatively free from oil, unless abnormal leaks occur. In the case of integrated steel works, the scale can be recycled at the sinter plant or, in the case of EAF plants, either recycled to the arc furnace or sold to other outlets, such as cement manufacturers. Waste refractory is normally landfilled.

2.13.3 Energy conservation measures (IPPC)

Energy consumption associated with preheating tundishes and the sequestered energy in the yield loss at the start and finish of a cast can be reduced by 'sequence casting', where successive ladles of steel are processed by the casting machine without interruption. This technique requires good operational practices and infrequent changes to the grade of steel being cast.

Where plant layout permits, the operator should explore the potential for 'hot connecting' the caster to the rolling mills. In the case of thin slab casting, this may be via 'direct' connection, where cast steel passes through an equalisation furnace before rolling, or in other cases, may be 'indirect', where warm steel is charged to a conventional reheat furnace.

2.13.4 Emerging techniques

'Near net shape' casting techniques and thin slab casting techniques are being increasingly applied throughout the world, particularly when new plants are being constructed or existing plants modernised. In such processes, a product that is nearer to the finished shape is produced in the casting machine and directly rolled to the finished product without the roughing mill stage and minimal or no reheating. 'Near net shape' casting techniques operate successfully at a growing number of plants worldwide and should be considered as an available technique for future developments.

2.14 Ingot casting

Ingot casting is the traditional method of forming molten steel into a solid shape for further processing. Continuous casting has largely replaced ingot casting within Western Europe, except in special circumstances such as the production of large forgings or small quantities of special steels.

Ingot casting involves pouring molten steel into open-top cast iron moulds, the dimensions of which depend on the final product and process route. The moulds may be filled from the bottom or the top and may be connected together through a runner system, so that a number of moulds can be filled simultaneously from a single pouring point. The moulds are usually pre-coated with a proprietary compound to facilitate removal of the ingot from the mould and may be part lined with refractory tiles to improve the internal metallurgical structure of the ingot on solidification. Dust is created during stripping of ingots from the moulds and runners and also when ingots are dressed to remove surface defects using oxygen lances or mechanical grinding.

2.14.1 Potential release routes from ingot casting

Releases to air

Metallic fume is released during ingot casting.

2.14.2 Control of releases arising from ingot casting

Control of releases to air

Appropriate fume collection and abatement is necessary to control the releases from ingot casting.

As in the case of continuous casting, dedicated fume extraction equipment and cleaning is essential when leaded or beryllium steels are produced.

2.15 Scarfing

Surface rectification of semi-finished products such as slab and bloom is performed by grinding or scarfing. Grinding is typically used for cold surface conditioning of ingots prior to reheating and rolling and is carried out either manually or by machines. Billets for special products such as cold heading qualities are usually surface conditioned by machine grinding.

Scarfing involves the removal of a thin surface layer of the slab or bloom by localised melting using an oxy-fuel flame. The flame rapidly melts the steel surface, blowing it away as the burner head automatically traverses the feedstock or vice versa. The scarfing head contains a number of flame cutting nozzles, which are designed to adjust to accommodate different size workpieces. After passing the scarfing head, the conditioned surface is scoured by water jets in order to remove the scale. The operation generates large volumes of moist iron oxide fume.

Spent water and slag are collected in a flume beneath the scarfing machine and are either treated in a dedicated water circuit or transferred to the water treatment plant of a nearby mill or continuous caster. The saturated fume produced by the scarfing operation is extracted, cleaned by a wet electrostatic precipitator or fabric filter plant and discharged to atmosphere via an exhaust fan and stack. In the case of fabric filters, care must be exercised to minimise the risk of 'blinding' the filter media with moist fume. In some cases, reheating of the fume above the dew point may be necessary to avoid the risk of blinding.

Depending on the type of product and quality requirements, blooms or slabs can be 'hot scarfed' after leaving the primary mill or continuous caster, prior to entering the finishing mill. Alternatively, the blooms or slabs can be allowed to cool for inspection before selective hot or cold scarfing to remove identified surface defects, such as cracks, scale inclusions or seams.

Scarfing can remove defects to a depth of around 4 mm, although it is not always economic to cut to the depths required to remove the deepest inclusions. The metal loss due to scarfing is typically of the order of 2-3%.

2.15.1 Potential release routes from scarfing

Releases to air

The main releases to air from the scarfing process are particulate fume and combustion products.

Releases to water

Releases to the water, which is transferred to the water treatment plant, comprise solids in the form of scale and sludge.

Releases to land

Scale and sludge are removed from the recirculating cooling water system.

2.15.2 Control of releases arising from scarfing

Control of releases to air

Efforts should always be made to improve the steel casting processes, so that rectification by scarfing is minimised. Dense brown fume is produced by scarfing using oxy-fuel torches. Hence, any such rectification work should be carried out in dedicated areas, with extraction to fabric filter units.

BAT for the treatment of the wet corrosive fume containing a high proportion of sub-micron particulates generated by a hot scarfing machine is either a wet electrostatic precipitator or media filter, which may need to be protected against blinding.

Continued efforts to optimise the continuous casting process may eventually lead to scarfing being mainly restricted to the feedstocks used for the highest surface quality rolled products.

Control of releases to water

The 'scour' water circuit becomes heavily contaminated with scale and slag removed during the scarfing operation. The spent water usually passes from the flume into a scale pit, which captures the heavier scale and slag. The water is then transferred to the treatment plant of the scarfing facility or the water treatment plant of the associated continuous casting plant or rolling mill.

Control of releases to land

Scale and sludge recovered from the water system should be recycled back to the steel making process where practicable.

2.16 Rolling

Rolling mills are classified by the type of product that they roll, the configuration of the rolling equipment and whether rolling is carried out 'hot' or 'cold'. Rolling processes can be divided into the following main categories:

- Hot rolling - flat products (strip and plate)

- Hot rolling - long products (rod, bar and sections)

- Cold rolling - strip

- Hot finishing - finishing processes applied to hot rolled products

- Cold finishing - finishing processes applied to cold rolled products

Hot rolling

Hot rolling mills roll slab, bloom or billet feedstock into hot rolled products such as strip, plate, sections, rod and bar. In a few instances, for quality reasons, ingots are processed by a primary mill into semi-finished feedstock before hot rolling into finished products.

The cast or rolled feedstock is preheated to rolling temperature in a reheating furnace (see IPC Guidance Note 2 S1.12). Following discharge from the reheating furnace, the feedstock is transferred to the mill via roller tables. During transfer, jets of high-pressure water are directed at all surfaces of the hot feedstock to displace any surface scale. The scale and water are collected in flumes constructed beneath the roller tables. Water is also used as a coolant on the mill rolls to prevent 'fire cracking' and this is also discharged into the flume beneath the mill and roller tables. Grease and oil leaking from the mill lubrication and hydraulic systems may also be washed into the

flume. The dirty water is channelled to the mill scale pit and then pumped to the water treatment plant, where contamination is removed and the water is cooled before being recycled to the mill.

Most strip, rod, bar and section rolling mills for high-volume production consist of a number of single-pass mill stands. Lower throughput facilities may have stands arranged 'cross country', with the rolls reversing in direction between passes. In the case of plate production, high-volume production may be obtained in a single reversing stand. In all cases, a flume is arranged to collect the cooling water to return it for treatment and recirculation.

Utilising the residual heat from the continuous casting or primary rolling process by charging the reheat furnace with hot feedstock can reduce the fuel consumption of the reheat furnace. However, sophisticated quality control methods, consistently high-quality cast product and effective coordination of the scheduling of the process plants are necessary preconditions to achieving a reasonably high 'hot charging' ratio.

When surface defects such as cracks, scale inclusions and seams are apparent on the slab, bloom or billet feedstock, it may be necessary to carry out remedial actions before hot rolling. The remedial action may include complete scarfing of the feedstock surfaces (see Section 2.15). This is often the case with steel slabs for making strip that is destined for automobile use.

Steel producers endeavour to minimise the need for surface conditioning by good casting practices, because the rectification processes can result in high yield losses.

Cold rolling

Cold strip mills process hot rolled strip in the form of coils to reduce the thickness of the strip to the final gauge. Cold reduction also leads to an increase in the tensile and yield strength of the material and improves the surface finish. However, the reduction process leads to a loss of ductility.

The loss of ductility can be reduced by annealing. Annealed strip is normally subject to a further finishing step of 'temper rolling', where the thickness of the strip is only fractionally reduced to attain the correct degree of temper and surface finish.

The process of cold reduction at high speeds leads to the generation of heat, which raises the temperature of both the product and the rolls. The heat generated is dissipated by spraying oil emulsions on to the product surface and the rolls. The resulting temperature of the steel product during rolling ranges between 70 and 200°C. The oil emulsion is collected in a sump beneath the mill and transferred to the treatment system of the emulsion coolant.

Temper rolling is employed to develop the required degree of stiffness and to improve the flatness and surface finish of annealed products. Owing to the light reduction in temper mills and the high degree of surface finish, machine cooling is not required, although oil may be applied to the strip at the

supply and delivery reels to aid rolling and guard against surface reoxidation.

Finishing of flat and long hot rolled products

The finishing processes that are commonly applied to hot rolled flat products are pickling, oiling, skin passing, edge trimming and cutting to length.

The pickling process is used to remove mill scale from the surface of the hot rolled strip and to edge trim the strip to the finished width. After pickling, the strip is oiled to prevent corrosion of the strip surface.

Light rolling in a skin pass mill is often applied to hot rolled strip to improve the surface finish of the hot rolled material. An elongation of less than 5% is made during the single pass.

When customers request hot rolled strip as sheets, they are produced in a cut-up line, which processes hot rolled coils into sheets of the sizes required.

Hot rolled strip products can now be rolled in some mills at less than 1.0 mm thick. In these circumstances, hot finishing facilities may be required to process gauges previously only processed after cold rolling.

In the case of long products, the finishing processes applied at the rolling mill in the case of rod and bar usually involve some degree of controlled cooling during or following rolling at the finishing mill.

Special products such as railway rails and seamless tubes may undergo other processes to check and improve their physical properties.

In all cases, there can be special preparation and packing or bundling of the product prior to despatch to customers.

Finishing of cold rolled flat products

The cold finishing processes included in the cold rolling plant often include batch or continuous annealing furnaces, temper and skin pass mills, cleaning and tinning facilities, galvanising, painting, slitting and cut to length facilities. Equipment to wrap the finished product is also necessary.

In the cold mill and cold finishing area, efforts have been made to reduce yield losses by linking plants together. An example of this process integration is linking of a pickle line with a tandem cold mill. Yield improvements, reduced manning costs, lower space requirements and reduced stock levels result from such process integration.

Recent rolling mill developments

In recent years, there have been significant developments in the production processes for manufacturing hot rolled coiled strip, which reduce the energy costs of both re-heating and rolling, whilst also improving product quality and plant yields.

The main change has been the development of direct casting/ rolling plants, where instead of conventionally cast slabs with thicknesses above 200 mm, slab thicknesses below 100 mm are

cast and transferred via a roller hearth furnace directly to the hot strip mill. In some plants, rolling hot strip to a finished gauge of less than 1.0 mm has been achieved in this manner.

Such practices can reduce the fuel consumption for slab re-heating to approximately one third of that required in a traditional re-heating furnace. In addition, there are benefits of increased yield during casting and rolling. In the case of some finished products, the need to cold-roll the strip can be avoided by producing sufficiently thin hot rolled strip.

The costs of the equipment and associated building are lower for this new generation of production facility, compared to the costs associated with traditional casting and rolling practices.

In the case of heavy section mills, yield losses and energy consumption have been reduced by continuously casting 'dog bones', to eliminate the roughing mill activities.

2.16.1   Potential release routes from rolling

Releases to air

The main releases to air from rolling activities comprise oil mist and water mists. Releases of combustion products associated with reheat furnaces are covered by the IPC Guidance Note S2 1.12.

Releases to water

Releases to water of the 'open' recirculating cooling water systems mainly comprise suspended solids in the form of mill scale and oils and grease. The concentration of dissolved solids also increases because of evaporation in the cooling tower(s) of the cooling water system.

The releases from the 'closed' evaporative cooling circuits serving motors, hydraulic coolers, etc., is limited to the blow-down necessary to control the level of dissolved solids.

Releases to land

Clean and oily mill scale and sludge removed from the open cooling system are the main solid wastes produced by hot rolling processes.

2.16.2   Control of releases arising from rolling

Control of releases to air

Releases of oil and water mists are mainly a local nuisance and occupational health issue, which can be satisfactorily dealt with using local extraction and mist eliminators.

Control of releases to water

The design of the 'open' recirculating water system and associated water treatment plant of a rolling mill depends on the type of mill and the local circumstances. The typical arrangement for a hot rolling mill is described below:

● Scale is separated by gravity within scale pits and removed by dredging or other means.

● Fine suspended particles are separated by sedimentation clarifiers or settling ponds, assisted by flocculating agents. Concentrated sludge is then removed by dredging or pumped to thickeners and/or dewatering filters.

● Oil is removed from the surface of scale pits and sedimentation equipment by oil skimming belts, discs or mops.

● The build-up of dissolved salts and metals is controlled by discharging limited volumes of treated water, which is replaced by fresh make-up water. Oil releases are minimised by only discharging treated water and by using oil traps or floating oil booms at the discharge point.

● The cleaned process water is recycled.

Many mills utilise sand filters as a final water treatment stage, to reduce further the suspended solids content of the recirculating process water. In such mills, some of the clarification stages of the water treatment plant are often omitted. Where sand filters are installed, the filter backwash should be recovered in a dedicated settling system.

A high proportion of mill operators have replaced mineral oils in certain types of hydraulic system with 'high water-based fluids', on the grounds of fire prevention. These mixtures contain a small proportion of proprietary fluids and additives and require the use of stainless steel ancillary equipment. Loss of hydraulic fluid from damaged or leaking hydraulic systems often causes contamination of the water or emulsion treatment systems. In the case of mineral oils, this can place an exceptional burden on the oil removal equipment of the water system following a major loss. The use of water-based hydraulic fluids removes this problem and is considered to be BAT. However, the environmental consequences of discharging such fluids should be carefully examined and satisfactory procedures for their disposal adopted.

Treatment plants for cold rolling emulsion coolant

Batch treatment plants for emulsion coolant only process the emulsion to remove undesirable tramp elements associated with the rolling process before recycling the emulsion to the mill. The life of the emulsion may potentially be extended by using a treatment plant through which a proportion of the emulsion is continuously circulated. Such a treatment plant might typically include filters, a separator to remove tramp oils and a sterilisation system to destroy micro-organisms. Disposal of the spent emulsion is usually the responsibility of licensed waste disposal contractors.

The alternative to disposal of spent emulsion is a continuous emulsion treatment plant to recover the oil fraction. The technology employed varies but typically involves the following stages:

● The oil within the emulsion is recovered by breaking the emulsion by adding acids or coagulants and allowing the oil and water to separate. -

● The water is then treated to remove suspended solids by sedimentation in clarifiers or settling ponds, assisted by flocculating agents. Concentrated sludge is removed by dredging or pumped to thickeners/filters for dewatering.

● Traces of oil floating on the surface of the clarifier or settling pond are removed by oil skimming belts or mechanical skimmers.

● Dissolved solids within the recycled water are controlled by discharging limited volumes of clarified water as effluent. Oil releases are minimised by using oil traps or floating oil booms at the discharge point.

An alternative treatment process employs ultrafiltration and reverse osmosis. The process technology shows a reduction in the levels of oil and suspended solids in any discharges to controlled water. Both technologies for the treatment of emulsions are considered to be appropriate for existing plants.

If tighter effluent discharge controls are introduced, the releases from conventional treatment systems may require the introduction of ultrafiltration and reverse osmosis stages to achieve the lower release levels.

BAT for new plants is considered to be the application of ultrafiltration and reverse osmosis as the alternative to conventional emulsion breaking technology.

Control of releases to land

Clean scale from hot rolling can normally be recycled to sinter plants. Raw oily mill scale may not be suitable for recycling because of its oil content. However, if this material is blended with clean scale arising from other sources, the resulting homogenous blend may meet the quality requirements for recycling.

Disposal of clarifier sludge is usually to landfill.

2.16.3 Noise issues (IPPC)

Rolling mill activities often generate high noise levels. The equipment and activities that often generate the highest levels of noise are:

● Combustion air fans at reheating furnaces

● Air compressors

● High-pressure water descaling sprays

● Bar transfer along roller tables

● Bar entry between mill rolls, with sudden steam generation from roll cooling water

● Coiling activities in strip mills

● Cold bar/section transfer and transport in long product mills

---

● Hot and cold sawing

● Counting, bundling and stacking activities in long product mills (including tube mills)

● Straightening activities

● Despatch and product handling activities in general

● Scrap handling

Plant operators have endeavoured to reduce noise whenever practicable. This has sometimes been achieved by employing 'lift and carry' methods for bar movement, where this is feasible. Such methods have been introduced on transfer banks for plates and heavy sections. Hot saws, in some plants, are equipped with hoods to contain noise, and compressors and fans are often isolated to reduce the effect of the noise they generate.

Protection for operators in the form of noise-insulated control rooms is now common practice and the use of ear protectors in open areas is mandatory in most rolling mills.

2.16.4 Energy conservation (IPPC)

The efficient use of energy is necessary to reduce production costs and eliminate waste.

Development of 'near net shape' casting and 'hot charging' techniques can reduce energy consumption significantly, since the mill is fed with hot feedstock that is already part processed in the casting facility. Continued developments are taking place to reduce the rolling activities still further, particularly for the production of flat products. However, quality control issues and plant scheduling difficulties are significant barriers to increased use of 'hot charging' and 'direct rolling' practices.

Notwithstanding the potential benefits of such new practices, it is of paramount importance that the mechanical properties of the finished products are not adversely affected by such new techniques and that customer satisfaction is not jeopardised.

The development of sophisticated control systems has allowed significant yield and energy savings to be made. Plant yields have been improved by maximising prime material, reducing crop lengths and cutting losses, and also by minimising edge trimming to achieve the desired width.

The introduction of completely automated finishing end activities has led to a reduction in the amount of handling equipment required. This has reduced damage to finished products and resulted in less double handling, all of which makes a contribution towards better energy efficiency, through improved yield of prime product.

2.17 Pickling and cleaning

Note: Acid pickling is also dealt with in IPC Guidance Note S2 4.03.

During hot rolling, the surface of the steel oxidises to produce a thin layer of scale. The surface scale must be removed prior to cold rolling operations in order to avoid surface defects, poor roll life and high mill power consumption.

Pickling is the process of chemically removing surface scale by dissolving it in aqueous acid solutions, by means of a batch, semi-continuous or continuous process. Sulphuric or hydrochloric acids are normally used to pickle carbon and low alloy steels. Nitric and hydrofluoric acids are employed for stainless steels.

Bars, rods and tubing are batch pickled in tanks containing sulphuric acid. After sufficient time has elapsed for scale removal, the work is lifted out of the pickling tank, rinsed with fresh water and dried. (See also IPC Guidance Note S2 4.03.)

Hot rolled strip in the form of coils is pickled in semi-continuous or continuous pickling lines. The pickling operations and equipment within semi-continuous and continuous lines are almost identical and the processes only differ in the manner in which the strip is handled. Hydrochloric acid is now preferred to sulphuric acid for this process, since it is cheaper, pickles 2.5 to 3.5 times faster, is effective at lower temperatures and hence uses less energy, whilst acid consumption is lower.

Semi-continuous pickling lines process individual coils and may contain one or two individual coils to be pickled simultaneously. Uncoiling and re-coiling facilities are provided at the entry and exit of the line.

Continuous pickle lines accept a constant flow of strip, which is achieved by welding the tail end of one coil to the head end of the next. An entry side strip accumulator, capable of storing several hundred metres of strip, provides the time for welding without stopping the line. The strip is pushed through two individual tanks by sets of electrically driven pinch rolls. Acid is pumped from holding tanks through heat exchangers and flows through the pickling tanks counter-current to the strip direction. Iron and acid concentration are continuously monitored within the system, with acid being added via pumps when required. In the case of a sulphuric acid pickle line, the strength and temperature of the acid within the pickling tanks are typically in the ranges of 10-12% and 95-98°C respectively.

The spent acid concentration within the system is controlled by periodically bleeding off a set volume of the acid to a recycling unit, which can be of several types.

In the most common type of system used to recover the 'free' acid, the spent acid is filtered in two stages to remove suspended solids and is then passed through a resin bed to regenerate the acid. The resin retains the 'free' acid, allowing iron, water and acid-metal complexes to pass through to the waste-water treatment plant. When the set volume of acid is treated, a counter-current flow of water is passed through the resin bed for a predetermined period to strip the purified acid from the resin. The purified acid is recycled to the acid holding tanks and the above procedure is then repeated.

Other acid recovery techniques with similar environmental performance may also be employed. In larger plants, the 'roasting' technique is used to recover both 'free' and 'spent' acid, without generating a liquid effluent and producing a saleable iron oxide by-product.

Acid mists, which are produced above the acid tanks, are captured by a fume extraction system and treated by a scrubber before discharge to atmosphere. Proprietary inhibitors are added to the pickling acid to suppress acid mist evolution, and neutralisation chemicals are dosed to the scrubbers.

After pickling in acid tanks, the strip is rinsed in successive water tanks or spray chambers in order to remove acid carry-over present on the strip surface. Hot water is provided for the final rinse, in order to warm the strip surface and promote drying. Spent rinse water is treated within the water treatment plant. Hot air driers are provided for strip drying. Prior to recoiling, small quantities of oil may be applied to both sides of the strip in order to prevent reoxidation of the surface.

Additional cleaning techniques are used in some steel processing lines, particularly those where oil must be removed from cold rolled coil prior to further processing.

2.17.1 Potential release routes from pickling

Releases to air

Acid mist is the main concern regarding emissions to air from pickling operations.

Releases to water

Pickling and rinsing effluent is usually discharged to drain after suitable treatment. Acidic discharges, contaminated with dissolved metals, are the main concerns.

Releases to land

Sludge produced at the neutralisation/waste-water treatment plants is often disposed of by landfill.

2.17.2 Control of releases arising from pickling

Control of releases to air

The evolution of acid mists above pickling tanks may be suppressed by the addition of proprietary inhibitors. This will reduce acid loss from the pickling tanks and ultimately reduce any releases to atmosphere. The use of inhibitors is therefore considered to be BAT.

Extraction equipment used for capturing acid mists above pickling tanks should include a packed tower wet scrubber to reduce acid discharge to the atmosphere. The scrubber may also

be used to recover lost acid and is considered to be BAT. (See also IPC guidance Note S2 4.03.)

Control of releases to water

The use of multi-stage counter-current rinsing techniques reduces the overall rinse water requirements and consequently reduces the total quantity of effluent discharged to drain.

The level of effluent discharged from pickle lines can be further reduced by employing acid recycling plant to recover spent acid, which otherwise would require treatment before disposal. Acid recycling also offers a substantial reduction in acid costs and is considered to be BAT.

Relatively simple acid recovery plants only recover the 'free' acid. At larger plants, it can be economic to install more complex 'roaster' type facilities to recover both the 'free' and 'spent' acid.

The technology and configurations employed within the waste-water treatment plant of a pickling line can vary. The following is typical of the waste-water treatment commonly employed and is considered to be BAT:

- The acidic waste water is neutralised under pH control, using sodium hydroxide or calcium hydroxide.

- The waste water is then treated to remove suspended particulates in clarifiers or settling tanks, assisted by flocculating agents. The concentrated sludge is removed by dredging or by pumping to thickeners and is dewatered by filtration.

- The treated water is recycled or discharged as waste water. All waste water discharged from the steel works site must comply with the authorised conditions.

Control of releases to land

Where possible, opportunities to sell the iron oxide by-products of 'roaster' acid recovery plants should be pursued.

Operators should be encouraged to continue developing techniques to utilise waste sludges recovered from the waste-water treatment plants of pickling and other finishing processes.

2.18 Skull burning

Solidified ferruginous material from furnaces, slag pots, ladles, tundishes and scrap ingots are cut up to handleable sizes, in order to facilitate recycling and disposal. Thermic or oxygen lances are often used, producing large volumes of dense brown metallic oxide fume. To minimise nuisance effects, this work has traditionally been carried out in the open air at a remote part of the site.

2.18.1 Potential release routes from skull burning

Releases to air

The main releases from skull burning operations is iron oxide fume.

2.18.2 Control of releases arising from skull burning

Control of releases to air

The lancing operation to cut up skulls and other material should be carried out, either in a building or movable enclosure, using appropriate extraction and abatement facilities. The operator should investigate the parameters that minimise the production of fume (e.g. speed of cutting), and ensure that appropriate measures to minimise pollution are implemented. Injection of carbon dioxide can change the colour of the fume but slows the process, so that the releases continue over a longer period.

2.19 Release routes

Releases to the environment that are commonly associated with the various processes described in Section 2 are listed in Table 2.1.

Table 2.1 Potential release routes for prescribed substances and other substances that may cause harm [a]

Sources of releases [b]	Oxides of sulphur	Oxides of nitrogen	Carbon dioxide	Carbon monoxide	Hydrogen chloride	Hydrogen fluoride	Hydrogen sulphide	Ammonia	Oxides of iron	Alkali metals	Alkaline-earth metals	Metal oxide particulates	Non-metallic particulates	Metallic iron	Inorganic fluorides	Hydrogen cyanide	Cadmium and cadmium oxide	Zinc, lead and their oxides	Other metals and their oxides	Phosphorus compounds	Sulphur	Carbon	Other inorganic chemicals	Oils and greases	Slag waste	Sludges	Refractory waste	Dioxins	Volatile organic compounds
Raw material handling									Aw			Aw	Aw				W	w	Aw				AW	w			Aw		
Sinter plant: flue gas cleaning	A	A	A	A	A	A			A	A	A	A	A				A	A										A	A
secondary emissions								•	A	A	A	A	A																
Coal pulverisation													A											⌐					
Hot blast stoves	A	A	A	A																							L l		
Stockhouse									A		A	A	A																
Blast furnace primary gas cleaning			A	A				w	A	A	A	A	A		A	w	A	A		wl		A			wLl	wLl	L l	A	A
Casthouse	A								A	A	A	A	A														L l		
Desulphurisation	A		A	A					A	AL	AL	A	A								l				L l				
BOS: blowing (primary emissions)	A		A	A			A		A	A	A	A	A			A	A	A		Awl	A				wLl	wLl	L l		
BOS: charging/tapping (secondary emissions)			A	A					A	A	A	A	A	A	A		A	A			A							A	A
EAF:charging	A	A	A	A	A				A								A	A	A		A						A		A
EAF:melting and refining	A	A	A	A		A			A								A	A	A		A				Ll				Ll
EAF:steel and slag tapping									A										A						Ll				
EAF:furnace and ladle lining repairs									Al						Al		Al	Al	ALl				Al		Al		Al		
Alloy addition and injection	A								A									A	A						ALl				
Ladle treatments	A	A	A	A		A			A										A	A			A		wLl				
Reladling and recarburisation		A	A						A										A						ALl				
Degassing																l	Wl	wl	wLl						l				l
Decarburisation		A	A						A								A	A	A										
Electroslag remelting						A			l								l	l	Ll						Ll				Ll
Vacuum induction melting																									Ll				
Induction melting	A	A	A	A					A																Ll				Ll
Ferro master alloys																									Ll				Ll
Ferrous alloy powders														A					A										
Continuous casting									Awl			Awl						Awl	Awl					w	Ll				Ll
Ingot casting									Al			Al							Al						Ll				Ll
Scarfing	A								Awl			Awl						Awl	Awl							wl			
Slag processing	A						A		wl	wL	wL	wl	wl	wl	wl			wl	wl	wl	wl				wLl		Ll		
Skull burning									Al	AL	AL	Al						Al	ALl						Ll				
Rolling mills									wl			wl							wl					Awl	Awl				A
Acid pickling		A				Aw			wl			wl			wl				wl				Aw						A

[a] Substances include their compounds, except where separate reference to the compound is made. Releases to air may also be released to land or water, depending on the abatement technology employed, e.g. via collected dusts, sludges or liquors

[b] Source of releases to air, water and land. Prescribed substances (defined within SI 472): A, W, L; other substances: a, w, l.

3 Best available techniques for controlling releases

3.1 Introduction

This section covers general techniques for controlling releases that are common to many processes or are considered to be general in their application. Such techniques include the overall management of a steel works to minimise releases to the environment.

Apart from the specific BAT applicable to the steel industry described in Section 2 and in the reference documents issued by the European IPPC Bureau[16], the common techniques for pollution abatement are outlined in other reference sources including:

- Separation Processes Service[17], manuals and reports;

- Air Pollution Advisory and Review Group[18], reports;

- appropriate BAT review reports on pollution control issued by EA/HMIP;

- Technical Guidance Notes issued by EA/HMIP;

- Environmental Technology Best Practice Programme, Good Practice Guides (ETBPP)[19];

- Energy Efficiency Best Practice Programme Guides (EEBPP).

The techniques need to cover releases from raw materials reception/storage, internal transportation, processing, and storage of waste materials.

The processes should be designed and operated in such a way that the substances released have the minimum impact on the environment. As a general principle, there should be evidence in the application submitted by the operator that the releases of prescribed substances will be prevented, or minimised and rendered harmless, and that releases of other potentially harmful substances will be rendered harmless. This should then be confirmed by the conditions in the Authorisation. Since the priority is to prevent releases, emphasis should be placed on the avoidance where possible of processes and abatement techniques that create emissions or wastes.

Prevention, minimisation[20],[21] and recycling practices should be applied whenever possible, within the criteria governing BATNEEC and BPEO.

An applicant should review all available options and demonstrate that the selected combination of primary process and abatement equipment represents BATNEEC, and that the concept of BPEO is satisfied.

The generic techniques for controlling releases fall into three main categories:

- management techniques, relating to the procedures and practices for designing, building, operating and maintaining a process;

- process techniques relating to the use of available opportunities to reduce releases from activities such as storage, transportation and processing; and

- abatement techniques, relating to 'end-of-pipe' techniques for controlling releases to air, water and land.

3.2 Management techniques

Effective management is central to environmental performance and is an important component of BAT. It requires a commitment to establishing objectives, setting targets, measurement of achievements and revision according to results. This systematic approach may be aided by the achievement of environmental management standards such as ISO 14001 and EMAS[22]. The following is a brief summary of some of the common elements of an environmental management strategy.

3.2.1 Senior management commitment

Essential features in any environmental management system are that:

- all health, safety and environmental impacts of activities, products and processes have been identified and considered;

- there is a commitment to conform with statutory regulations as a minimum and work with authorities to develop and implement improvement measures where needed;

- employees and contractors are aware of the commitment and are involved in its delivery; and

- the company is open with information both inside and outside the organisation.

Whilst a company might not be a signatory to a formal initiative, it could still be expected to aspire to such principles.

3.2.2 Organisation and responsibility

There should be a clear structure for managing environmental issues in general and ensuring compliance with the IPC Authorisation in particular. This should be fully integrated with the process operator's wider company and site decision-making systems. Many sites have a management committee and it would be expected that environmental matters are represented on such a committee and discussed at regular intervals.

There should be a defined contact point for the IPC Authorisation. Usually, this requirement can best be met by having a single point of contact. This should be seen as clarifying the interface between the Agency and the process operator. However, it should not reduce the responsibilities of other members of staff for ensuring compliance with the Authorisation.

The environmental performance of a process is highly dependent on the motivation and knowledge of the process operator's staff and their attention to the environmental performance of the plant. They should be aware of this, and their role in achieving satisfactory environmental performance made clear. The company should reinforce the message to all staff that environmental protection is important to the company. One way to achieve this is to include environmental performance as a part of annual performance assessments.

Incidents have occurred in the past as a result of poor communication among operations staff during shift changes and maintenance or other engineering work. Specific procedures should be in place to avoid such problems.

The planning and scheduling of some of the batch processes used in the steel industry can influence waste production and energy consumption. The company operating such processes should be able to show that the opportunities to improve yield, reduce waste and conserve energy have been considered and, where favourable, implemented.

The overall environmental performance of the processes should be monitored and the results should be considered on a regular basis, as part of the management assessment process. Environmental performance indicators (EPIs) should be devised for this purpose, although the potential difficulties of deriving them for the various production mixes and differing extent of finishing operations within the steel industry need to be recognised.

A 'contingency plan' should be in place, which identifies the potential types of environmental incident that could occur and provides clear guidance on how such incidents will be managed and who is responsible. In some circumstances, these will need to be notified to the Agency as a condition of the process Authorisation.

Procedures should be in place to identify, respond to and learn from all complaints and incidents.

3.2.3 Maintenance

A programme of preventive maintenance should be in place and recorded, coupled with diagnostic testing where appropriate.

Records of process performance should be available and used to monitor trends of change in environmental releases that may signal the need for maintenance.

All staff should be aware of the role they can play by maintaining vigilance, for example, in relation to process upsets, spillage and leaks. Appropriate procedures should be

adopted to encourage staff involvement.
A procedure should be in place to authorise modifications and to undertake checks after modifications, prior to start-up of the process.

3.2.4 Process control

The operator should be able to demonstrate that the process is being adequately controlled. In many cases this will involve the use of computer-based systems, with facilities to ensure control in emergency situations.

The operator should also have appropriate procedures in place to deal with malfunctions or breakdowns that could lead to abnormal releases.

As noted above, there should be records of production and the associated environmental releases, together with a procedure to ensure that they are subject to periodic review.

3.2.5 Waste minimisation

Waste minimisation audits should be conducted periodically, in accordance with a prioritised programme. The Agency, amongst others, has issued guidance on waste minimisation[10],[11], whilst a number of 'Waste Minimisation Clubs' have been set up throughout the UK.

The active participation of staff should be encouraged in these initiatives, with recognition given to those who identify waste minimisation improvements.

There should be active monitoring of materials throughput and mass balances should be available for all processes. Monitoring should also include water, power, fuel, oxygen, acid and solvent use, as appropriate to particular processes.

Whilst the steel industry has made considerable progress in utilising by-product materials such as slag for use as 'secondary materials', Agency staff should encourage further efforts by operators to minimise, recycle or utilise the waste materials that are still disposed of by landfill. Such materials typically include electric arc-furnace dust, fume cleaning sludge, oily mill scale sludge and waste refractories.

Since the steel industry is a large consumer of water and electrical power, Agency staff should also encourage operators to identify and pursue potential conservation opportunities in these areas.

Many of the production costs of the steel industry are influenced by the 'yield' of intermediate and final product at the various stages of the manufacturing process. Improvement in yield normally has a direct environmental benefit in terms of energy conservation, emissions and waste.

3.2.6 Design

The environmental implications of a new process or product should be considered at the earliest stages of the project and should continue to be reviewed at regular intervals thereafter. This is the most cost-effective stage to introduce improvements in the overall environmental performance of a steel works.

There should be evidence that alternative process options were considered and assessed from the environmental viewpoint. It should be possible to maintain an audit trail of the design and decision making process.

3.2.7 Training

All staff should be aware of the regulatory and statutory implications of the IPC Authorisation for the process and for their responsibilities in this regard.

There should be a clear statement of the skills and competencies required for each job.

Training should be given to all staff involved in process operation and this should include the environmental implications of their work and the procedures for dealing with incidents that may have environmental implications.

There should be records of the training given to process operation and maintenance staff.

3.2.8 Finance and accounting

There should be a clear understanding of the costs associated with the generation of waste within the process. This can be achieved by having accounting practices in place that ensure that the direct and indirect costs of waste and other significant environmental costs are attributed to the processes involved and are not treated simply as a site overhead.

3.2.9 Commissioning

When a new or modified process is to be brought into service, it may be appropriate to apply requirements specific to the commissioning phase. These may include operation of the process in an abnormal manner in order to demonstrate the effectiveness of plant items or systems.

Aspects that should be considered include the following:

● The applicant or operator should demonstrate that the proposed trial is necessary, and should provide information on releases, and their environmental impact.

● The principles set out in Sections 3.2.1 to 3.2.8 apply to commissioning activities. In particular, attention should be paid to the management and training of commissioning staff.

● Where release limits set for normal operation can only be met after a period of process optimisation, the operator should provide details of the optimisation procedure to be followed, together with information concerning potential releases during that period.

Where appropriate, interim release limits should be set, which will provide for effective regulation of the process during the commissioning period.

3.3 Process techniques to minimise and abate releases to air

3.3.1 Particulate/fume emissions

The processes for the production, treatment or handling of molten iron and steel have the potential to generate dust and fume. Hence the primary objective should be to prevent/minimise the generation of dust and fume. Where this is not possible, the emissions should be captured by suitable arrestment equipment.

The appropriate abatement technique depends on the characteristics of the particulates, their concentration and the carrier gas stream. Process conditions such as temperature, pressure and dew point, together with plant lay-out and space availability, influence the choice of abatement technique.

Table 3.1 provides a guide to the selection of particulate arrestment plant. Important criteria when considering the installation of new plant are those related to the determination of BPEO. Arrestment plant that collects the particulate matter in a form that is re-usable is to be preferred. Dry abatement techniques, which avoid the potential risk of water pollution, would normally be preferred, unless the water treatment plant of a wet fume arrestment system achieves a dry cake and near 100% recycling of the water.

The following main techniques are used in the steel industry to abate the release of dust and fume:

● suppression at source;

● local containment and extraction;

● remote extraction; and

● roof extraction.

A combination of these techniques will commonly be required to eliminate the discharge of untreated dust and fume. Keeping air away from molten metal or slag by placing covers over runners and using an inert atmosphere at transfer points (e.g. from the furnace to transfer vessel) can sometimes achieve suppression at source. Where designs are shown to be fully effective, this is a preferred method for new and existing processes.

Where appropriate, simple methods of suppressing particulate/fume emissions at source should be adopted (e.g. slow pouring of molten metal during charging and tapping BOS converters and conditioning dusty materials with water sprays/mist).

Local containment is generally satisfactory for primary fume generation, where containment can be fully effective. For secondary fume releases, local containment and extraction can sometimes be difficult to design in a manner that does not impede operations, such as overhead crane movements, and can cope with sudden peaks of fume generated over short

Table 3.1 *Guide to selection of particle arrestment plant*

Particle size range (µm)	Type of Collector	Pressure drop (mbar)	Collection efficiency (%)			Maximum temperature (°C)	Condition of effluent	Dew point sensitivity	Effect of particle density
			at 5 µm	at 2 µm	at 1 µm				
> 150	Settling chamber	< 2.5	150 µm-50% >300 µm-95%			500	Dry	Fairly sensitive	Efficiency increases with density
> 10	Cyclones	2.5-10	5 µm-40% 20 µm-80% >50 µm-97%			500	Dry	Sensitive to plugging and corrosion	Efficiency increases with density
> 5	Irrigated cyclone	5-20	5 µm-50% 20 µm-95% >50 µm-95%			350	Wet	Not sensitive	Efficiency increases with density
> 5	Spray tower	5-17.5	94	87	55	350	Wet	Not sensitive	Little effect
> 3	Wet impingement scrubber	15-30	97	95	80	350	Wet	Not sensitive	Little effect
> 0.1	Ceramic filter	15-20	99.9	99.5	99	900	Dry	Sensitive	Little effect
> 0.5	High-pressure venturi scrubber	35-90	99.8	99	97	350	Wet	Not sensitive	Little effect
> 1	Medium-pressure drop wet scrubber	30-100	97	95	80	350	Wet	Not sensitive	Little effect
> 0.1	Fabric bag filter	8-18	99.8	99.5	99	220 (with special material)	Dry	Very critical	Little effect
> 0.5	Wet disintegrator	10-20	98	95	91	350	Wet	Not sensitive	Little effect
> 0.01	Dry electrostatic precipitator	0.6-2	99	95	86	375	Dry	Critical	Little effect
> 0.01	Wet electrostatic precipitator	0.6-4	98	97	92	375	Wet	Not sensitive	Little effect

periods. In these circumstances, consideration should be given to full or partial sealing of the roof of the furnace building, with high-level extraction to a bag filter plant.

Intermittent roof discharges of visible fume arising from primary, secondary or fugitive releases should be avoided. Where existing plants fail to meet this criterion, improvement plans to meet this standard of environmental control within an agreed timescale should be implemented at the earliest opportunity.

As a general principle, extraction to the abatement plant should maximise the collection of dust and fume at or adjacent to the sources of release. This will maximise the concentration of the particulate matter collected and minimise the volumes of 'dilution' air to be treated.

Agency staff should be aware of the health and safety implications of any proposals brought forward, and are advised to consult with the HSE on such matters.

The preferred abatement technique is dry filtration, wherever practicable.

Fugitive emissions

The potential for fugitive releases should be considered in the design of the equipment, in the plant lay-out and in the operating practices, in order to eliminate the release of untreated emissions. The degree of capture of both primary and fugitive emissions is commonly as important as the cleaning efficiency of the abatement equipment in determining the overall effectiveness of the pollution control systems. Consideration of such factors is therefore necessary to achieve the regulatory requirements in the most cost-effective manner. .

Suitable operational techniques should be employed to minimise fugitive releases, particularly during the handling of molten metal and dusty materials.

Roads and open storage areas should be hard surfaced where necessary and should be regularly cleaned and, if appropriate, damped down with water sprays in dry weather. Fugitive dust from open-air stockpiles of dusty materials can be minimised by appropriate techniques. Raw materials containing fines may need to be transported in sealed containers or in closed vehicles. Handling of alloy addition materials should be minimised by direct delivery to bunker systems. The number of material transfer points should be minimised.

Fugitive releases from process sources can be minimised by suitable process control to avoid surging, by sizing off-gas handling equipment to accommodate unavoidable peaks and, where appropriate, by maintaining a slightly reduced pressure inside equipment. Dust collection systems should be designed to take into account potential releases, which may occur during filling of bins, bunkers and silos. Where appropriate, such storage facilities should be fitted with level indicators and alarms.

Materials handling equipment should be enclosed, as far as is practicable, to minimise the escape of dust. Where effective

enclosure or dust suppression techniques cannot be used, extraction to a fabric filter should be provided. The dust captured by fabric filters should be handled in totally enclosed systems, from the filter to a storage silo or sealed transport containers.

Dilution air

Although the use of dilution air as a means of cooling hot gas streams prior to treatment in fabric filters is legitimate, where alternative cooling methods are available then the use of dilution is to be discouraged. Unnecessary dilution and air infiltration increase the volume of gas treated by the filter plant for the same quantity of particulate and therefore increases the demands on the abatement equipment and increases the power consumption of the extraction fan. Dilution can be minimised by optimum control of valve and damper positions on multiple off-take extraction systems and extraction flowrates can be optimised by using variable-speed extraction fans controlled by suitable closed-loop feedback signals.

3.3.2 Emissions of sulphur and nitrogen oxides

The emissions of SO_x and NO_x vary between steel works sites and depend upon individual plant design, operational practices, raw materials and fuel characteristics. Large integrated steel works sites are the major sources of these pollutants within the UK steel industry. In order to indicate the relative contributions of the various process plant areas, typical percentage releases of SO_x and NO_x from the UK integrated steel works sites are given in Table 3.2 below. Within the areas that are of concern in this Guidance Note, the control of SO_x from the sinter plant is considered to be an important issue and attention is drawn to the candidate BATs described in the European 'BREF' Note[19]. Wet or dry desulphurisation processes are applicable. In wet systems SO_2 is absorbed in a spray tower with a solution containing calcium or magnesium. Dry techniques are based on the adsorption of SO_2 on activated carbon. Such systems, which have large space requirements, and are expensive, would only be appropriate in circumstances where air quality standards are likely to be exceeded.

The use of lower calorific fuels, such as the by-product gases of an integrated steel works, will lead to lower peak temperatures and less NO_x formation than conventional fuel.

Thus burning of blast furnace or BOS gas in preference to natural gas has an added advantage. In Table 3.2 it has been assumed that BF gas is used in the hot blast stoves.

Table 3.2 *Typical percentage releases of SO_x and NO_x*

Plant area	% of total NO_x generated	% of total SO_x generated
Coke ovens	21-48	8-18
Sinter plant	21-57	22-31
Boilers	8-10	10-42
Blast furnaces and stoves	2-4	2-12
Steel plant	~1	~1
Reheat furnaces	9-17	8-30
Annealing, finishing and flares	~2	~1

3.3.3 Control of particulate emissions

The abatement of releases of particulates has been an important concern in the steel industry for many years. A wide variety of abatement techniques is available and Technical Guidance Note A3(23) is a primary source of information on BAT in this regard. The main abatement techniques that are available for the control of particulates are:

O   cyclones;

O   scrubbers;

O   media filters; and

O   electrostatic precipitators.

Cyclones

Cyclones, 'spark boxes' and similar devices are effective for the removal of particles with a diameter >10 μm and are often used as a pre-treatment device prior to fume cleaning in more expensive abatement equipment that can achieve lower release levels. This can reduce the risk of fabric filters being damaged by larger incandescent particles in the fume. There are two basic types of cyclone:

O   reverse flow; and

O   straight through.

These are differentiated by the geometry with which the gas stream enters the cyclone. The design of a cyclone will depend upon the characteristics of the gas stream that is being treated and the allowable pressure drop. Recent innovations have seen the development of cyclones containing a rotating impeller to improve the efficiency of dust removal.

Scrubbers

Scrubbers operate on the principle that particulates can be removed from the gas stream by dissipating their momentum. This dissipation can be achieved either by impacting the particulate on to the scrubbing liquid or by impacting a solid surface, which is then washed.

Scrubbing systems tend to be less effective than alternative abatement options for the control of particles <10 μm, unless high-pressure scrubbers are employed. They also generate an effluent that will require treatment and a wet sludge that can be difficult to handle and recycle.

Media filters

Media filters are widely used for the collection of particulates >1 μm and can usually achieve efficiencies of greater than 99%. The main variables that are considered when designing media filters are:

O   the gas temperature, humidity and particle sizes;

O . the filter medium;

O   the filter area and face velocity; and

O   the manner in which the filter is periodically cleaned.

Filter media

A variety of filter media are available to deal with a wide range of variables such as temperature, corrosiveness, composition, particle size, etc. Table 3.3 summarises the characteristics of some of the more important types of media commonly used.

Fabric filters can cope with a wide range of substances and operating conditions but there are limitations to their use, particularly with regard to the temperature and moisture content of the gas stream. For treating very high temperature gases, ceramic or steel mesh filters may be appropriate.

Table 3.3 *Materials utilised in fabric filters*

Common name	Generic name	Chemical resistance		Maximum normal operating temp. (°C)	Maximum peak temp. (°C)	Fire resistance
		Acids	Alkalis			
Cotton	Natural fibre cellulose	Poor	Excellent	80	105	Poor
Polypropylene	Polyolefin	Excellent	Excellent	87	87	Poor
Polyester	Polyester	Good	Fair	135	170	Poor
Glass	Glass	Good	Poor	260	287	Good
Nylon	Polyamide	Poor	Excellent	93	121	Poor
Nomex	Aromatic polyamide	Fair	Very good	204	218	Poor
Teflon	Polytetrafluoro-ethylene (PTFE)	Excellent	Excellent	232	260	Poor
Goretex	PTFE coated fabric	Excellent	Excellent	230	260	Poor
Dralon T	Homopolymer acrylic	Good	Excellent	140		Poor
Bekipor	Stainless steel	Good	Good	454	538	Good

Cleaning mechanisms

As particles build up on the surface of the filter medium, they initially aid the filtration mechanism but eventually begin to reduce gas stream throughput and the removal efficiency. Hence, fabric filters are fitted with automatic cleaning facilities that periodically remove the build-up of particles on the filter media. The main cleaning mechanisms available are:

● shaker - where the bag is shaken to dislodge the particulates;

● reverse flow - where clean air is passed through the filter medium in the reverse direction to the normal flow of the gas stream; and

● pulse-jet - whereby a pulse of compressed air is applied to the filter in the reverse direction to the normal flow of the gas stream.

Shaker cleaning has been largely superseded by the more efficient pulse-jet cleaning system.

Control of fabric filters

The main factors that are important for satisfactory control of the operation of fabric filters are:

● continuous particulate monitoring of the clean exhaust gas stack to detect deterioration of the filter bags;

● ensuring that the automatic cleaning systems prevent the operating efficiency of the filter being compromised by excessive build-up of captured particulates;

● ensuring that the dust removal system operates satisfactorily without spilling dust;

○ managing the operating temperature of the gas stream to avoid temperature excursions exceeding the recommended limits; and

● minimising the risk of fire caused by particles that are incandescent and avoiding the risk of explosion caused by explosive dusts or explosive gas concentrations.

Electrostatic precipitators

Electrostatic precipitators use an electrostatic field to charge the particles in a gas stream. The charged particles are then attracted to a grounded surface, from which they are periodically dislodged into a collection system.

3.3.4 Evaporative cooling towers

Several types of evaporative cooling tower are in common use. These include:

○ natural draught parabolic cooling towers; and

○ low-level mechanically assisted cooling towers.

Condensed plumes of water vapour from evaporative cooling towers that come down to ground level can include droplets containing biocides or organisms that could be harmful. Such plumes from very large cooling towers can also cause loss of light, poor visibility and icing of roads. For these reasons, plume grounding should not be permitted.

Where visible plumes of water vapour from evaporative cooling towers or other sources need to be abated, the temperature and the humidity must be controlled. This may be achieved by combining conductive heat exchange and evaporative cooling in the design of the cooling tower. The degree of abatement required will depend upon local conditions and the distance from the towers to the nearest sensitive area. When new large cooling towers are proposed, plume modelling should be employed by the operator to confirm that the visible (condensed) plume will not ground beyond the boundary fence nor reach areas of habitation at a height that will cause significant loss of light. (As a guide, the width of the plume should not fill an arc that subtends an angle greater than 10° when viewed vertically upwards from the ground.)

An operator may propose to guarantee to reduce load or to take other appropriate action to ensure that the above conditions are met. Where necessary, performance curves should be provided to demonstrate plume behaviour under a wide range of ambient conditions.

3.3.5 Vent plumes

Where possible, releases of humid gases from vents should be hot enough to avoid visible plume formation in the vicinity of the vent. Exhaust gases from a wet scrubber can be heated by using waste process heat to raise the exit temperature of the exhaust gases and prevent immediate condensation on exit from the vent. This procedure also assists the thermal buoyancy of the plume. Where there is no available waste heat and the vent contains no significant environmentally harmful substances, the applicant may be able to demonstrate that the BATNEEC/BPEO criteria have been met.

3.3.6 Dispersion from chimneys and vents

The applicant will need to demonstrate that an appropriate assessment of vent and chimney heights has been made to provide adequate dispersion of prescribed substances, and other substances that might cause harm, which cannot be prevented and may be released. Some guidance is given in Technical Guidance Note D1[4].

For all major sites, it is considered to be BAT for dispersion modelling to be carried out, taking into account local meteorological data, local structures and topography, as well as other local releases, to provide estimates of the contribution of the main processes to ground-level concentrations of significant pollutants under appropriate production and ambient scenarios. Agency staff should expect operators (or relevant experts acting for them) to produce and maintain an up-to-date multi-stack dispersion model for the steel works. Operators should provide clear information on the parameters used and the assumptions made in their use of dispersion models. Of particular relevance will be the assessment of

background concentrations of pollutants and the fate in the environment of the pollutants released. Statutory air quality standards[9] and other recognised criteria relating to international obligations should be taken into account.

When a significant change is being considered that could lead to an Authorisation variation (e.g. new plant with significant emissions, uprating of existing plant or major change in feedstock or fuel quality, which is outside the normal range). Agency staff should request a new dispersion model to be presented. This should take into account the proposed changes and show the environmental impact of making them.

Where appropriate, the operator should also recognise the possibility of a chimney or vent acting as an emergency release point. Process upsets or equipment failure that might create abnormally high release levels from a chimney or vent over short periods should also be assessed, taking particular account of acute toxic effects. Even if a low probability of occurrence can be demonstrated by the applicant, an appropriate value for the height of the chimney or vent should nevertheless be set to avoid risk of serious damage to health.

The assessments made by the operator should be validated using the appropriate calculations or dispersion models available to the Agency.

All releases must be controlled and minimised to ensure that ambient air quality beyond the process boundary complies, as a minimum, with the relevant air quality standards[7].

3.3.7 Odours

Any substances present in the emissions to air that are known to be odorous should be identified and quantified. Appropriate techniques should be employed to ensure that odours are minimised, to prevent them being noticeable outside the site boundary.

3.4 Minimisation and treatment of releases to water

3.4.1 Minimisation

Aqueous wastes generated by the processes in the iron and steel industry may contain a wide range of species, including cyanides, sulphides, dissolved organics, suspended organics, dissolved heavy-metal compounds, including sulphates and fluorides, as well as suspended solids containing high levels of ferrous compounds.

The characteristics of releases to water from an iron and steel plant largely depend upon the type of processes involved, quality of the feedstocks, the maintenance standards, the degree of water recycling, the sophistication of the process water and effluent treatment plants, and whether or not potential releases to air are transferred to the aqueous medium (e.g. by wet scrubbing).

The following basic techniques should be considered for reducing or preventing waste-water discharges and avoiding accidental pollution:

O   Establish a water and effluent management regime, with clear responsibilities for monitoring consumption and implementing water conservation measures.

O   Where appropriate, minimise the use of water in the processes.

O   Use 'dry techniques', where feasible, to abate particulate and gaseous exhaust streams.

O   Maximise the recycling of process water and utilise waste water where feasible.

O   Rinsing processes should seek to minimise water consumption by reducing process drag out and using appropriate water conservation techniques to minimise the volume of waste water.

O   Rinse water consumption should be metered.

O   In cases of intermittent discharge or large variations in flow, concentration or other characteristics, the process water or waste water should be balanced before treatment.

O   Employ indirect-contact heat exchange devices, where cost-effective.

O   Segregate direct-contact process water, rain water and indirect cooling water streams, to reduce the hydraulic loading on waste-water treatment equipment and sewers.

O   Carry out risk assessments to minimise the risk of accidental releases of raw materials, fuel, oils, acids and other chemical reagents into water systems. Develop emergency contingency plans to minimise the risk of such materials or fire-fighting water entering surface water drains, watercourses or other sensitive receptors.

O   Where practicable, use dry methods for cleaning up spillages of solid materials or deposits of dust. Vacuum extraction can sometimes increase the feasibility of recycling such materials back to the process.

Where appropriate, liquid effluents with different characteristics should be kept segregated for separate treatment.

Areas where spillages are most likely, such as transfer and sampling points, should drain to sumps. The sumps should be emptied by a waste management contractor or be discharged to an effluent treatment plant after the composition of the contents has been checked. Self-sealing couplings should be used where applicable.

Storage tanks and, where appropriate, process vessels should be bunded. The bunding arrangements should be subject to risk assessment and be capable of containing at least 110% of the

capacity of the largest tank within any one bund. Bunds should be impermeable and should have no direct connection to drain. The Environment Agency has issued guidance on oil storage tanks[24].

Bunds should be regularly inspected for structural integrity by a competent person. Bunds not frequently inspected should be fitted with a high-level probe and an alarm, as appropriate.

Contaminated rain-water accumulations should be directed to appropriate treatment facilities.

Care should be taken in the choice of cleaners used (e.g. detergents), which can enter the effluent system, as they may act as complexing agents with metals and impair treatment performance.

Water treatment chemicals, such as corrosion inhibitors, coagulants, flocculants, descaling agents, sodium hydroxide and biocides, should be chosen to minimise the use of substances prescribed for water (e.g. potential mercury contamination in sodium hydroxide).

Water treatment chemicals and biocides should be stored in sealable bunded areas, or equivalent, and returned to those areas after use.

The dilution of aqueous process streams by mixing with general site effluent or mixing of process streams from different processes to achieve co-dilution is generally not considered to represent BAT. An applicant wishing to use this practice should demonstrate that it represents BPEO, compared to applying appropriate treatments to the concentrated process stream.

3.4.2 Water systems

Process waters
'Direct-contact' process water is used in steel works in a wide variety of applications, including:

- gas cleaning at blast furnaces and BOS plant;

- secondary spray or air mist cooling on continuous casting plant;

- descaling and roll cooling on mills; and

- as a major constituent of pickling and cleaning solutions and for rinsing in various finishing processes.

In addition, there are a variety of other smaller sources of direct-contact process water arising from such duties as vacuum pump sealing, steam ejector condensate and scrubbing of acidic fume.

Most of the main process plants are cooled by 'closed-circuit' clean cooling water systems, which are not contaminated by contact with the steel product or dirty process gases. Such

circuits provide cooling for a variety of process equipment, including:

- blast furnace structure, tuyeres and hot blast valves;

- fume hood, hot gas ducting and lances of BOS converters;

- wall panels, roof, electrode arms, fume elbow and hot gas ducting of arc furnaces and ladle furnaces;

- moulds and machine cooling of continuous casting plants;

- structural elements of reheat furnaces;

- other furnaces and heat treatment facilities; and

- large mill motors.

Most of the above closed-circuit process cooling is by conventional evaporative cooling circuits or air-cooled fin-fan radiators. However, there are occasional variants, such as air mist cooling of BOS converter cones, evaporative spray cooling of EAF roofs/shells and evaporative cooling for steam recovery at reheat furnaces.

General purpose and utility service water
Water is used for a variety of other purposes at a steel works site, including domestic use and for utility services such as steam turbine condenser cooling, compressor cooling, diesel generator cooling, hydraulic system cooling, and as a feed to water softening and demineralisation plants. General service water is also used for dust suppression, hosing down and general cleaning, which can be sources of pollution unless properly controlled.

Site drainage waters
These are essentially rain water running off hard surfaced process areas and roofs or collected by purpose-designed drains.

In many cases an oil interceptor will be required prior to final discharge of site drainage waters[25], and an appropriate monitoring regime will be required for both surface water and treated effluent discharged from the site.

The site drainage should be designed such that any potential spillages of chemicals, oils, etc. should be routed to the effluent treatment system, with appropriate provisions to contain surges and storm-water flows.

Absorbents should be used to mop up minor leaks and spills, which should then be disposed of in leak-proof containers.

Discharges from 'once-through' cooling water systems or other clean sources should not be used to achieve, by dilution, authorised release limits for substances prescribed for water that are being discharged from effluent treatment plants.

3.4.3 Water and effluent balance

Agency staff should request operators to submit an overall water and effluent balance for the steel works site, which shows the sources and use of water, sources and volumes of effluent and the interconnections between the various water circuits described in Section 2.

Operators should be encouraged to conserve water and consequently minimise effluent discharge through traditional good water management techniques, including the waste minimisation techniques mentioned in Section 3.4.1 and described more fully in the guidance published by the Agency and others.

3.4.4 Water and effluent treatment methods

The waste water treatment plants at a particular steel works are likely to reflect the history of the site, the nature of the process plants, the availability and cost of raw water, the difficulties of effluent disposal and the Consent conditions applied to the various effluent discharges. Agency staff should ensure that applications for IPC Authorisation demonstrate that alternative water utilisation and treatment technologies have been considered to meet BATNEEC criteria, which includes the minimisation of waste.

Information on effluent treatment techniques is available in Technical Guidance Note A4[26] and from many other sources, including the ETBPP Guides[19].

The main treatments available for contaminated process water and waste water are summarised in Table 3.4.

At a steel works, it is common for the dirty process water circuits and waste-water treatment and waste disposal facilities to comprise:

● Primary water treatment

● Secondary and sometimes tertiary water-treatment

● Sludge dewatering

● Sludge utilisation or disposal

● Treated effluent utilisation or disposal.

Primary treatment
Primary treatment prepares either the dirty process water for recirculation or waste waters for further treatment or direct discharge from the site. The primary treatment techniques commonly used in steel works are generally physical/chemical treatments, including the following:

● Suspended solids removal
- settlement, with or without flocculation
- flotation, with or without air assistance
- hydrocyclone separation
- removal and dewatering of scale and sludges
- sand filtration of treated water

● Oil removal
- chemical
- physical
- thermal

● Neutralisation

● Chemical precipitation
- by pH control
- by other means

● Oxidation:
- by ozone, hydrogen peroxide, sodium hypochlorite, chlorine or oxygen
- by a combination of techniques, including ultraviolet radiation and catalyst system

Secondary/tertiary treatment
Secondary treatment systems can be either single systems or conjugated systems to reduce or eliminate chemical species present in the aqueous stream.

Typical secondary/tertiary treatments include:

● Activated carbon adsorption
● Ion exchange/macroreticular resins
● Membrane processes
● Biological treatment
● Electrochemical techniques, including electro-deposition.

Sludge dewatering
Waste solids in slurry form are produced by primary and secondary treatment of process water and waste water. These sludges normally have to be thickened and dewatered before they can be recycled, landfilled, incinerated or otherwise disposed of. The typical methods of dewatering sludge include combinations of the following:

● Sludge lagoons

● Gravity thickening

● Filtration
- by rotary vacuum filters
- by other filters

● Mechanical dewatering
- by belt presses, tube presses, filter-plate presses
- by centrifuging

● Drying
- natural
- thermal

Scale and sludge disposal
Depending on the nature of the scale and sludge, this can be either:

● recycled to the steel making process;

● sold to third parties as a by-product;

Table 3.4   *Waste-water abatement techniques*

Contaminant	Abatement techniques
Suspended solids	Coagulation/flocculation Sedimentation Hydro-cyclone Flotation Filtration
Oil/grease	Chemical treatment 'Mops'/'Skimmers'
pH	Neutralisation
Insoluble organics	Seperators
Biodegradable organics	Aerobic treatment Anaerobic treatment
Volatile organics	Air stripping Steam stripping Distillation Activated carbon Evaporation Thermal oxidation
Metals	Chemical coagulation Ion exchange
Ammonia	Ammonia stripping
Cyanide	Oxidation Ion exchange Stripping Carbon adsorption
Nutrients (N)	Suspended-growth nitrification and denitrification variations Fixed-film nitrification and denitrification variations Ion exchange Breakpoint chlorination Natural systems
Nutrients (P)	Metal-salt addition Lime coagulation Biological phosphorus removal Biological-chemical phosphorus removal
Nutrients (N+P)	Biological removal
Refractory organics	Carbon adsorption Ozonation Supercritical water oxidation Wet air/oxidation Chemical oxidation
Dissolved organic solids	Ion exchange Membrane separation Carbon adsorption

O   disposed of at an on-site or off-site landfill; or

O   disposed of by incineration, in either an incineration plant or cement kiln.

Before certain sludges can be disposed of by some of the above routes, further processing is necessary. Such processing can include:

O   mixing with other waste products that are suitable for recycling;

O   briquetting (probably with a binder); and

O   stabilising with a suitable additive to reduce the risk of leaching.

The operator should demonstrate that the principles of 'sustainability' and the concept of the 'waste hierarchy' have been adopted in developing the disposal strategy for sludges recovered from the various water treatment plants.

Effluent disposal
Depending on the quality of the treated waste water and the circumstances at the steel works, the effluent may be:

O   discharged to foul sewer;

O   Discharged to surface water drain or watercourse or the sea; or

O   Utilised on site for low-grade duties such as dust suppression, slag quenching or irrigation.

Agency staff must ensure that, if disposal methods other than discharge to a foul sewer are proposed, the appropriate safeguards are in place to prevent the risk of pollution of groundwater or surface water.

All discharges from the site must comply with the authorised conditions at all times.

3.5   Minimisation of waste to land

3.5.1 General requirements

The application should identify the key pollutants likely to be present in releases to land, based on a knowledge of the composition and characteristics of the wastes and an assessment of the risks of pollution arising through leaching, chemical changes or interaction between materials, erosion, corrosion or other mechanisms that might release pollution. Where necessary, appropriate experimental and analytical techniques shall be used to assess the magnitude of the potential risks.

The presence of substances created by abnormal operation should be identified, since process abnormalities can carry through substances into the solid waste that are not normally present.

The application should include estimates of the quantity and anticipated composition of the likely releases to land, for the foreseeable range of operating conditions.

Efforts should be made to reclaim raw materials from waste prior to disposal to land and, where feasible, the recovered materials should be recycled or utilised as secondary by-products, in order to minimise the quantities landfilled. Where practicable scale, dusts and sludges recovered from the steel making processes should be re-used in the process (or sold), provided this does not adversely affect the operation of the process plant, jeopardise product quality or create environmental risks.

The identification and application of techniques for preventing, minimising and controlling releases to land should reflect the principles of 'sustainability' and the concept of the ' waste management hierarchy'. Thus:

O   Waste arisings should be prevented at source. Techniques should include the use of waste minimisation programmes to identify waste prevention opportunities (see Section 3.2).

O   Where waste arisings cannot be prevented, they should be characterised and classified. This should occur at the earliest possible stage in the process and should cover both composition and quantity. Waste characterisation helps to identify potential opportunities to recycle/re-use the material and, where this is not possible, allows the development of a suitable programme for handling, storing and disposing of the waste.

O   The opportunities to recycle or re-use wastes can be identified through a waste minimisation programme. It should be borne in mind that recycling opportunities are not confined to the process.

O   A system should be in place to monitor waste arisings on the steel works site. This should allow trends to be identified and underpin the waste minimisation programmes and disposal practices. The amount of information collected on each waste stream will depend upon its potential hazardous properties and potential value. It would not be expected that as much detail would be collected on inert or non-hazardous wastes, as would be the case for potentially hazardous wastes.

O   A system should be in place to manage all waste arisings. This should cover the use of appropriate labelling, storage containers, storage areas, handling, transportation and disposal.

Wastes should be sampled and characterised, which may include detailed analysis at appropriate frequencies, to ensure they may be accepted at the licensed waste disposal facility and so that the relevant information can be made available to the next holder, as required by the Duty of Care and Special Waste Regulations[27],[28]

Table 3.5 summarises the common disposal routes of the various waste streams from typical integrated and EAF steel works sites. Whether recycling is possible at a given site will depend on the particular plant configuration, raw materials, product qualities and methods of operation. Table 3.5 indicates where internal recycling or sale as a by-product can often be achieved, subject to an appropriate combination of factors and suitable location of the steel works relative to the potential markets for 'secondary' by-product materials.

In the case of leaded steel manufacture, all dust should be collected in labelled containers, sealed and then disposed of to land or other authorised disposal route by a licensed waste disposal company. Contaminated refractory from leaded steel production should be collected and disposed of by a similar procedure.

Applications should include details of the facilities for the collection and storage of solid and liquid wastes that are taken off-site for treatment and/or disposal. Procedures should be established, to ensure that there is no mixing of wastes, except in purpose-built equipment that is designed for the treatment of the wastes to make them less harmful or to aid recycling. Such equipment will form part of the authorised process.

Conditions should be included in the Authorisation to ensure that all substances produced by the process and disposed of to land, either on or away from the site, are handled, loaded and transported so as to prevent spillage, dust or VOC release, or the generation of odours.

The term 'handling' includes collection, treating, conveying, transporting, discharging and storing waste materials. Equipment design should ensure that dust generation is minimised and that reliance is not solely placed upon dust extraction and treatment plant.

All spillage should be cleaned up without delay and, where the consequence could be environmentally significant, the spillage should be prevented from entering any sewer or watercourse.

3.5.2 Contamination of soil and groundwater

Hard surfacing should be provided in areas where accidental spillage may occur (e.g. in storage areas, in loading areas and within bunded areas). This will facilitate recovery and clean-up operations and prevent penetration of spillage into the ground.

Hard surfaced areas subject to potential contamination should be drained to prevent potentially contaminated surface run-off being discharged to the ground, thus causing a breach of the requirements of the Groundwater Directive, as noted in Section 1.6.6. Particular care should be taken in areas of inherent sensitivity to groundwater pollution. Poorly maintained drainage systems are in many cases known to be the main cause of groundwater contamination and, hence, surface/above-ground drains are preferred to facilitate leak detection.

In addition to sealed bunds, possible measures to reduce contamination from large storage tanks include:

- double walled tanks; and

- leak detection channels.

Such additional measures could be justified in locations of particular environmental sensitivity. Decisions on the measures to be taken should take account of the risk to groundwater, taking into consideration the factors outlined in the Agency document, Policy and Practice for the Protection of Groundwater[13], including groundwater vulnerability and the presence of groundwater protection zones.

The vulnerability of groundwater to contaminants will depend on the natural characteristics of any given site, particularly the physical, chemical and biological properties of the soil and rock or clay structure beneath and around the site. The Environment Agency has produced a series of maps of England and Wales that provide a guide to areas of potential groundwater vulnerability. Source Protection Zones are intended to aid protection by defining annular zones around each major potable water source (including springs, boreholes and wells), based on travel times.

Surveys of plant, equipment and services that may contribute to leakage into or onto the ground should also be considered, as part of an overall environmental management system. In particular, operators should consider undertaking leakage tests and/or integrity surveys to confirm the containment of underground drains and tanks.

Table 3.5 *Solid waste stream disposal routes*

Process plant source	Waste stream disposal route
Raw material bag filters	Recycle to sinter plant if possible
Coal handling bag filters Sinter plant, primary and secondary collection plant	Add to coal blend if possible
- coarse dusts	Recycle to sinter plant
- fine dusts	Dispose of to landfill (if high heavy-metal content)
Blast furnace	
- cyclone grit	Recycle to sinter plant
- gas cleaning sludges	Recycle to BF or sinter plant (possibly after segregating coarse and fine sludge), otherwise dispose of to landfill
- ironmaking slag	Sold wherever possible, otherwise landfill
Casthouse	
- collected dust	Recycle to sinter plant
Desulphurisation	
- collected dust	Not suitable for recycling - dispose of to landfill unless other application identified
- desulphurisation slag	Not suitable for recycling - dispose of to landfill unless other application identified
BOS	
- primary drop-out grit	More readily recyclable than the fine material in the gas cleaning sludge. Recycle to BF or sinter plant
- primary sludges	Potentially recyclable to BF or sinter plant. Percentage recycled depends on tramp materials. (Possibly segregate coarse and fine sludge.) Remainder to landfill
- secondary and fugitive collected dusts	Subject to tramp metal limits, briquette and recycle to BOS. Otherwise landfill
- steel making slag	Small proportion recyclable to BF or sinter plant (after Fe removed), to recover free lime, manganese and combined iron. Maximise potential sale of material and dispose of remainder to landfill
EAF	
- slag	Sold as a roadstone after recovery of Fe for recycling to EAF
- EAF baghouse dust	Potentially charge to the EAF to minimise waste prior to landfilling and, if viable, process or sell zinc enriched dust for non-ferrous metal recovery
Continuous casting:	
- scrap	Recycle to BOS/EAF
- scale	Recycle to sinter plant/BF/BOS/EAF or sell to cement industry
- sludge	Recycle as scale if possible; otherwise dispose of to landfill until recycling is feasible
Rolling mills	
- scrap	Recycle to BOS/EAF
- scale	Recycle to sinter plant/BF/BOS/EAF or sell to cement industry
- sludge	Recycle as for scale if possible; otherwise dispose of to landfill until recycling is feasible
Finishing processes	
- pickling sludge	Seek opportunities to recycle; otherwise landfill
- acid recovery	Recycle recovered acid and dispose of treated effluent. Sell iron oxide recovered from roasting process if possible
- other finishing processes	Seek opportunities to recycle wastes arising at galvanising, tinning and coating lines (Note: not Part A processes)
Waste refractories	Seek cost-effective opportunities to recover material for re-use or process to recycle; otherwise dispose of to landfill

4   Benchmark release levels

The benchmark release levels given are achievable by all new processes using the best available techniques described in Sections 2 and 3. They are applicable to each non-combustion point source. The benchmark release levels should not be applied as uniform release limits, but should be assessed to take account of site-specific conditions, so as to comply with the requirement to apply BATNEEC and BPEO and any relevant environmental quality standards.

4.1   Benchmark release levels to air

The benchmark releases to air and typical mass release rates achievable for key substances are given in Table 4.1.

Table 4.1 *Releases into air*

Process	Emission	Typical loading (kg/tonne)	Level		
			Average concentration (mg/m³)	Peak concentration (mg/m³)	Typical mass emission (g/tonne liquid steel)
All raw materials handling dust collection	Particulate		10		
Coal pulverisation	Particulate		10	20	
Sintering: primary flue	Particulate Cadmium Lead SO$_x$ (as SO$_2$) PCDD/F (ITEQ)	<5 <1.2	20 0.1 2 250 (25) 0.5 ng/m3		170-280 0.002-0.04 0.04-7 900-1850 0.5-6.5 µg/tonne
Sinter: secondary releases	Particulate		10		75
Pelletising plant	Particulate SO$_x$ (as SO$_2$) HF HCl		10 20 1 1		
Blast furnace	Particulate	<4	10		
Stockhouse	Particulate		10		
Casthouse	Particulate		15	20	50
Hot blast stoves	Particulate NO$_x$ SO$_x$		10 350 400		
Slag granulation	Particulate SO$_2$ H$_2$S		20 200 100		
Desulphurisation	Particulate SO$_2$		20		70
BOS gas cleaning * (normal operation)	Particulate Lead Cadmium CO	<20	15 1 1 *	80	20

Table 4.1 *Releases into air (cont'd)*

Process	Emission	Typical loading (kg/tonne)	Level Average concentration (mg/m³)	Peak concentration (mg/m³)	Typical mass emission (g/tonne liquid steel)
BOS gas cleaning (charging and tapping)	Particulate			15	40
EAF primary	Particulate		10	15	200
EAF secondary	Particulate		10	15	50
EAF combined extraction	Particulate		10	15	
Roof extraction	Particulate		10	20	
Ladle treatment	Particulate		10	20	
AOD primary	Particulate		10	20	
Other species from above processes (carbon steel)	Fluorides Cadmium Dioxins (ITEQ) Lead Chromium Nickel		5 0.2 0.5 ng/m³ 1 2 1		
Other species (leaded steel)	Lead		3		
Other species (stainless steel and special alloys)	Chromium Nickel		4 2		
Machine scarfing	Particulate		30		
Oxy-gas cutting	Particulate		10		
General local extraction	Particulate		10		
Rolling and pickling	Particulate Oil mist VOC as total carbon HCl NOx		20 20 50 10 300		

Notes on Table 4.1:

Figures are based on measurements taken at the point of discharge.

Figures in brackets for SO_x are the releases following suitable desulphurisation-techniques.

For batch operations the average concentration figures refer to measurements taken over a complete process cycle.

For continuous processes, releases are based on an hourly average figure over a rolling 24 hour period, taking into account only the hours when the plant is in actual operation, including start-up and shut-down.

Start-up and shut-down conditions may be excluded from the release limits in the Authorisation, subject to the provision of acceptable reasons by the operator.

* When employing a suppressed combustion and gas recovery system on BOS converters, primary emissions occur only at the beginning and end of the steel making cycle. In this case the average concentration and mass emission to atmosphere will be reduced. When gas recovery is not employed, the release of CO gas must be minimised by flaring.

4.2 Benchmark release levels to surface water

The benchmark levels for releases to water are listed by substance in Table 4.2.

Table 4.2 *Releases to controlled waters*

Discharge concentration (μg/litre) of effluent based on a 24 hour flow proportional sample	
Cadmium	50
Mercury	20
Cyanides	500
Chromium	200
Lead	200
Nickel	500
Zinc	500
Suspended solids	30 000
Oil	10 000
Copper	500
Iron	5 000

Note:
The release levels given in Table 4.2 may not be appropriate for stainless and leaded steels where suspended solids may contain higher levels of heavy metals.

5   Economic considerations

5.1   Introduction

In determining an application, the Agency must translate BATNEEC into conditions to be included in the Authorisation. The BATNEEC criterion requires that a judgement is made that balances cost against environmental gain. The operator should have constructed a BATNEEC case, after examining the range of technically feasible process and/or abatement options.

The cost of controlling releases should not be disproportionate to the environmental benefits delivered and, in some instances, cost savings may be derived from changes made to improve environmental performance. BATNEEC is not concerned with the financial strength or resources of a particular Operator and 'excessive' costs are to be viewed in the context of the process and the industry, taking into account any site-specific issues. Whilst techniques and achievable release levels may vary between industry sectors, the same principles apply to all sectors. For existing processes, the timing of proposed process investment and improvement programmes may be a factor in the determination of BATNEEC.

The UK has a wide diversity of manufacturing facilities for steel products, in terms of both the scope of operation and the processes employed, and it is rare to encounter identical economic conditions at any two steel plants.

The following gives background information for Agency staff on the economics of the steel industry, as well as an indication of the typical range of costs for common abatement equipment.

5.2   Market demand

The iron and steel making sector in the UK produces a wide variety of material specifications and types of product, predominantly for use in the automotive, packaging, engineering and construction industries.

The market for steel is cyclic and over the past 20 years the UK demand has fluctuated between lows of approximately 12 million tonnes per annum during recessionary periods, to a maximum of around 16 million tonnes during periods of growth.

The UK demand for steel in 1998 was reported to be around 15 Mt, of which roughly 55% (8.6 Mt) was satisfied by UK producers and the remainder was supplied by imports.

Despite fluctuations in the home market demand and import penetration, successful growth in exports achieved by the UK steel industry, particularly over the last 10 years, has been a key factor in maintaining the high capacity loadings that are necessary for profitable operation. Sustained exports at relatively high levels are therefore likely to be vital to continued survival of the UK steel industry in its present form (even though the selling price of exports is often extremely competitive).

The UK steel industry operates in a global market, where the international prices for the various types of basic steel product are governed by the balance between supply and demand. Towards the end of the twentieth century there has been a significant global surplus of steel making capacity, which has led steel companies to chase market share through price competition. This situation has been recently exacerbated by economic upheavals in Asia and Russia, which resulted in a steep fall in steel prices in the second half of 1998.

As a result of this phenomenon, the stainless steel market has been particularly affected.

5.3   Production

Despite significant reduction in production capacity through various plant closures and rationalisation within the UK steel industry over the past 20 years, the total production of crude steel has only fluctuated between 16.2 Mt/y and 18.9 Mt/y over this period.

The total crude steel production within the UK in 1998 was reported to be around 17.4 Mt, of which roughly 77% (13.4 Mt) was produced by the four blast furnace/basic oxygen route integrated steel works owned by British Steel and around 23% (4 Mt) was produced by the electric arc furnace process route. The future output and product mix will depend on both domestic and global market influences.

5.4   Key economic considerations

The economics of the steel industry are market- and technology-driven, which are both influenced by a wide range of dynamic changes within the competitive global steel industry. The following is a brief review of some of the key issues of which Agency staff should be aware.

5.4.1   Global competition

'Globalisation' of the world economy has had a profound effect on the steel industry and it will continue to do so. Despite, or perhaps because of, market stagnation, the industry is undergoing intensive structural change. This is characterised by privatisation, integration, re-structuring and the development of new concepts in steel making (e.g. enhanced mini-electric steel mills producing a wider range of products, new electric arc furnace concepts, new casting techniques, process integration (particularly pickling/annealing) and further developments of direct/smelting reduction techniques). Highly competitive market conditions may accelerate such changes and encourage consolidation within the steel industry. This is evident from the growing number of alliances, cooperative ventures and take-overs.

The future shape and profitability of the UK steel industry will be influenced by a range of domestic factors such as the strength of the home economy, exchange rate movements, raw

material prices, fuel and electricity costs and wage inflation. The external influences on the future of the UK steel industry include the international demand for steel, foreign competition and the creation of new capacity. Recent growth in import penetration of European markets from non-EU countries in Asia, Eastern Europe and other areas has been perceived as a threat to the wellbeing of the European steel industry and, consequently, 'anti-dumping' measures were initiated by the EU in 1998.

5.4.2 Investment

A characteristic of the steel industry is the major investment needed to build new facilities and modernise existing equipment, in order to remain competitive and meet the ever-increasing quality and customer service demands of the market place.

Such major investment usually involves long term strategic decisions, which cannot easily be revised when market conditions or international perception of BAT changes.

Reduction of releases to the environment through design of the process plant can usually be achieved more cost-effectively as an inherent part of major investment in plant modernisation than can be achieved by retrofitted 'end-of-pipe' abatement techniques.

For the above reasons, Agency staff are encouraged to liase closely with the process operators to develop an on-going sustainable strategy for environmental improvement, which is consistent with the regulatory requirements and competitive position of the UK steel industry within Europe and the wider world market.

5.4.3 Operating costs

In addition to the fixed costs associated with major investment and overheads, the main variable input costs of the steel industry are summarised in Table 5.1.

Table 5.1 *Main operating costs*

Integrated steel works
• Iron ore • Coking coal • Refractories • Oxygen • Fuel • Electricity • Labour
EAF steel works
• Scrap and scrap substitute • Electricity • Electrodes • Refractories • Oxygen • Fuel • Labour

Iron ore is an internationally traded commodity, which is usually purchased on the basis of annually negotiated supply contracts that normally reflect the worldwide demand for steel. Similarly, the cost of scrap and directly reduced iron, which can be used as a scrap substitute, reflect the international demand for steel. The cyclic price movement of scrap, which is governed by demand, is relatively volatile and is often regarded as an early indicator of an impending change in economic activity.

Steel companies striving to achieve a competitive cost advantage have focused attention on a wide range of measures such as:

o   Improving the effectiveness of the management structure by 'organisational slimming'.

o   Reducing the cost of labour through increased productivity, multi-skilling and demanning.

o   Reducing the cost of raw materials by strategies such as injection of non-coking coal, recycling of by-product materials, improving yields and reducing energy consumption.

o   Reducing the costs of production, through technological changes such as thin slab casting, direct rolling, hot connection/charging, maximising the utilisation of process gases and recovering waste heat.

o   Reducing the cost of electricity through negotiation with the supply company, load management, maximising on-site power generation and optimum use of oxy-fuel burners.

o   Development of sophisticated production management systems to control orders, purchases, inventories and other aspects of the business.

o   Supply chain integration with customers and suppliers, including minimising inventories of feedstock and products, just in time strategies, expansion of distribution centres and technical/product support for customers.

o   Expanding the production of 'added value' products and developing new products to meet market demand.

o   Rationalising production facilities and plant closures to enhance profitability through the lower marginal costs associated with operating plant at full capacity.

In the face of strong international competition and likely continuation of surplus global steel making capacity into the new millennium, the UK steel industry is likely to continue pursuing cost-effective opportunities to strengthen its profitability.

Because of the cost of energy and labour in the UK and the threat of future energy/CO_2 taxes, it is conceivable that some UK steel companies may consider either locating part of their primary steel production in low-cost areas of the world or importing semi-finished products for conversion into finished products.

5.4.4 Technological change

Two significant technological changes to emerge in recent years are the development of thin slab casting and the growth of gas- and coal-based direct/smelting reduction technology.

The investment necessary to melt 'low residual' mixtures of scrap and DRI/HBI in an electric arc furnace to produce strip products by thin slab casting and direct rolling is modest compared to the high investment in large conventional integrated steel works, which have traditionally been used to produce flat products. The low overheads and other cost advantages associated with the 'mini-mill' culture adopted by such modern developments can give these plants a competitive advantage over traditional integrated steel works.

The future implications of such developments and other emerging technologies on the large integrated UK steel works are at present unclear. However, within the international market, the growth of such medium-sized plants, particularly in areas with low gas and electricity prices, is likely to place greater pressure on the exports from traditional European integrated steel works.

With advancing technology, the future success of the UK steel industry may depend on its ability to modernise, to improve the quality and range of its products, and to reduce costs. Modernisation normally also enhances the environmental performance of a steel works.

From the environmental viewpoint, the inherent releases associated with a conventional integrated steel works are considerably higher than from a scrap/DRI fed electric arc furnace plant; although the environmental burdens created by the power stations supplying electricity to the arc furnace plant need to be taken into account.

However, for very large-scale primary production of steel, the basic oxygen process route has an advantage compared to the arc furnace process route. (For example, it is feasible for a single 350 tonne BOS converter to produce around 4.5 million tonnes of liquid steel per year.)

5.4.5 Site-specific issues

Raw material costs and markets are the predominant economic factors determining the profitability or otherwise of an individual steel plant but site-specific issues can also have a significant effect in determining the viability of a steel works.

Site-specific issues may include plant location (proximity to raw material sources and markets), steel manufacturing processes and product range, age and design of equipment, quality and tonnage of finished products, etc.

5.4.6 Currency exchange rates

Because the UK steel industry relies on exports to achieve the high capacity loadings necessary for profitable operation, it is vulnerable to changes in international exchange rates.

However, since the pound/US dollar exchange rate has not changed greatly in the recent past, the costs of importing iron ore and coking coal, which are internationally traded in US dollars, have not been significantly influenced by exchange rate movements in the last few years.

In the late 1990s roughly two-thirds of the steel exports from the UK were despatched to other EU countries. Hence, strengthening of the pound relative to currencies such as the deutschmark in the latter half of the decade has reduced the competitiveness (i.e. margins) of the UK steel industry in some of its main export markets.

In order to reduce exposure to exchange rate movements, some steel companies may decide to adopt the euro as the basis for commercial transactions.

5.5   Cost of air pollution abatement techniques

The cost of abatement techniques varies widely, depending on the process duty and site specific factors. It is for the operator to develop robust cost estimates that correspond to the specific process and circumstances at the steel works site.

5.5.1 Particulate matter

The cost of particulate abatement is highly dependent on the flowrate, but less dependent on the particulate loading.

5.5.2 Gas scrubbing

Scrubbing techniques are widely used to control atmospheric emissions. However, the diverse nature of the pollutants, the scrubbing medium and operating conditions make it impracticable to give average annualised costs.

5.6   Cost of waste-water treatment techniques

The capital costs of waste-water treatment are affected by flowrate, the nature and concentration of the pollutants in the waste water, and specific issues relating to individual techniques and particular sites.

Biological treatment is sometimes used for final polishing of treated effluent before discharge. However, it defies all but the most broad cost estimates because of the large number of interdependent factors that can affect such costs.

At the very simplest level, a basic reed bed may cost relatively little for a low-volume, low-strength and biodegradable effluent. Conversely, a large activated sludge plant may cost several million pounds.

6   Monitoring

6.1   General

There is an expanding series of HMIP and Environment Agency Technical Guidance Notes on monitoring, containing information on the theory and methodology, and providing technical information on monitoring techniques (see *Associated publications* in this Note).

Reference should be made to the application when setting standards of release in Authorisations to ensure that such conditions are accessible by the means described by the applicant, and are properly enforceable. In particular, when defining release limits, Inspectors should take into account the availability of suitable monitors, and the precision and accuracy of both continuous monitors and calibration methods.

Particular attention should be paid to features that give rise to fugitive releases. Frequently these are the result of poor extraction, which may be the result of an undersized extraction plant, or be due to the poor performance of fans, filters or ductwork.

Leaks in ducts that permit air to enter the system between the emission source and the filtration plant can contribute to poor extraction plant performance. Furnace exhaust systems where the ductwork is subjected to high and variable temperatures are particularly prone to air ingress. Checks can be made by testing the exhaust gases for, say, carbon dioxide at a point close to the source and comparing it with the concentration present on the discharge side of the filter. From these figures the quantity of clean air being drawn into the filter can be calculated.

Facilities for such checks should be designed into the system and regular checks instituted if there is evidence of fugitive releases.

Where there is a significant potential for fugitive releases into the air, long path monitoring systems fitted above furnaces are a practical means of assessing the level of performance. Other methods of assessing and monitoring the extent of fugitive emissions include time-lapse photography (which is particularly useful for assessing the volume of fume generated when metal is being poured) and infrared photography (which can be used when hot gases escape). An assessment of the quantity of material being lost can be made by sampling the air being discharged through roof vents, though estimates of the volumetric rate will be significantly less accurate than for ducted releases.

6.2   Systems monitoring

Monitoring should not be restricted to systems that directly assess releases into the environment. Secondary measurements such as pressure drops, flow, temperature and power consumption should supplement direct release assessments, and in some cases may be an acceptable surrogate. In all cases consideration should be given to the demonstration of the proper functioning of the process and abatement plant.

Monitoring should be undertaken during commissioning, start-up, normal operation and shut-down unless the Inspector agrees that it would be inappropriate to do so. The manner in which results obtained during commissioning, start-up and shut-down are reported should be defined by the Inspector.

6.3   Monitoring of releases to air

6.3.1   Continuous monitors

Where appropriate, continuous monitoring techniques should be used, commensurate with the limitations and accuracy of continuous monitors. When continuous monitoring is not appropriate or available, non-continuous monitoring should be undertaken, together with surrogate measurements, where applicable.

The Agency has established its Monitoring Certification Scheme (MCERTS). Continuous emission monitoring systems should be expected to meet the performance standards published under the Scheme. Manual stack testing should be reported using the Agency's standard reporting formats. MCERTS performance standards are currently being developed and should be given due consideration when available.

Of particular relevance is the Agency Report *A Review of the Industrial Uses of Continuous Monitoring Systems: Metals Industry Processes*[19]. Section 3.2.2.2 of this review should be noted when assessing the need for and value of continuous monitors used to measure particulate concentrations.

All types of particulate continuous monitor are influenced to a greater or lesser degree by changes in the particle size distribution of the emitted material. When a filter plant fails, e.g. through rupture of the fabric, then in most applications there will be a dramatic change in the particle size distribution of the emitted material. Consequently, particulate monitors can only give semi-quantitative indications of releases during failure. However, they will provide an indication of filter deterioration and failure.

Table 3.1 of the above review, which summarises the source of potential errors, is reproduced in this section as Table 6.1. Inspectors should also take note of the comments regarding the precision and accuracy of available standard reference methods that would be required to calibrate monitors. Standard reference methods, if competently applied, will provide results to a specified degree of accuracy and precision under a wide range of conditions. Routine checks on the other hand may be very simple, and involve a different principle of operation. They will need to be proven for each process and set of circumstances. Inspectors should be aware that simplified methods used for routine checks will be less precise and less accurate than reference methods.

Table 6.1 *Overview of particulate measurement techniques*

Type	Sensitivity	Influences	Problems/advantages
Transmissivity (Opacity)	Range limited to approximately 100 mg/m3. Output is related to concentration not mass emission.	Particle size Particle shape Particle colour Ambient light	Dirt on lens windows. Misalignment of the transmitter and receiver reflector units owing to thermal expansion of duct.
Scattering	Output is related to concentration not mass emission. Not suitable for high-opacity applications such as smoke.	Particle size Particle shape Particle colour Ambient light	Dirt on lens windows. although less sensitive to this than is the transmissivity type.
Optical scintillation	AC measurement. Higher sensitivity than transmissivity type. Response is related to mass emission, i.e. velocity-dependent.	Particle size Particle shape Particle emission reflection effects Dynamic flow conditions	Dirt on lens windows. although less sensitive than the transmissivity type. Suitable for small - and large - diameter ducts.
Triboelectric	DC or AC measurement. High sensitivity. DC type: response is related to mass emission (velocity-dependent).	Particle size Particle shape Particle electrostatic characteristics Duct electrostatic characteristics Dynamic flow conditions	Not suitable for damp or wet gas. Influenced by ionisation and humidity variations. Will tolerate superficial contaminations (AC type: high tolerance). Applicable to small-diameter ducts down to 100 mm.
Acoustic	Moderate sensitivity. Response is related to mass emission. Alarm duty only.	Particle mechanical characteristics Dust geometry Dynamic flow conditions Ambient noise	Complex and application -dependent.

Where continuous monitors are fitted, release limits are normally set on the basis of 95% of the hourly average readings for each rolling 24 hour period not exceeding the value (or alternatively not more than one hourly average reading in any rolling 24 hour period shall exceed this value), and that the maximum hourly average figure shall not exceed 150% of this value.

In order to relate emission concentrations to mass releases, it will be necessary to measure or otherwise determine the gas flow. Additionally, in order to relate measurements to reference conditions, temperature will need to be determined. All such measurements should be recorded.

6.3.2 Sampling and analysis

The frequencies at which operators are required to sample environmental discharges will vary. Typically monitoring frequencies will be in the range from quarterly to every six months. However, the frequencies set in Authorisations should be proportionate to environmental risk.

In selecting appropriate sampling frequencies, consideration should be given to:

O   the size of the mass discharge;

O   the nature of the substances discharged, namely their toxicity;

- the ability of the local environment to withstand the expected level of discharges, existence of potential receptors, etc.;

- whether reliable continuous monitors are in use;

- the extent to which other process parameters can be relied upon to indicate correct operation; and

- the extent to which abatement plant failures can be readily detected.

Particular consideration should be given to variable discharges, such as batch operations. Monitoring periods must be designed to give an accurate picture of the performance of the process, with samples taken that represent both peak and average performance. The peak monitoring period should not be more than one-hour duration and shall include the period of maximum emission. The average monitoring period shall include the period of maximum emission, but may be extended to include the whole operating cycle.

The Agency will normally carry out periodic check monitoring for key substances. This will be at a lower frequency than the operator's discharge monitoring. The monitoring frequency should typically be annual, but in setting frequencies, the Agency will take into account the potential for releases from the process and their possible environmental impact.

6.3.3 Particulates

Potential releases of particulate matter into the atmosphere may be particularly coarse, such as those arising from materials handling operations; or they may be very fine, such as electric arc furnace fume. Likewise the potential for release may be almost constant for long periods (e.g. sinter plant), or may vary substantially over a short period of time in the case of batch processes. All continuous particulate monitoring systems are affected to a greater or lesser degree by the physical characteristics of the particles being emitted, and where this can vary, any calibrations should be treated with caution.

Monitoring procedures must take into account this variability, the effectiveness of continuous monitors under the circumstances in which they are to operate, the scale of the operation and potential consequences of a failure remaining undetected.

6.4 Monitoring releases to surface water

It is anticipated that some ancillary processes may discharge into a common system, which also serves some or all of the main processes. Monitoring requirements for the discharge system should therefore take into account possible releases from the ancillary processes.

Continuous monitoring and flow proportional sampling for releases to water are always preferable but the use of a fixed interval or time proportional sampler for flowrates of less than 1 litre per second may be acceptable. Spot sampling may be used for audit or enforcement purposes.

Monitoring of process effluents released to controlled waters and sewers will commonly be made for the following:

- flowrate,

- pH,

- temperature,

- TOC/COD/BOD,

- turbidity, and

- dissolved oxygen.

In addition to the regular monitoring carried out by the operator to demonstrate compliance with the release limits set by the Agency, the operator should have a fuller analysis carried out covering a broad spectrum of substances to establish that all relevant substances have been taken into account when setting the release limits.

Samples should also be monitored for other appropriate parameters, such as those listed below, over relevant time periods; typically daily, weekly or monthly, depending on the circumstances:

- COD,

- suspended solids,

- phenols, cyanide, thiocyanate and ammonia (if applicable),

- oil,

- dissolved oxygen (where justified by the nature of the receiving water), and

- metals (including Fe, Ni, Hg, Cr, Zn, Pb, As, Cu, Cd, as appropriate).

The operator must be able to demonstrate compliance with any condition of the Authorisation. Thus any concentration limit must either be set higher than the reasonable limit of detection or it must be calculable by reference to source data, such as feedstock quantity and quality. To quantify mass releases, the load calculation can be based on the multiple of concentration and flow or inferred at a higher degree of accuracy from feedstock quality and use.

It may be appropriate to use surrogate parameters, which reflect the optimum environmental performance of the plant, as the routine measurement, supported by less frequent check analyses on the final concentration. Examples of this approach would be continuous measurement of conductivity (after ion-exchange treatment) or total carbon (before a guard column in activated carbon treatment), to indicate when regeneration or replacement is required.

Where Agency staff need to obtain a better understanding of the performance of an effluent treatment plant (ETP), a short-term monitoring exercise to provide information about the inputs to the ETP may be appropriate, as part of an improvement programme.

6.5 Monitoring releases to land

The applicant should record and advise the Agency of the quantity and composition (including prescribed substances) of waste released to land. In addition, the applicant should have written procedures, to ensure that releases are handled, treated and disposed of in an approved manner, and specify how the accumulation and storage of wastes are controlled.

The frequency of analysis of the waste materials is site- and/or process-specific, influenced by considerations of the anticipated quantity, its frequency of despatch from the site, physical form, containment (for transport) and composition. Applicants should be aware that the Agency will wish to be satisfied that analyses should be sufficient to ensure that wastes are acceptable under the terms of the Waste Management Licence of the facility where they are to be disposed of and fulfil the waste description requirements of the Duty of Care regulations.

6.6 Environmental monitoring

6.6.1 Atmospheric impact

Table 2.1 illustrates the wide range of atmospheric releases from the various processes within a steel works. Technical Guidance Notes M1, M2, M3 and M4 and Reference[29] provide Agency guidance on the monitoring of such emissions.

The following comments relating to coarse dust particles and VOCs are supplementary to the guidance given in the above sources.

Coarse particulates
Discharges into the atmosphere of coarse particulates may arise from failure of gas cleaning plant, mechanical or pneumatic conveying systems and other equipment. Coarse dust can also arise from traffic on unclean or unmade roads and raw material stockpiles.

Releases of coarse particulate will not travel far and the area affected is not normally great. Within the affected area, however, the environmental impact can be severe.

Simple deposit gauges placed in suitable locations may be used to detect dust arising from plant failures or other reasons and should be required when plant is within 25 metres of a sensitive boundary.

VOCs
Volatile organic compounds may be released in pure form from storage or handling activities. They are also generated during coke manufacture and during organic coating of strip, which is not at present a Part A process.

In circumstances where significant amounts of highly volatile materials are used, an environmental sampling programme, using a suitable network of adsorption tubes, may be required.

This technique can provide an economic method of identifying the origin of environmental problems associated with VOCs and enables activities to be identified where more effective containment is required.

6.6.2 Groundwater impact

Where on-site disposal of waste products occurs, or where there are discharges to groundwater, either directly or indirectly, the requirements of the Groundwater Directive for 'prior investigation' of the potential effects on groundwater and 'requisite surveillance' need to be addressed. The form that these will take will depend on circumstances, but it may be appropriate to include a structured programme of groundwater monitoring (e.g. using borehole monitoring).

In addition, where there is reason to suspect that leakage into the ground of chemicals, including acids, alkalis, oils or contaminated water, may have occurred or may be occurring, a programme of investigations should be instigated and preferably agreed with the Agency (some activities may require the Agency's prior consent).

For many sites, it will be appropriate to incorporate a programme of background monitoring of groundwater, to ascertain whether the steel works process has given rise over time to groundwater contamination via leaking pipes, accidental spills, leachate, contaminated run-off, etc. This is over and above any monitoring required to measure the effects of specific on-site disposals of solids or liquids on groundwater. Owing to the lengthy residence time and differing modes of transport and degradation in the underground environment, such monitoring is likely to be long-term and should be adapted to the types of contaminant that could be present in the potential discharges. It is essential to include background monitoring of groundwater that has not been affected by the processes and other activities at the site (normally 'up-gradient' in the hydraulic sense), to determine objectively the degree of contamination that may be attributable to the activities on the steel works site.

It should be noted that, due to the variety of flow mechanisms, background water quality and modes of transport in the subsurface environment, the sampling methods, frequencies and the determinands to be measured should be assessed on a site-specific basis, following consultation with a suitably qualified hydrogeologist.

In setting out a programme of investigations, and when interpreting the results, operators should take account of the specific risks to groundwater and seek advice from the Agency in cases of uncertainty.

6.7 Records and reporting

Agency staff shall have regard to the instructions on:

⊖   reporting and monitoring, and

⊖ . records and notifications related to incidents,

given with the standard IPC Authorisation format.

Appendix 1 Volatile organic compounds

Introduction

Volatile organic compounds (VOCs) are of serious environmental concern because of the harmful or offensive properties that they exhibit in varying degrees. These include:

● direct toxicity to human health and other eco-systems;

● contribution to photochemical ozone creation at ground level, with consequent harmful effects;

● destruction of stratospheric ozone;

● contribution to global climate change; and

● sensory effects such as malodour.

The harmfulness of VOCs varies greatly, not only because the individual and combined significance of these properties exhibits wide variation between substances, but also because it is dependent on the presence of the substance in the environment. This is related to mass release rate and subsequent dispersion and to the environmental persistence and fate of the substance under prevailing conditions.

Categorisation

In order to enable Agency staff properly to assess applications for processes that release VOCs, it is necessary to categorise VOCs according to their harmfulness.

Substances such as benzene, vinyl chloride and 1,2-dichloroethane pose serious health risks to humans and are regarded as highly harmful. Hence individual, very low achievable levels of emission are necessary for such species.

Some other VOCs carry a lesser but still significant health risk or may contribute substantially to photochemical ozone creation or stratospheric ozone destruction or global warming. These are considered to be of medium harmfulness and are allocated to Class A. They will include the substances listed in the Montreal Protocol, the phase-out of which is covered by EC Regulations 594/91, 3952/92, 2047/93 and 3093/94.

The remaining majority of VOCs are of low harmfulness but are also prescribed substances, whose release must be prevented or minimised. These are allocated to Class B.

The definition of 'harm' given in the Environmental Protection Act 1990 includes offence to any of man's senses. Odorous VOCs may be offensive at extremely low concentrations and this property may indicate the need for very tight control of a substance, that would otherwise be categorised as of low harmfulness.

The research report *The Categorisation of Volatile Organic Compounds*[20] (DOE/HMIP/RR/95/009) provides a method of categorisation, information on the properties of some 500 VOCs and a summary table of resulting categorisations.

In seeking to categorise a VOC, Agency staff should first search the summary table of categorisations. If the VOC is not included, the method and decision tree given in the research report should be used to arrive at a conclusion, supported as well as possible by information from established sources. These include the Registry of Toxic Effects of Chemicals, the 'CHIP' list[11], the Montreal Protocol and Sax's *Dangerous Properties of Industrial Materials*.

Knowledge of the harmful effects of VOCs is developing and there may be occasional differences of experts' opinions on the precise interpretation of information. In these few instances, it will be prudent to adopt the more cautious view.

Achievable benchmark levels

The levels of emission that can be achieved are dependent on factors that include the prescribed process itself, the VOC concerned and the abatement method used. Before abatement equipment is considered, the operator should review the process to determine whether the emission can be reduced by changes in equipment or operating conditions. It may also be possible to improve the situation by substitution with a less harmful or less volatile compound.

Where possible, process- and substance-specific achievable levels of release are given in Table 4.1 of this Note.

A BPEO/BATNEEC assessment should be made wherever possible to determine an acceptable release level. However, in the absence of sufficient information or where it is agreed by the Agency staff that an assessment is not possible, the following guidelines may be used to provide a practical approach to setting limits. Agency staff should also consider all relevant information contained in applications and other appropriate sources when they set VOC emission concentrations or mass emission limits in Authorisations.

● The benchmark release concentrations given below should be aimed for where the following mass release limits are exceeded:

Total Class A	100 g/h
Total Class B (expressed as toluene)	2 kg/h

Releases below these mass emission levels may not be trivial, and so may still require controls and the setting of appropriate release limits.

● Highly harmful VOCs pose major human health risks and have individual guidance levels.

- For Class A compounds, state-of-the-art abatement techniques can achieve a benchmark release level of 20 mg/m³ for continuous releases.

- Some VOCs cause significant malodour problems even at very low concentrations after dispersion and limits lower than Class A compounds may be required.

- Class B compounds are those of low environmental harmfulness, such as acetone and toluene. Toluene has been used as a reference material, as it is a common Class B solvent. If emission levels were expressed as total organic carbon (TOC), the mass concentration limit, particularly for halogenated compounds, would be too lax, as such a compound may have a high molecular weight relative to its number of carbon atoms.

- The Class B benchmark level has been set at 80 mg/m³ toluene, based on abatement techniques involving adsorption with activated carbon.

  The benchmark release level for a Class B substance may be determined by multiplying the molecular weight of the pollutant by a factor of 0.87, to give the release level in mg/m³.

  For mixed streams, the release level may be calculated by summing the release levels for each class, multiplied by their respective mass fractions.

- The above is for guidance on setting release levels only and not for monitoring those releases. Monitoring would be expected to be for individual substance or for TOC.

  HMIP Technical Guidance Note M2 gives more information on monitoring techniques.

- The use of a release concentration limit is not normally appropriate in the case of a release from an air-deficient saturated vapour space, such as storage tanks for solvents or process vessels. An approach based on limiting total mass released or mass per unit of production is likely to be more effective.

- In some processes, the VOCs released to air may consist of partial oxidation products, rather than defined compounds that can be classified as above. In such cases, an approach based on a TOC release concentration is likely to be more effective. Reference may be made to IPCGN S2 5.01 [33] and the release emission concentrations used should take into account the harmfulness of the products that are released.

Abbreviations and definitions of terms used

AOD	Argon-oxygen decarburisation
BAT	Best available techniques
BATNEEC	Best available techniques not entailing excessive cost
BF	Blast furnace
BOD	Biochemical oxygen demand
BOF	Basic oxygen furnace
BOS	Basic oxygen steel making
BPEO	Best Practicable Environmental Option
CFCs	Chlorofluorocarbons
CO	Carbon monoxide
COD	Chemical oxygen demand
CPI	Corrugated plate interceptor
DRI	Directly reduced iron
EAF	Electric arc furnace
EIS	Environmental impact statement
EP	Electrostatic precipitator
EPA90	The Environmental Protection Act 1990
ETBPP	Environmental Technology Best Practice Programme
ETP	Effluent treatment plant
GAC	Granular activated carbon
HBI	Hot briquetted iron
HCFCs	Hydrochlorofluorocarbons
HCl	Hydrogen chloride
HEPA	High-efficiency particulate arrestment
HF	Hydrogen fluoride
HMIP	Her Majesty's Inspectorate of Pollution (former)
H_2S	Hydrogen sulphide
HSE	Health and Safety Executive
IPC	Integrated Pollution Control
IPPC	Integrated Pollution Prevention and Control
NDA	New drug approval (US)
NO_2	Nitrogen dioxide
NOX	A mixture of nitric oxide and nitrogen dioxide
PAC	Powdered activated carbon
PAH	Polyaromatic hydrocarbon
PCB	Polychlorinated biphenyl
PCCD/F	Poly chlorinated dibenzo dioxins/furans
PPI	Parallel plate interceptor
RD	Recirculation degassing
SCR	Selective catalytic reduction
SNCR	Selective non-catalytic reduction
SO_2	Sulphur dioxide
SO_3	Sulphur trioxide
SOX	Oxides of sulphur
SRU	Sulphur recovery unit
SWS	Sour water stripping
TEL	Tetraethyl lead
TML	Tetramethyl lead
TOC	Total organic carbon
TVP	True vapour pressure
VAD	Vacuum arc degassing
VOC	Volatile organic compound
VAR	Vacuum arc remelting
VIM	Vacuum induction melting
VOD	Vacuum oxygen decarburisation

Associated publications

The following are available from Stationery Office bookshops (see back cover), their accredited agents, and some larger bookshops.

Series 2

Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)

Fuel production processes, combustion processes (including power generation)

S2 1.01 Combustion processes: large boilers and furnaces 50 MW(th) and over
November 1995, £9.95, ISBN 0-11-753206-1
Supersedes IPR 1/1

IPR 1/2 Combustion processes: gas turbines
September 1994, £4.00, ISBN 0-11-752954-0

S2 1.03 Combustion processes: compression ignition engines 50 MW(th) and over
September 1995, £7.95, ISBN 0-11-753166-9
Supersedes IPR 1/3

S2 1.04 Combustion processes: waste and recovered oil burners 3 MW(th) and over
September 1995, £7.95, ISBN 0-11-753167-7
Supersedes IPR 1/4

S2 1.05 Combustion processes: combustion of fuel manufactured from or comprised of solid waste in appliances 3 MW(th) and over
September 1995, £9.95, ISBN 0-11-753168-5
Supersedes IPR 1/5-1/8

S2 1.06 Carbonisation processes: coke manufacture
September 1995, £9.95, ISBN 0-11-753176-6
Supersedes IPR 1/9

S2 1.07 Carbonisation and associated processes: smokeless fuel, activated carbon and carbon black manufacture
September 1995, £9.95, ISBN 0-11-753177-4
Supersedes IPR 1/10

S2 1.08 Gasification processes: gasification of solid and liquid feedstocks
November 1995, £9.95, ISBN 0-11-753202-9
Supersedes IPR 1/11

S2 1.09 Gasification processes: refining of natural gas
November 1995, £9.95, ISBN 0-11-753202-7
Supersedes IPR 1/12 and 1/13

S2 1.10 Petroleum processes: oil refining and associated processes
November 1995, £14.00, ISBN 0-11-753204-5
Supersedes IPR 1/14 and 1/15

S2 1.11 Petroleum processes: on-shore oil production
November 1995, £8.25, ISBN 0-11-753205-3
Supersedes IPR 1/16

S2 1.12 Combustion processes: reheat and heat treatment furnaces 50 MW(th) and over
September 1995, £8.50, ISBN 0-11-753178-2
Supersedes IPR 1/17

IPC Guidance Notes (prepared by the Environment Agency)

Metal industry sector

S2 2.01 Iron and steel making processes
September 1999, £50.00, ISBN 0-11-310163-5
Supersedes IPR 2/1 and IPR 2/3

S2 2.02 Ferrous foundries: supplementary guidance
September 1999, £50.00, ISBN 0-11-310164-3

Mineral industry sector

S2 3.01 Cement manufacture, lime manufacture and associated processes
August 1996, £21.00, ISBN 0-11-310120-1
Supersedes IPR 3/1 and IPR 3/2

S2 3.02 Asbestos processes
August 1996, £15.00, ISBN 0-11-310118-X
Supersedes IPR 3/3

S2 3.03 Manufacture of glass fibres, other non-asbestos mineral fibres, glass frit, enamel frit and associated processes
August 1996, £21.00, ISBN 0-11-310121-X
Supersedes IPR 3/4 and IPR 3/5

S2 3.04 Ceramic processes
August 1996, £17.00, ISBN 0-11-310119-8
Supersedes IPR 3/6

Chemical Industry Sector

S2 4.01 Large-volume organic chemicals
February 1999, £40.00, ISBN 0-11-310153-8
Supersedes IPR 4/1 to 4/4 and 4/6

S2 4.02 Speciality organic chemicals including pesticides and pharmaceuticals
February 1999, £40.00, ISBN 0-11-310154-6
Supersedes IPR 4/5, 4/7 to 4/9, 4/12 and 4/15

S2 4.03 Acids and halogens
February 1999, £40.00, ISBN 0-11-310141-4
Supersedes IPR 4/10, 4/11, 4/13 and 4/14

S2 4.04 Inorganic chemicals
February 1999, £40.00, ISBN 0-11-310140-6
Supersedes IPR 4/16 and 4/18 to 4/25

Waste disposal and recycling sector

S2 5.01 *Waste incineration*
August 1996, £30.00, ISBN 0-11-310117-1
Supersedes IPR 5/1, 5/2, 5/3, 5/4, 5/5 and 5/11

S2 5.02 *Making solid fuel from waste*
July 1996, £15.00, ISBN 0-11-310114-7
Supersedes IPR 5/6

S2 5.03 *Cleaning and regeneration of carbon*
July 1996, £13.00, ISBN 0-11-310115-5
Supersedes IPR 5/7
S2 5.04 *Recovery of organic solvents and oil by distillation*
July 1996, £17.00, ISBN 0-11-310116-3
Supersedes IPR 5/8 and IPR 5/10

Series 1

Chief Inspector's Guidance Notes (prepared by Her Majesty's Inspectorate of Pollution)

Metals production and processing

IPR2/2 *Ferrous foundry processes*
October 1994, £10.00, ISBN 0-11-752962-1

IPR2/4 *Processes for the production of zinc and zinc alloys*
November 1994, £7.50, ISBN 0-11-753024-7

IPR2/5 *Processes for the production of lead and lead alloys*
November 1994, £7.50, ISBN 0-11-753025-5

IPR2/6 *Processes for the production of refractory metals*
November 1994, £6.50, ISBN 0-11-753026-3

IPR2/7 *Processes for the production, melting and recovery of cadmium, mercury and their alloys*
November 1994, £7.00, ISBN 0-11-753027-1

IPR2/8 *Processes for the production of aluminium*
November 1994, £8.50, ISBN 0-11-753028-X

IPR2/9 *Processes for the production of copper and copper alloys*
November 1994, £7.00, ISBN 0-11-753029-8

IPR2/10 *Processes for the production of precious metals and platinum group metals*
November 1994, £8.00, ISBN 0-11-753030-1

IPR2/11 *The extraction of nickel by the carbonyl process and the production of cobalt and nickel alloys*
November 1994, £7.50, ISBN 0-11-753031-X
IPR2/12 *Tin and bismuth processes*
November 1994, £7.50, ISBN 0-11-753032-8

Waste and recycling sector

IPR5/9 *Regeneration of ion exchange resins*
May 1992, £4.30, ISBN 0-11-752650-9

Other Industries

IPR6/1 *Application or removal of tributyltin or triphenyltin coatings at shipyards or boatyards*
March 1995, £6.00, ISBN 0-11-753079-4

IPR6/2 *Tar and bitumen processes*
March 1995, £7.00, ISBN 0-11-753080-8

IPR6/3 *Timber preservation processes*
March 1995, £6.00, ISBN 0-11-753081-6

IPR6/4 *Di-isocyanate manufacture*
March 1995, £8.00, ISBN 0-11-753082-4

IPR6/5 *Toluene di-isocyanate use and flame bonding of polyurethanes*
March 1995, £7.00, ISBN 0-11-753083-2

IPR6/6 *Textile treatment processes*
March 1995, £7.00, ISBN 0-11-753084-0

IPR6/7 *Processing of animal hides and skins*
March 1995, £7.00, ISBN 0-11-753085-9

IPR6/8 *The making of paper pulp by chemical methods*
May 1995, £8.50, ISBN 0-11-753105-7

IPR6/9 *Paper making and related processes, including mechanical pulping, recycled fibres and de-inking*
May 1995, £10.00, ISBN 0-11-753106-5

Technical Guidance Notes

Monitoring

M1 *Sampling facility requirements for the monitoring of particulates in gaseous releases to atmosphere*
March 1993, £5.00, ISBN 0-11-752777-7

M2 *Monitoring emissions of pollutants at source*
January 1994, £10.00, ISBN 0-11-752922-2

M3 *Standards for IPC monitoring Part 1: Standards, organisations and the measurement infrastructure*
August 1995, £11.00, ISBN 0-11-753133-2

M4 *Standards for IPC monitoring Part 2 : Standards in support of IPC monitoring*
August 1995, £11.00, ISBN 0-11-753134-0

Dispersion

D1 *Guidelines on discharge stack heights for polluting emissions*
July 1993, £8.00, ISBN 0-11-752794-7

Abatement

A1 *Guidance on effective flaring in the gas, petroleum, petrochemical and associated industries*
December 1993, £4.25, ISBN 0-11-752916-8

A2 Pollution abatement technology for the reduction of solvent vapour emissions
October 1994, £5.00, ISBN 0-11-752925-7

A3 Pollution abatement technology for particulate and trace gas removal
April 1994, £15.00, ISBN 0-11-752983-4

A4 Effluent treatment techniques
January 1997, £28.00, ISBN 0-11-310127-9

Environmental

E1 Best practicable environmental option assessments for Integrated Pollution Control
April 1997, £35.00, ISBN 0-11-310126-0

Relevant DETR publications

Integrated Pollution Control: a practical guide.
DETR, 1995, ISBN 1-85112-021-1. Available from:

> DETR Publications Sales Centre
> Unit 8
> Goldthorpe Industrial Estate
> Goldthorpe
> Rotherham
> S63 9BL

> Tel: 01709 891 318

Secretary of State's Process Guidance Notes

Processes Prescribed for Air Pollution Control by Local Authorities

A list of these notes is available from:

> Department of the Environment, Transport and
> the Regions
> Air and Environmental Quality Division
> Ashdown House
> 123 Victoria Street
> London
> SW1E 6DE

> Tel: 0171 890 633

References

(1) The Environmental Protection (Prescribed Processes and Substances) Regulations 1991, SI 1991 No 472. ISBN 0-11-013472-9 as amended by:

The Environmental Protection (Amendment of Regulations) Regulations 1991, SI 1991 No 836, ISBN 0-11-013836-8

The Environmental Protection (Prescribed Processes and Substances) (Amendment) Regulations 1992, SI 1992 No 614, ISBN 0-11-023614-9

The Environmental Protection (Prescribed Processes and Substances)(Amendment) Regulations 1993, SI 1993 No 1749, ISBN 0-11-034749-8

The Environmental Protection (Prescribed Processes and Substances)(Amendment) (No 2) Regulations 1993, SI 1993 No 2405, ISBN 0-11-035405-2

The Environmental Protection (Prescribed Processes and Substances, etc)(Amendment) Regulations 1994, SI 1994 No 1271, ISBN 0-11-044271-7

The Environmental Protection (Prescribed Processes and Substances, etc)(Amendment) (No 2) Regulations 1994, SI 1994 No 1329, ISBN 0-11-044329-2

The Environmental Protection (Prescribed Processes and Substances, etc)(Amendment) Regulations 1995, SI 1995 No 3247; ISBN 0-11-053799-8

The Environmental Protection (Prescribed Processes and Substances, etc)(Amendment) (Hazardous Waste Incineration) Regulations 1998, SI 1998 No 767, ISBN 0-11-065758-6

(2) Integrated Pollution Control: A Practical Guide (HMSO) April 1994, ISBN 0-11-752750-5

Guidance Notes to Applicants for Authorisation - processes prescribed for regulation by the Environment Agency, available from the Agency

(3) Monitoring Emissions of Pollutants at Source, HMIP Technical Guidance Note (Monitoring) M2 (HMSO) January 1994, ISBN 0-11-752922-2

(4) Guidelines on Discharge Stack Heights for Polluting Emissions, HMIP Technical Guidance Note (Dispersion) D1. (HMSO) June 1993, ISBN 0-11-752794-7

(5) Environmental, Economic and BPEO Assessment Principles for Integrated Pollution Control, HMIP Technical Guidance Note (Environmental) E1

(6) EC Directive on the Combating of Air Pollution from Industrial Plants (framework), 84/360/EEC (OJL188, 16/7/84)

(7) The Air Quality Standards Regulations 1989. SI 1989 No 317, ISBN 0-11-096317-2 and subsequent air quality requirements

(8) Environment Protection, The Air Quality Regulations 1979, Statutory Instrument 1997 No 3043

(9) Protocol to the 1979 Convention on Long Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions, Oslo 1994

(10) Reducing Emissions of Volatile Organic Compounds (VOCs) and Levels of Ground Level Ozone: A UK Strategy, DOE, Romney House, 43 Marsham Street, London SW1P 3PY

(11) On the Limitation of Emissions of VOCs due to the Use of Organic Solvents in Certain Activities and Installations, EC Directive. 1999/13/EC

(12) The Surface Waters (Dangerous Substances Classification) Regulations 1989, SI 1989, No 2286

(13) Policy and Practice for the Protection of Groundwater. Environment Agency, SO 1998. ISBN 0-11-310145-7

(14) The Groundwater Regulations 1998, SI 1998 No 2746

(15) Control of Major Accident Hazards - Consultation paper, SO

(16) Draft Reference Document on Best Available Techniques in the Iron and Steel Industry, Institute of Prospective Technological Studies, European IPPC Bureau, Seville, 1999

(17) Separation Processes Service, Harwell Laboratory, Didcot, Oxfordshire OX11 0RA

(18) Air Pollution Advisory and Review Group, Air Quality Division, DoE, Romney House, 43 Marsham Street, London SW1P 3PY

(19) The Environmental Technology Best Practice Programme, ETSU, Harwell, Oxfordshire OX11 0RA. Helpline Telephone: 0800 585794

Good Practice Guides (relevant selection includes):

GG12 - Solvent capture for recovery and re-use from solvent-laden gas streams

GG71 - Cost-effective reduction of fugitive solvent emissions

GG37 - Cost-effective separation technologies for minimising-wastes-and-effluents

GG54 - Cost-effective membrane technologies for minimising wastes and effluents

GG100 - Solvent capture for recovery in practice: industry examples.

GG101 - Environmental Technology Best Practice Programme (ETBPP): reducing vacuum costs 1998.

(20) *Waste Minimisation - An Environmental Good Practice Guide for Industry*. Environment Agency, 1998

(21) *Waste Minimisation - A Practical Guide*, Institution of Chemical Engineers, 1995

(22) *Standard for Environmental Management Systems*, International Standards Organisation (ISO), ISO 14001.

Regulation (1836/93) allowing voluntary participation by companies in the industrial sector in a Community Eco-Management and Audit Scheme (EMAS). *Official Journal*, L168/1, 10/7/93

(23) *Pollution Abatement Technology for Particulate and Trace Gas Removal*. Technical Guidance Note (Abatement) A3: (SO). ISBN 0-11-752983-4

(24) *Above Ground Oil Storage Tanks - PPG2*, Pollution Prevention Guidelines: Environment Agency and Scottish Environmental Protection Agency:

CIRIA/Environment Agency Joint Guidelines: *Concrete bunds for oil storage tanks*

CIRIA/Environment Agency Joint Guidelines: *Masonry bunds for oil storage tanks*

CIRIA Report 163: *Construction of bunds for oil storage tanks*

(25) *Use and Design of Oil Separators in Surface Water Drainage Systems*, Pollution Prevention Guidelines PPG3, Environment Agency

(26) *Effluent Treatment Techniques*, Technical Guidance Note (Abatement) A4, SO, January 1997, ISBN 0-11-310127-9

(27) The Collection and Disposal of Waste Regulations 1988. SI No 819. ISBN 0-11-086819-6

(28) *The Special Waste Regulations 1996*, SI No 972; and *The Controlled Waste Regulations 1992*, SI No 588. ISBN 0-11-023588-6.

The Environmental Protection (Duty of Care) Regulations 1991, SI No 2839. ISBN 011-015-8539

Waste Management, The Duty of Care, A Code of Practice, HMSO, ISBN 0-11-752557-X

The Controlled Waste (Registration of Waste Carriers and Seizure of Vehicles) Regulations 1991, SI No 1624. ISBN 011-014-6247

(29) *A Review of the Industrial Uses of Continuous Monitoring Systems: Metals Industry Processes*, Report No NCAS/TR/98/003

(30) *Categorisation of Volatile Organic Compounds*, DOE Research Report No DOE/HMIP/RR/95/009, available from the Environment Agency's Public Enquiries Unit, Rio House, Waterside Drive, Aztec West, Bristol BS12 4UD

(31) *The Chemicals (Hazard Information and Packaging) Regulations Approved Supply List*, (SO), ISBN 0-11-882156-3

(32) *Waste Incineration*, Integrated Pollution Control Guidance Note S2 5.01. Environment Agency, ISBN 0-11-310117-1

MANAGEMENT AND CONTACTS:

The Environment Agency delivers a service to its customers, with the emphasis on authority and accountability at the most local level possible. It aims to be cost-effective and efficient and to offer the best service and value for money.

Head Office is responsible for overall policy and relationships with national bodies including Government.

Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS32 4UD
Tel: 01454 624 400   Fax: 01454 624 409

Internet World Wide Web   www.environment-agency.gov.uk

ENVIRONMENT AGENCY REGIONAL OFFICES

ANGLIAN
Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough PE2 5ZR
Tel: 01733 371 811
Fax: 01733 231 840

MIDLANDS
Sapphire East
550 Streetsbrook Road
Solihull B91 1QT
Tel: 0121 711 2324
Fax: 0121 711 5824

NORTH EAST
Rivers House
21 Park Square South
Leeds LS1 2QG
Tel: 0113 244 0191
Fax: 0113 246 1889

NORTH WEST
Richard Fairclough House
Knutsford Road
Warrington WA4 1HG
Tel: 01925 653 999
Fax: 01925 415 961

SOUTHERN
Guildbourne House
Chatsworth Road
Worthing
West Sussex BN11 1LD
Tel: 01903 832 000
Fax: 01903 821 832

SOUTH WEST
Manley House
Kestrel Way
Exeter EX2 7LQ
Tel: 01392 444 000
Fax: 01392 444 238

THAMES
Kings Meadow House
Kings Meadow Road
Reading RG1 8DQ
Tel: 0118 953 5000
Fax: 0118 950 0388

WALES
Rivers House/Plas-yr-Afon
St Mellons Business Park
St Mellons
Cardiff CF3 0LT
Tel: 01222 770 088
Fax: 01222 798 555

For general enquiries please call your local Environment Agency office. If you are unsure who to contact, or which is your local office, please call our general enquiry line.

ENVIRONMENT AGENCY GENERAL ENQUIRY LINE

0645 333 111

The 24-hour emergency hotline number for reporting all environmental incidents relating to air, land and water.

ENVIRONMENT AGENCY EMERGENCY HOTLINE

0800 80 70 60

ENVIRONMENT AGENCY

The Environment Agency has a commitment to
follow developments in technology and
techniques for preventing or minimising, or
remedying or mitigating the effects of pollution
of the environment. It publishes information
provided to its staff, in the form of Guidance
Notes, to make it available to potential operators
and other interested parties.

In the revision of the Integrated Pollution Control
Guidance on the iron and steel making industry,
the two original Notes on integrated iron and
steel works, and on electronic arc steel making,
secondary steel making and special alloy
production have been consolidated into this
Note. In addition to updating the earlier
information, new sections on management
techniques, groundwater protection and
sectoral economics have been included.

£60