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ENVIRONMENTAL ASPECTS OF THE IRON AND STEEL INDUSTRY WORKSHOP PROCEEDINGS

Geneva, 17-20 October, 1978.

Part 2

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VOLUME II

CONSULTANTS REPORTS

THE ENVIRONMENTAL IMPACT OF THE
STEEL INDUSTRY IN DEVELOPED NATIONS

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Originally issued as UNEP/WS/IS.3

1. INTRODUCTION

This report is concerned with the overview of the steel industry in developed nations, viz the EEC, USA, Canada, Australia and Japan; another report, prepared by Mr. Obata is devoted to the problems in developing nations and one by Mr. Jarzebski on the situation in Eastern Europe, while M. Astier considers the impact of advanced technology.

It has been intended that the present report should be addressed to the following problems:

(i) Identification of the environmental problems arising from steel production, including aspects of occupational health.

(ii) Discussion of existing pollution control technologies.

(iii) Discussion of unresolved environmental problems.

(iv) Discussion of new, less polluting technologies.

(v) Discussion of the role of resource utilization and recycling pertaining to environmental problems.

(vi) The assessment of long term trends regarding the environmental aspects of steel production.

(vii) The definition of desirable global goals, regarding environmental and resource utilization aspects of the steel industry.

However, because of the limitations on resources available for the preparation of the report and the extensive documentation available on certain aspects of this problem, it was thought preferable to avoid the routine compilation of data, that are readily available elsewhere, such as the detailed description of ironmaking and steelmaking technology and the established environmental control procedures; rather, in the report, emphasis has been placed on the identification and discussion of the as yet unresolved issues pertaining to the environmental impact of the steel industry.

The actual methodology adopted for the study included the critical review of the published literature, notably recent reports by the Arthur D. Little Co., (1), the OECD (2), the Dravo Corporation (3) and others, (4,5,6) extensive correspondence with environmental experts from various iron and steel Societies (including the American Iron and Steel Institute, the Japanese Iron and Steel Institute, the Verein Deutsche Eisenhüttenleute, etc.) together with a limited number of personal discussions and telephone conversations, with experts, both in the US and overseas.

Regarding the organization of the report, the following Section 2 is devoted to a very brief description of ironmaking and steelmaking technology, together with a discussion of the principal pollution sources.

The following Section 3 is concerned with a brief description of the pollution abatement devices currently used in the iron and steel industry.

In Section 4 new developments in iron and steelmaking technology that are relevant to pollution abatement, are discussed, while Section 5 is devoted to unresolved environmental problems in iron and steelmaking technology. The unresolved issues regarding the environmental impact of the steel industry are treated in Section 6 while projections for future trends are contained in Section 7. Finally, the concluding remarks are given in Section 8.

2. STEELMAKING TECHNOLOGY WITH EMPHASIS ON POLLUTION SOURCES ASSOCIATED WITH IRONMAKING AND STEELMAKING

2.1 Perspectives

The iron and steel industry is an important component of every industrialized society. The total raw steel production[1] in the world amounted to 595 million tons in 1970, and that estimated for 1980 is about 939 million tons. The corresponding figures for the developed nations[2] (i.e. the OECD) are 373 and 532 million tons respectively. Thus the developed nations are responsible for well over 50% of the steel produced in the world.

Steel production is a major consumer of resources. The manufacture of one ton of finished steel products using iron ore as a starting point requires some 37 Giga Joules (35 million Btu) of energy (7), uses about 151 tons (40,000 gallons) of water* and about 12 man hours of production labour.

Like all primary metals producing operations the steel industry has a major impact on both the ambient air and water quality and on the working environment of its production workers.

2.2 Description of Ironmaking and Steelmaking Technology

The transformation of iron ore into steel products involves the following principal processing steps:[8]

a. Raw materials preparation.

b. Cokemaking.

c. Ironmaking

d. Steelmaking

e. Finishing of steel products.

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*The actual water consumption is only a small percentage of this figure.

The various components of these processing steps are shown in Figures 1 and 2.

(a) Raw Materials Preparation

Sinterplants

The iron bearing materials are delivered to the steelplant from the mine in the form of lump ore, ore pellets or relatively fine ore particles. Lump ore or pellets are ready for subsequent processing in the iron blast furnace, but the fine ore particles must be agglomerated in the sinterplant before they can be used for ironmaking. In essence the sinterplants are large moving grates onto which a mixture of ore, return sinter, mill scale and about 5 wt % coke breeze is being fed. This mixture is ignited and then air is sucked through the bed such that the combustion of the coke produces a narrow, high temperature zone which travels through the system. This brief exposure to high temperature produces the desired degree of agglomeration.

The principal pollution produced by sinterplants is the emission of particulates, SO_2, and NO_x and small amounts of hydrocarbon vapours. The particulates emitted are relatively coarse and are readily removed by electrostatic precipitators. At present no SO_2, NO_x and hydrocarbon removal is being practiced, with the exception of some experimental Japanese installations.

(b) Coke Manufacture

The coke which serves as a fuel and a reducing agent in the blast furnace is produced by heating metallurgical coal in the absence of air to a temperature at which the major part of the non-ash components of the coal (i.e. volatile matter, water and sulphur) are driven off. The by-product coke ovens used for this purpose are rectangular in shape, some 10 - 13m long, 2 - 7m high and some 0.3 - 6.0m wide. A typical coke oven battery may contain up to 100 such units. Some 25 percent of the coal is volatilized during the coking process thus large amounts of gas (approximately 4 - 500 Nm^3/ton of coke) are generated.

This gas is treated to remove by-products, such as tars, phenols etc and then part of it is used to underfire the coke ovens, while the remainder is generally used as a valuable fuel elsewhere in the plant.

Some of the hydrocarbons emitted through leaking doors and during the charging of the ovens with coal are known to be carcinogenic and represent a major problem regarding the working environment and possibly the ambient air quality. The solids emitted during the discharge of the ovens, viz "pushing", also have an adverse environmental impact.

In addition the removal of the residual tars, phenols and hydrocarbons from the wash water of the coke oven gas also poses certain difficulties.

(c) Ironmaking

The iron blast furnace is a vertical shaft some 30m high, having a maximum diameter, ranging from say 10 - 15m. Into this shaft furnace iron bearing materials (ore, pellets or sinter) fluxes and coke are being charged at the top, while preheated air is introduced through horizontal tuyeres near the bottom. As a result partial combustion of the coke occurs and the iron ores are reduced to metallic iron during their descent through the furnace.

The principal product of the blast furnace process is molten iron, containing some 3 - 4 wt% carbon, some 0.5-1 wt% silicon, some manganese, sulphur and phosphorus. Typically blast furnaces produce some 1,000 - 10,000 tons per day of molten iron, larger production rates being obtained in the larger, more modern furnaces.

In addition blast furnace gas is produced, which with a heating value of about 2 MJ/m^3 is a useful fuel. A somewhat less desirable by-product is blast furnace slag which may be used as roadfill or in the manufacture of cement (mainly in Europe).

The main environmental problems associated with iron production in the blast furnace are the emission of particulates and the fugitive emission of particulates and sulphur compounds (SO_2 and H_2S) encountered in the tapping of molten iron and slag respectively. In addition the cyanides found in the blast furnace gas wash water also pose a problem.

Of these, the removal of particulates from the blast furnace off gases is quite straight-forward, but with the exception of a few new large scale installations, little work has been done, up to the present, regarding the treatment of the fugitive emissions in the blast furnace cast house.

Direct Reduction

The so-called "direct reduction" processes provide an alternative to ironmaking, especially for small scale operations and under conditions where oil or natural gas are readily available.

Direct reduction units are generally vertical shaft furnaces, in which iron ore pellets are contacted with an ascending (oil or natural gas based) reducing gas mixture in a counterflow arrangement. The product of direct reduction units is solid sponge iron which has to be smelted in electric arc furnaces to obtain steel.

Direct reduction units are available in modules, producing some 300-400,000 tons per annum, so that for large scale production the economies of scale would not be realized. The operation of direct reduction units does not pose the same serious environmental problems that are encountered in coke making and in the production of blast furnace hot metal. However, in assessing the environmental impact of direct reduction units, one has to consider the environmental pollution inherent in power generation (emission of particulates and SO_2 if coal is being used) in addition to the fact that oil or natural gas are not readily available in many parts of the world.

At present less than 5% of the total ironmaking capacity in the world is based on direct reduction and while direct reduction is finding increasing popularity, particularly in the developing countries, one may argue whether this corresponds to an optimal resource allocation, especially for large scale operations.

(d) Steelmaking

The hot metal produced in the blast furnace contains various impurities such as carbon, silicon, manganese, sulphur and phosphorus, the presence of which would prevent the direct use of this material for most steel applications, such as structural members, rails, sheet and the like. The objective of steelmaking processes is to effect selective oxidation of these impurities. In addition, steelmaking processes use scrap (both generated in the plant itself and externally purchased) and may make use of reduced pellets of sponge iron.

Three major modes of steelmaking are in current use, namely:

(d1) The Open Hearth Process

(d2) The Basic Oxygen Process, - including the

so-called Q-BOP and

(d3) The Electric Steelmaking Process.

(d1) The open-hearth steelmaking process is the oldest of the currently used technologies and is rapidly fading in significance due to its high energy use and labour requirements. In essence the open-hearth process involves the treating of blast furnace hot metal and scrap in a shallow reverbatory furnace, with a metal pool depth of say 0.5 - 1.0m, which is heated by burning oil or natural gas, using preheated air. The oxidation of the impurities is promoted by oxygen injection, but even under these conditions it may take some 5 - 6 hours to finish a given "heat of steel", the size of which may vary between 100 - 500 tons.

The principal environmental problems associated with open hearth furnace operation are the "point source" emission of particulates carried by the furnace off gases and the "fugitive" emission of finely divided iron oxides, through leaking doors and during the teeming operation. *

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* The terms "point source emission" and "fugitive emission" will be defined subsequently.

(d2) The Basic Oxygen (BOF) process has become the most dominant steel-making operation at the present. In this operation blast furnace hot metal and scrap are charged (in a ratio of about 3 - 1) into a pear shaped vessel, together with fluxing materials, and then a supersonic oxygen jet is blown onto the bath surface. The oxygen reacts with the impurities and thus the refining of the bath is completed in about 20 - 25 minutes. The typical heat sizes would range from about 60 - 300 tons. A variant of the basic oxygen process is the Q-BOP operation, which involves the blowing of oxygen (and a coolant) through the bottom of the vessel.

The principal environmental problem associated with the operation of the BOF and the Q-BOP is the point source emission of fine iron oxide fume, carried by the gaseous reaction products. Additional environmental problems are posed by the "fugitive dust emission" during tapping, by slag disposal and by the disposal of the dust collected from the exhaust gases.

(d3) Electric furnaces consist of cylindrical shell of relatively large diameter, with a dished bottom; this shell is covered by a removable roof, through which three graphite electrodes are inserted. Electric furnaces currently in use range in capacity from 5 - 400 tons.

A solid charge, consisting of scrap or pre-reduced pellets is fed to the furnace. This charge is then melted by the heat supplied by the electric arc. The refining of the charge takes place by oxygen injection.

Electric furnaces are attractive, because they can use scrap and pellets, furthermore high quality steels are readily made in electric furnace shops. The principal environmental problems associated with electric furnace operations are point source and fugitive dust emissions during oxygen lancing, and fugitive dust emissions during charging and tapping.

An additional environmental factor that has to be considered in the operation of electric furnaces is the pollution produced (viz SO_2, NO_x and particulates) while generating the electric power.

(e) Finishing of Steel Products

As seen in Fig. 1, the raw steel produced in the BOF, the electric furnace or the open hearth furnace has its composition adjusted by de-oxidation, and possibly vacuum degassing. Then the steel is cast, either into ingots or cast continuously into slabs or billets.

The subsequent processing steps are illustrated in Fig. 2, which for the sake of brevity does not indicate the soaking pits and the re-heating furnaces. The ingots cast (after conditioning in the soaking pits) are processed in the primary (rolling) mills to produced blooms or slabs. These intermediate products are again brought to the desired rolling temperature and are then processed to produce bars, pipes or strip respectively.

If continuous casting is used, slabs and billets are produced directly, which then enter the operational sequence as shown.

In general the finishing operations pose less severe environmental problems than the primary end of iron and steel production. The main environmental problems associated with finishing are the point source emission of waste waters containing acids and heavy metals from the pickling operation, oil bearing waste waters from the rolling mill operation which also contain particulates. The solid wastes resulting from the finishing operations, viz mill scale are generally recycled.

2.3 The Principal Pollution Sources in the Ironmaking - Steel Processing Sequence

In the processing, brief description of the ironmaking - steel processing technology, note was made of the main pollution sources associated with the various operations. In the following we shall provide an alternative classification, with emphasis on the quantitative aspects of these emissions.

The emissions by the steel industry are conveniently classified as:

(A) Point Source Emissions

(B) Fugitive Emissions

(i) air pollution

(ii) water pollution

(iii) solid waste

It should be noted that point source emissions refer to pollutants discharged in a gaseous or aqueous stream, which leaves the plant through a well defined conduit, such as a stack or discharge pipe. In contrast, fugitive emissions are defined as pollutants that escape from the system, in a manner not associated with a well defined gaseous or liquid stream.* Thus particulates carried by waste gases exiting a Basic Oxygen Furnace and ultimately exiting through a stack would constitute a point source emission, while hydrocarbons, or particulates emitted through ill fitting coke oven doors or dust picked by the wind from stockpiles would constitute fugitive emissions. Fugitive emissions occur almost inevitably when molten steel is being poured, or when solid materials are being handled.

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*According to US terminology only gaseous emissions are classed as "fugitive", but in the present context we shall use this term in a broader sense.

Highlighting the most important pollution sources:

(A) POINT SOURCE EMISSIONS

(i) AIR POLLUTION

The principal sources of air pollution in iron and steel production due to point source emissions and steel processing are listed in the following, with the numbers indicating the raw residual load (contained in the untreated effluent) in the kg/ton of steel produced:

Sinterplants		
	particulates	15 - 20
	SO_2	1 - 12
	NO_x	0.3 - 0.8
	hydrocarbons	0.02 - 0.2
Coke Manufacture		
	SO_2	0.2 - 5.0
	hydrocarbons	0.2 - 2.0
	H_2S	0.1 - 0.8
	HCN	0.1 - 0.6
	CO	0.4 - 0.8
	NO_x	0.2 - 2.5
Iron Blast Furnaces		
	particulates	20 - 30
Basic Oxygen Furnace (BOF)		
	particulates	30 - 33
Open Hearth Furnace		
	particulates	5 - 30
	SO_2	1 - 6
Electric Arc Furnace		
	particulates	3 - 20
Vacuum Degassing		
	particulates	1 - 15

(ii) WATER POLLUTION

Sinterplants	
suspended solids	8 - 10
oil	0.4 - 0.8
Coke plants	
ammonia	0.3 - 2.0
phenols	0.3 5.0
cyanides	0.15 - 5.0
oil	0.1
suspended solids	0.1 - 1.15
Blast Furnace	
ammonia	0.1 - 0.2
phenols	0.05
cyanides	0.05 - 5.0
suspended solids	0.8
Steelmaking	
BOF (wet)	
suspended solids	10
Electric Furnace (wet)	3.5
Continuous Casting	
suspended solids	0.5 - 4.0
Finishing Operations	
suspended solids	0.1 - 2.0
oil	1 - 1.5
free HCl	1.5 - 10
free H_2SO_4	2.0 - 20
heavy metals, such as Cr, Pb, Sn	

(iii) SOLID WASTE

Steel mills are major producers of solid waste. In terms of tonnages by far the largest component is provided by the slags produced in the iron blast furnace and in the steelmaking operations. Additional amounts of solid waste are being produced by the partial recovery of the solid content of the point source emissions listed above.

Ironmaking

Some 200 - 220 kg of slag is being produced per ton of hot metal. This material is used as roadfill and as a filler in cement manufacture.

Steelmaking

Some 120 - 150 kg of slag is produced per ton of steel made.

Solid wastes from gaseous and liquid environmental control operations

While these materials are present in smaller absolute quantities, their disposal may pose more serious problems, because of their consistency.

The principal components of the solid wastes resulting from environmental control operations have been already listed under (A) (i) and (ii), and in total these could amount to some 70 - 90 kg/ton of steel produced.

(B) FUGITIVE EMISSIONS

In contrast to point source emissions, such as gaseous streams existing furnaces, aqueous streams exiting clarifiers or filters, fugitive emissions are more difficult to identify or abate. Typically, fugitive emissions would refer to gas streams escaping from coke ovens, dust pick-up from piles of materials within the plant, run-off water, and the like. By and large, point source emissions could have a major effect over a larger environment surrounding the plant, while fugitive emissions have their principal effect on the working environment within the plant.

The principal fugitive emissions pertain to air quality and are listed in the following. All these entries refer to kg emitted/ton of steel produced.

ore and coal yard operations	5 - 10 kg/ton particulates
coke manufacture*	0.5 - 3.5 kg/ton particulates
blast furnace cast house	1 - 4

* In addition, fugitive emission of hydrocarbons, hydrogen sulphide and aromatic hydrocarbons must also be considered.

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In addition to the above, we must also consider the water borne fugitive emissions, resulting from the leaching of solid wastes.

Thus in summary the principal problems encountered in steelmaking operations are the following.

AIR POLLUTION:

Point source emission of particulates from sinterplants, the blast furnace and oxygen steelmaking; emission of particulates of hydrocarbons, SO_2 and H_2S from the coking process.

Fugitive emission of particulates from solids handling, from coke manufacture, from cast houses and from the finishing operations; gaseous fugitive emissions, sulphur compounds from cast houses, hydrocarbons and sulphur compounds from the coking operation.

WATER POLLUTION

The principal point sources of water pollution are the waste waters from coke plants, containing chemicals and suspended solids, the waste waters from the blast furnace, the BOF and the finishing operations, all containing suspended solids; in addition the latter also contains emulsified oils.

Spent pickle liquor also constitutes an important source of water pollution.

SOLID WASTE

Finally, the manufacture of iron in the blast furnace and the steelmaking operations produces appreciable amounts of solid waste, in the form of slag and materials removed from effluent gas streams (BOF dust).

3. BRIEF REVIEW OF EXISTING POLLUTION CONTROL TECHNOLOGIES

The diverse sources of pollution produced by the iron-making - steel processing operational sequence, described on the preceeding pages, necessarily require a broad range of treatment facilities. The removal of particulate solids from dust laden gases and the removal of suspended solids or chemical contaminants from aqueous streams is not unique to the steel industry, because similar problems are encountered in the combustion of solid fuels (power generation) and by the chemical industry. It follows that in general, technology is available for the treatment of the majority of point source emissions, although the actual implementation of this technology could be costly in many instances.

However, there are certain aspects, regarding which the steel industry is unique. The large volume of materials to be handled, the very small particle size of dusts produced, and the existence of fugitive emissions, may be cited as examples.

A detailed review of pollution abatement technologies is available in references (3,4,6) for this reason we shall restrict the present treatment to some brief comments pertaining to treatment methods available for dealing with air pollution, water pollution and solid waste.

3.1 Air Pollution

3.1.1 Point Sources

The treatment methods for point source air pollution may be divided into the removal of particulates, and the chemical contaminants, primarily hydrocarbons, sulphur compounds and nitrogen oxides.

Particulate Removal

The principal methods for the removal of particulates from gas streams are listed in the following:

cyclone and inertial separators

wet scrubbers

electrostatic precipitators and

bag filters.

Fig. 3 shows a plot of the relative particle collection efficiencies of these various devices, where it is seen that cyclones are not adequate for removing fine particles and that high energy scrubbers and electrostatic precipitators are about equally efficient, down to a particle size of about 1 micron. Below that size, fabric (bag) filters appear to be the most efficient, although these devices may pose serious maintenance problems.

As a practical matter, for the treatment of dust laden gases from steel making operations the choice is between electrostatic precipitators, wet scrubbers and fabric filters; ultimately the selection is governed by local circumstances.

It is noted that particles within the size range 0.01 - 0.05 µm are most likely to be retained within the lungs (9) and thus could pose particular health hazards, although these effects have not yet been demonstrated. At the same time there is not satisfactory industrially proven technology for the removal of such very small particles from gas streams.

Removal of Chemical Contaminants

The principal chemical contaminants in gaseous effluents from steel plants are sulphur compounds, contained in the coke oven gas and also generated in course of the combustion of sulphur containing fossil fuels. Adequate technology is available for handling this problem. Another air pollution problem is the emission of hydrocarbons, contained in sinter plant waste gases.

3.1.2 Fugitive Emissions

In sharp contrast to our understanding of point source air pollution from steel plants and the ready availability of technology for abating such pollution, our understanding of fugitive emissions and the technology for its abatement are much more limited.*

Important sources of fugitive particulate emissions are the stockpiles of ore and coal, virtually all solids handling operations, the coke ovens (particularly during charging and pushing). Furthermore, particulate emissions occur when molten metal is poured, and during all stages of the finishing process.

Fugitive emission of chemical contaminants occurs during the coking process, and to a lesser extent during slag quenching operations.

While these fugitive emissions do not have an adverse effect on the ambient air quality, they represent a serious hazard to the working environment.

Various treatment methods have been suggested for dealing with fugitive emissions, but most of these are in the experimental or the demonstration stage. Special hoods and "pushing control systems" have been installed in certain coke oven plants and some of the very modern Japanese plants have provided covered storage areas for particulate solids. Perhaps the most progress has been made regarding the installation of special hoods in

*It has been found that in the Lackawanna New York area the ambient air quality exceeded the State Standards, even when the steelplant at Lackawanna was closed down, because of a strike. This was attributable to the fugitive emissions generated by the dust deposited by the steelmaking operations over the years.

modern Basic Oxygen and Electric Furnace shops to abate fugitive emissions. The planting of trees and "green belts" around steel plants has been suggested as a means of abating the adverse effects of fugitive particulate emissions.

An alternative treatment of fugitive emissions that has been suggested is that the "complete evacuation" of buildings be considered, i.e. the air space in buildings be replaced rather frequently, using large fans. In addition to cost, this raises an important issue, whether it is worthwhile to trade pollution abatement in one location (i.e. the steelplant) for pollution where power is being generated.(10)

3.2 Water Pollution

The principal sources of water pollution are the waste waters from the coke plant operation, which contain various organic chemicals, cyanides and thiocyanides; the waste waters from the blast furnace and from the wet scrubbers (attached to BOF-s) contain suspended solids, the waste waters from the rolling mill operation contain both suspended solids and emulsified oils. Finally the waste waters from pickling operations contain acids and dissolved heavy metals.

In general adequate technology is available for dealing with most of these problems, although its use may be costly in some instances. Suspended solids are readily removed by sedimentation, to be followed by filtration. Biological treatment may be used for the oxidation of organics in coke plant waste waters, while deep bed filtration may be employed for the removal of emulsified oil from rolling mill wastes. In some instances deep well disposal is being used for spent pickle liquor, although this practice has to be regulated.

3.3 Solid Waste

Steelplants produce appreciable quantities of solid waste, both in the form of ironmaking and steelmaking slags, and solids formed as residues from gas cleaning operations. At present most of the ironmaking and steelmaking slag is dumped, while about one half of the pollution abatement residues are recycled; this figure is somewhat higher in Japan.

An extensive review of solid waste recycling technology and its implementation has been prepared by Pasztor and Floyd.(3)

4. NEW DEVELOPMENTS IN IRONMAKING AND STEEL PROCESSING TECHNOLOGY THAT ARE RELEVANT TO POLLUTION ABATEMENT

The highly capital intensive nature of the iron and steel industry has resulted in evolutionary rather than revolutionary developments. In essence the changes that have occurred in recent times, that are relevant to pollution abatement may be classified into the following three major categories.

4.1 The construction of large modern plants

4.2 The development of modern, less polluting processes and

4.3 Recent advances in pollution abatement technology.

4.1 Construction of Large Modern Steelplants

In recent years a number of large, modern steelplants have been constructed, notably in Japan. These new plants have tended to incorporate what is best in current technology, viz large efficient blast furnaces, continuous casting, in some cases direct rolling and the like. It is estimated that in order to comply with pollution control regulations, which are rather strictly enforced for new plants, more than 15% of the total capital investment was being spent on pollution control facilities. These factors, coupled with "good housekeeping measures" have greatly reduced the adverse environmental impact of steel production in modern plants, even without the use of specially innovative technology.

4.2 The Development of Modern, Less Polluting Processes

While pollution abatement has been a factor in new process development, the primary driving force in new process development has been economic.

The following two new technological developments could perhaps be singled out as having the greatest potential impact on the environment, namely:

(i) Direct Reduction

(ii) Form Coke Manufacture

(i) Direct Reduction

As discussed earlier, in Section 2, direct reduction produces sponge iron from the ore directly, thus the coking process and the blast furnace operation are eliminated from the ironmaking steel processing sequence. It follows that the air pollution and water pollution inherent in coke oven operation are eliminated, together with the adverse environmental impact of ironmaking in the blast furnace. However at present direct reduction is well proven only with oil or natural gas based feedstock, which limits its applicability to regions where these fuels are readily available. It is noted, furthermore, that in many locations the power required for smelting the sponge iron in electric furnaces has to be generated by burning fossil fuels which in turn may be a pollution source.

Overall, however, direct reduction is much less polluting than the conventional blast furnace - BOF route to steel. From the viewpoint of economics, direct reduction processes are attractive for production levels below about 1 - 2 million tons/annum. At higher production levels, the economies of scale allowed by the blast furnace process are likely to become overwhelming.

(ii) Continuous Cokemaking (Form Coke) Manufacture

It has been noted earlier that the conventional coke manûfacturing process poses the most serious environmental problems in steel processing. In recent years alternatives to this conventional operation have been proposed, which are the so-called form coke processes* (1). These operations do not require the expensive coking coal and are much less polluting than conventional coke ovens. Since the quality of the coke has a marked effect on ther performance of blast furnaces, and the acceptability of form coke has not been conclusively proven, as yet no commercial operations use form coke on a regular basis.

4.3 New Pollution Abatement Technologies

By and large the pollution abatement technologies used in iron and steel production have been adopted from other manufacturing operations. In addition to the evolutionary improvements in conventional pollution abatement devices, such as electrostatic precipitators and venturi scrubbers some interesting and novel ideas have also been put forward in recent years. Some of these will be noted in the following:

(i) Pushing Control Systems for Coke Ovens

Various ingenious devices have been proposed to minimize the fugitive emission of chemicals and particulates during the "pushing" operation, when the finished coke is being discharged from the coke ovens. Many of these involve the placing of hoods over the discharge area, while others propose the complete evacuation of the building.

(ii) Novel Particulate Removal Systems

In all these systems the collection of the dust laden gas streams is the main problem. Their subsequent treatment involves conventional technology.

The main drawback of the existing dust removal devices such as electrostatic precipitators and venturi scrubbers is their incapability of removing effectively particles that are smaller than about 0.5 - 1 microns in diameter. Novel systems including gas-stream atomized wet scrubbers and two phase electrostatic precipitators are currently in the development stage which would be more effective for removing smaller particles. (12,13,14)

5. UNRESOLVED ENVIRONMENTAL PROBLEMS IN STEEL MILL OPERATION

In spite of the substantial advances made regarding pollution abatement in the iron and steel industry, major unresolved problems

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*The form coking operations are proprietary, so detailed information on the technology difficult to obtain. It is almost certain that from the viewpoint of air pollution, form coke plants are vastly superior to conventional coke oven batteries. The water pollution aspect of form coke operations is rather more difficult to assess.

still remain. Theses unresolved problems fall in the following two main categories:

5.1 Inadequate implementation of available technology.

5.2 Non-availability of satisfactory technology.

5.1 Inadequate Implementation of Available Technology

While modern steelplants generally incorporate most of the up to date pollution abatement devices, (by necessity because operating permits would not have been granted otherwise) the retrofitting of pollution control equipment to old plants has lagged behind. This is a particular problem in Western Europe, and perhaps to a lesser extent in the USA. The retrofitting of pollution control equipment is necessarily costlier than a corresponding new installation and may be hard to justify on economic grounds. For this reason the various pollution control agencies have allowed considerable latitude regarding this problem, especially in Western Europe, when economic hardship could be demonstrated.

Another important practical point should be raised here.

It is common knowledge among steel mill operators that pollution may be appreciably reduced by the proper maintenance of equipment and by small adjustments in operating procedures. This "common sense" approach should be encouraged, by rewarding those who practise it.

5.2 Non-Availability of Satisfactory Technology

At present there is no really satisfactory technology available for dealing with the majority of fugitive emissions, such as produced by stockpiles of particulate solids, solids handling operations, coke ovens, cast house emissions and the finishing steps. Of these, the problems involved in solids handling, the operation of coke ovens and the cast house emissions appear to be the most serious. The non-availability of satisfactory technology, does of course not justify inaction, but rather it has to be stressed that these problems require technological solutions.

This non-availability of technology raises important policy issues, which will be discussed in the following section.

6. UNRESOLVED ISSUES REGARDING THE ENVIRONMENTAL IMPACT OF THE STEEL INDUSTRY

The current status of pollution abatement in the iron and steel industry in developed nations raises a number of important issues, where the interaction of social - economic, health related and technological factors have to be considered in combination.

Some of these issues are stated in the following:

6.1 The need for an accurate assessment of the costs and benefits of pollution abatement.

6.2 The economics of pollution abatement as it affects energy and resource conservation.

6.3 The effect of pollution on the working environment.

6.4 Development of pollution abatement devices versus new, non-polluting technology.

6.5 Policy issues raised by possible differences in pollution abatement for different countries.

Let us consider these issues in detail:

6.1 The Need for an Accurate Assessment of the Costs and Benefits of Pollution Abatement

While the adverse physiological effects of air-borne and water-borne pollutants are understood in a qualitative sense, there is considerable controversy regarding the threshold level above which pollutants cause serious damage to health. Reliable statistical information is lacking to relate morbidity, mortality and property damage to steelplant emissions levels, which makes a realistic cost benefit analysis difficult to perform.

It should be stressed that the above statement of facts does not advocate blanket suspension or easing of environmental standards imposed on steelplant operations. However, one has to be aware of the fact that these standards have been established on the basis of often meager physiological information and that further, unbiased data would be badly needed in this area.

Another important point should be raised here. Even if certain types of pollution did not have a demonstrably adverse health effect, the adverse impact on the quality of life has to be considered also, particularly in locations with high population densities.

Both pollution and its abatement are costly; although the costs are borne by different segments of society, ultimately resources are being consumed by both. It would be desirable to develop means for an optimal resource allocation in this area.

6.2 The Economics of Pollution Abatement and its Effects on Energy and Resource Conservation

It is a widely held, but unfortunately naive viewpoint that in the steel industry pollution abatement is readily implemented such that it is combined with the conservation of both energy and resources. If we are thinking in terms of technology available at present the above viewpoint is untenable.

The abatement of air pollution, and particularly of fugitive emissions is a major consumer of electric energy. Ironically the pollution produced by generating the power needed to drive pollution abatement devices could under certain circumstances exceed the pollution it has abated in the steel industry.

The high price and non-availability of oil and natural gas in certain developed countries has promoted increasing reliance on coal. By reducing oil and natural gas injection into blast furnaces, one has reduced the thermal efficiency of the process and at the same time increased its adverse environmental impact.

While the recycling of solid wastes is a desirable goal, in many cases the economic incentives are not available at present for doing so. Unless appropriate technology is developed (e.g. for removing copper from automobile scrap, dezincing of BOF dust etc.) recycling may seriously interfere with the production process.

Clearly this is a complex, interwoven problem, for which no simplistic solutions could be realistically advocated. The policy decisions that have to be made must weigh the costs and benefits that would ultimately accrue to society.

6.3 The Effect of Pollution on the Working Environment

There is little question that the pollution described on the preceeding pages of this report also has a deleterious on the working environment in the steel industry. Since the actual population thus affected is much smaller than the population as a whole statistical sampling is somewhat easier.

Documentation is available that workers in coke oven plants suffer a substantially higher mortality and morbidity from various forms of cancer than would a corresponding control group. This finding has led to the establishment of the revised standards of coke oven emissions in the USA. The effect of these new standards cannot be assessed at the present.

In general terms the fugitive, air borne pollutants represent the major pollution induced hazards to the working environment in the steel industry. As noted earlier satisfactory technology is not available for the comprehensive abatement of this environmental problem. It would be reasonable to expect that the representatives of steelplant workers should press for the development of such technology or better still, for alternative less polluting steel processing technologies.

6.4 The Development of Pollution Abatement Devices Versus New Non-Polluting Technology

Up to the present the principal developments regarding pollution abatement in the steel industry have involved the attachment of pollution abatement devices to existing processes. Typical examples of such applications include the use of electrostatic precipitators for dust removal, hooded coke oven pushing control systems, and the like.

The installation of these devices in conjunction with new plant construction is quite costly (say 15% of the total plant cost) and the retrofitting of these units would be even costlier. If more stringent environmental control laws are enacted the proportion of the pollution abatement cost would increase even further.

It is felt that ultimately, cost effective pollution abatement, combined with maximum resource utilization would be possible only through the use of drastically innovative steelmaking technology. Ideally such technologies should evolve in different directions in different locations, depending on the natural resources that may be available locally viz biomass, charcoal in tropical locations etc. The developed nations do have the technological infrastructure for initiating such developments, but under the present circumstances the steel industry in developed nations lacks the resources for financing such an effort.

Cooperative ventures between technologically advanced and resource rich nations would be very worthwhile in this area.

6.5 Policy Issues Raised by Differences in Pollution Abatement in Different Countries

Ideally it would be desirable to perform a critical comparison between the environmental laws and their enforcement in different developed countries, as these affect the steel industry. However, this would be an enormous task, way beyond the scope of the present study.

Nonetheless, by studying selected documentation that has been made available together with personal discussions with representatives from developed countries, the following tentative opinion has been formed that:

(i) For the principal pollutants the regulations are comparable for the various developed countries. The USA has developed rather more detailed documentation than available in Western Europe of Japan. It is thought that overall the USA and the Japanese regulations are the toughest, with German Federal Republic occupying an intermediate position regarding the remainder of the EEC.

(ii) Actual compliance is much more difficult to assess, although there appears to be agreement that Japan is the world leader in pollution abatement practices in the steel industry.

However in this regard Japan is in a unique position, by having a much larger proportion of modern steelplants, where the enforcement of environmental control regulations is rather more straightforward, through the issuance in construction permits depending on compliance.

It is suggested that while there are differences in pollution abatement between the various developed countries, no major economic advantages are derived by countries which lag behind in pollution abatement. Nonetheless uniformity of pollution abatement would be desirable, together with a more extensive interchange of information.

6.6 Globally Optimal Policies for Plant Location

The worldwide demand for steel has been cyclic. After the worldwide steel shortage and correspondingly very high steel prices in 1973, at present there appears to be an over-capacity in steel, which may persist for several years or longer, unless current plans for the construction of new steel facilities are modified.

Regarding the developed nations, Japan has very modern, efficient steelplants, incorporating the state of the art pollution abatement facilities. In contrast the majority of steelplants in the USA and in EEC tend to be older, less efficient energetically and the retrofitting of pollution abatement devices has been somewhat less satisfactory. Many of these older plants are faced with serious financial difficulties.

It would be tempting to suggest that a globally attractive policy might be to allow the closing of older plants in developed nations and replace these with modern steelplants to be constructed in less developed countries. Such a policy should minimize pollution and encourage industrial growth.

However, such a policy would not be politically acceptable to developed nations. Many of the older steelplants within the OECD community are located in already depressed areas (Youngstown, USA, South Wales, U.K. etc.) and to inflict additional economic hardship on these communities would be difficult to justify.

At present the international iron and steel trade is complex and full of controversy, with accusations of dumping, unfair trading practices and the like. In view of the uncertainty of this situation it would be reasonable for a developing nation to build up a steel industry supplying its own needs; however the commitment of resources for the establishment of a steel industry to serve the export market is highly questionable on economic and political grounds.

7. LIKELY FUTURE TRENDS REGARDING THE ENVIRONMENTAL IMPACT OF THE STEEL INDUSTRY

In view of the many uncertainties surrounding the steel industry at the present it is difficult to make definite predictions regarding likely future trends.

During the past decade very marked improvements have been made minimizing the adverse environmental impact of the steel industry. In Western Europe and in the USA these improvements are largely owed to the retrofitting of environmental control devices to existing steelplants and to a lesser extent to the commissioning of new plants, which already incorporated equipment of this type. In Japan the construction of new plants, incorporating the latest environmental control equipment is to be credited largely with the improved environmental impact of the industry.

Over the intermediate term the greatest promise for improved environmental impact of the steel industry would lie in the construction of new plants, incorporating the latest pollution control technology. However, the current slump in steel demand and the corresponding financial problems encountered by virtually all the major steel producers makes large scale plant construction unlikely in the developed nations. Furthermore, due to the financial difficulties of the industry, even the retrofitting of environmental control devices is likely to proceed at a slower pace, particularly in Western Europe.

From an environmental standpoint, one positive exception is that some of the older, polluting plants in the OECD countries may be closed down for good, thus reducing the total emission of pollutants. However, the financial hardships and major dislocations thus inflicted on these local communities render these developments a rather mixed blessing.

It follows from the foregoing, that for the short and the intermediate term one would expect more or less steady, but unspectacular improvements as the various mandated environmental control schemes are implemented, largely by retrofitting.

Over the longer term the most attractive avenue would be the development of alternative technologies for steel production, through which resources and energy would be conserved while the adverse environmental impact would be minimized. Such developments would be costly and would require major resources, but would probably be very worthwhile.

8. CONCLUDING REMARKS

In this report a brief assessment is given of the environmental impact of the steel industry in developed nations. The report includes a review of steelmaking technology, together with the current environmental problems and their solutions. The as yet unresolved environmental problems are identified, together with the principal issues that are posed by the environmental impact of the steel industry.

The principal findings of the report are summarised as follows:

(1) While steel production does have a major, adverse effect on the environment, the actual costs of environmental pollution or the benefits realizable from pollution abatement have not yet been quantified. There is controversy regarding the allowable threshold levels of pollutants.

(2) The principal unresolved environmental problems fall in two categories, namely:

(i) The non-implementation of available technology for pollution abatement and

(ii) the non-availability of appropriate abatement technology.

In this latter category a great deal of improvement would be necessary regarding the treatment of fugitive emissions.

(3) There has been no major breakthrough regarding the development of non polluting steelmaking processes, although direct reduction and the manufacture of form coke are promising.

(4) Over the intermediate term the greatest promise for improved environmental control would lie in the construction of new steelplants, incorporating the latest pollution abatement technology. However, the current downturn in demand for steel renders such a development unlikely for the near future. It is thought, therefore that for the near future further improvements regarding environmental control in the steel industry are not likely to be great.

(5) Ultimately the most cost effective way of minimizing pollution and maximizing energy and resource utilization would be the development of alternative steelmaking technologies. Such an effort would require substantial resources and represents a very suitable area for international cooperation.

Acknowledgements

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However, the author accepts responsibility for the views expressed in this report.

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Figure 1

PRINCIPAL PROCESSING STEPS IN IRON AND STEEL PRODUCTION

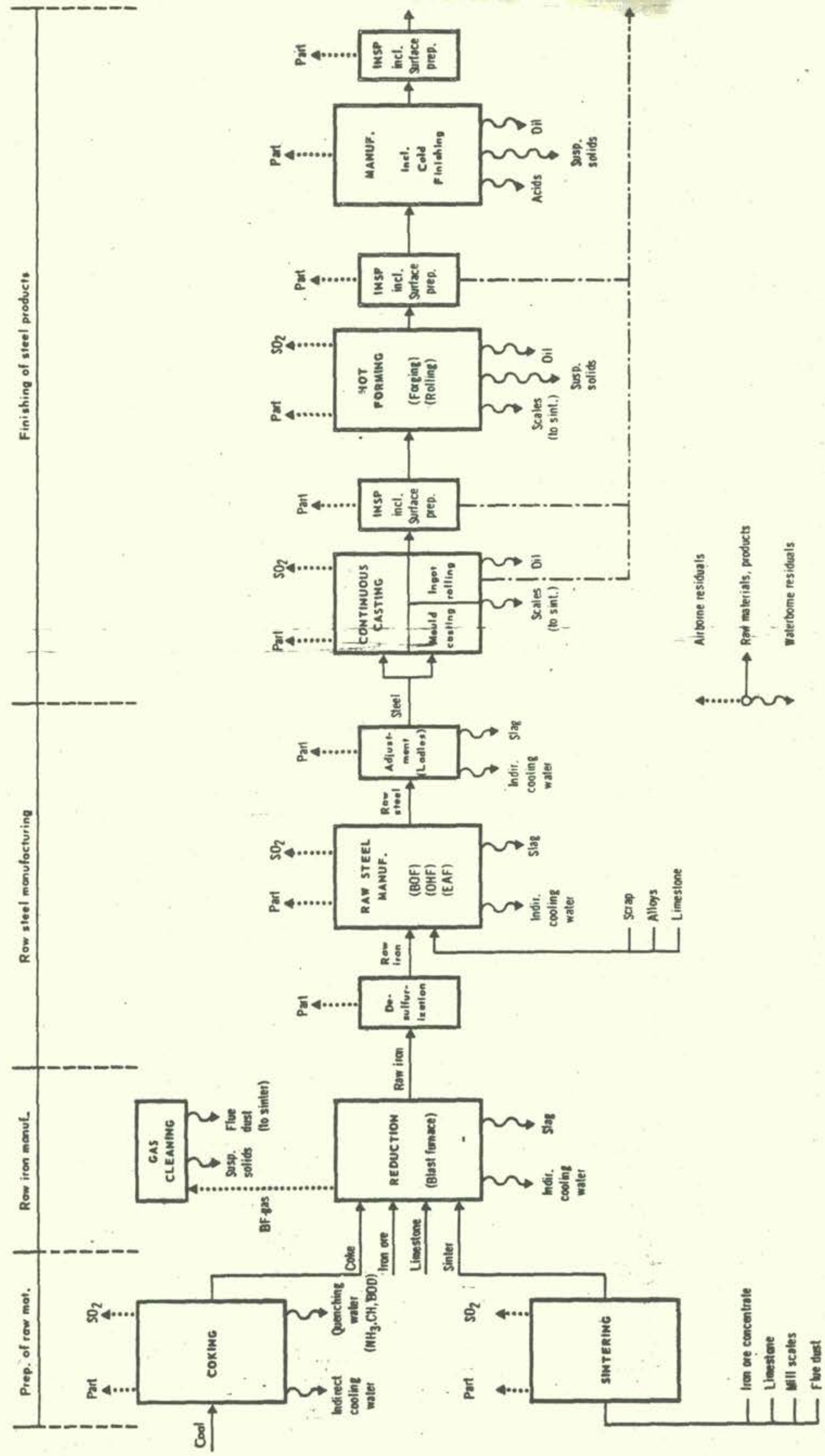
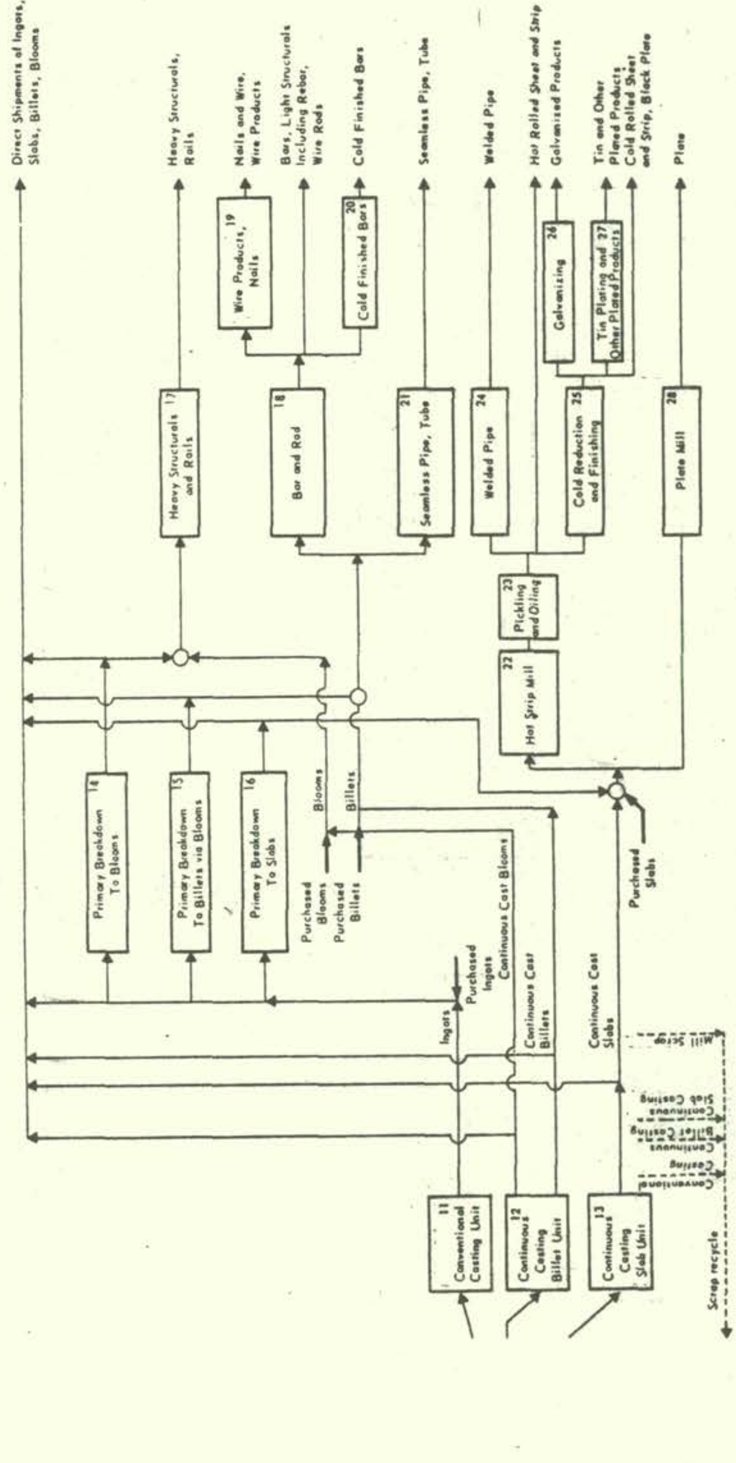


Figure 2

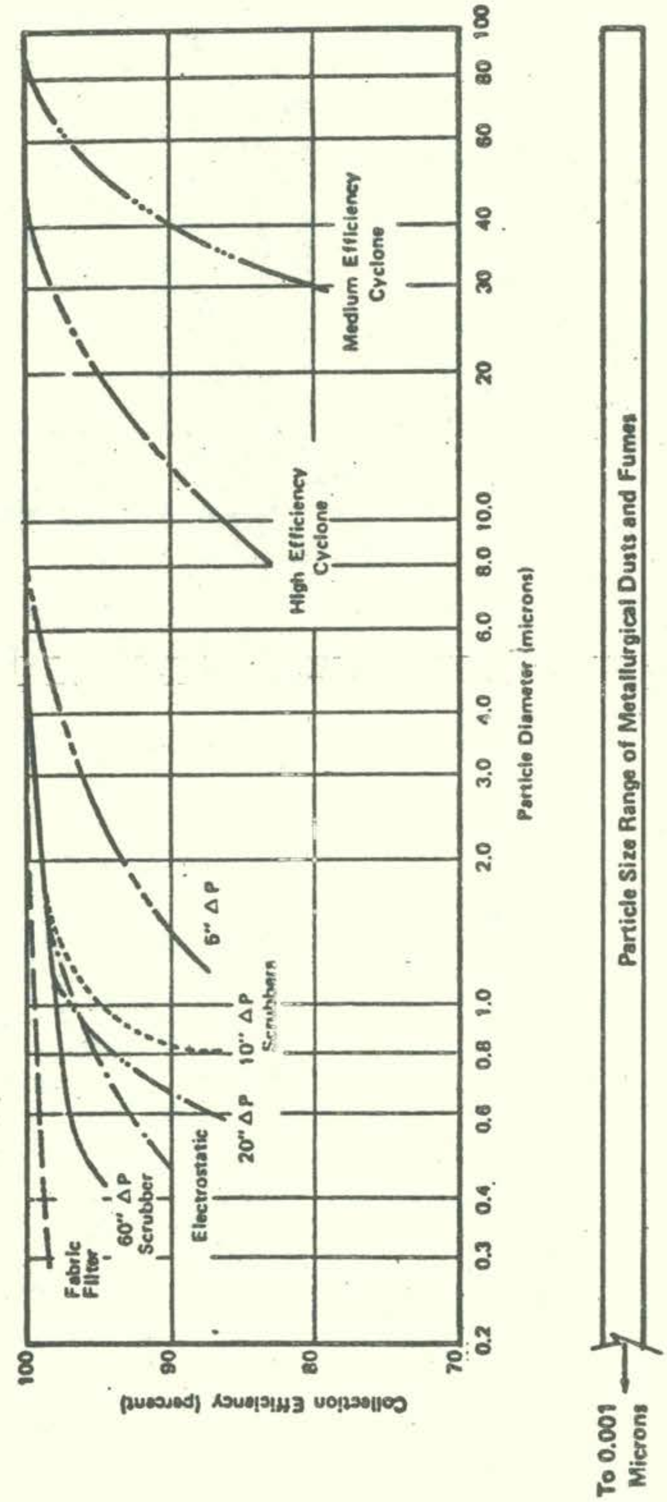
FLOW SHEET OF THE STEEL FORMING OPERATION



Source: Arthur D. Little, Inc. Steel and the Environment. A Cost Impact Analysis. May, 1975.

Figure 3

A COMPARISON OF PARTICULATE REMOVAL DEVICES



THE ENVIRONMENTAL IMPACT OF THE STEEL INDUSTRY IN DEVELOPING NATIONS

BY HIDEHIRO OBATA

Summary of the original document issued as UNEP/WS/IS.4

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1 - STEELWORKS IN THE DEVELOPING COUNTRIES

1) Current situation.
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1.1 Current Situation

There are already many sorts of steelworks in the developing countries; integrated steelworks; semi-integrated steelworks, rolling mills; tube mills or pipe fabrication; cast iron products; coating lines (galvanising lines, etc), whether with multinational participation or not, the production capacity of which varies from some tens of thousand tons a year to millions of tons a year.

Usually those countries with some sources of raw mateials own integrated steelworks. Others, without raw materials sources, began with Open Hearth Furnaces - OHF - or Electric Arc Furnaces, melting imported scrap or rolling imported semi-finished product, rerolling imported coil for further transformation (sheet, cold formed product, galvanised or pipes, etc.)

Usually the production is to meet the domestic market. The market depends on GNP per capita, stage of development of the economy, population, etc.

~~According to the IISI study* and~~ when GNP/capita reaches around US $200 (1963 rate) the economy reaches the stage of take off point and starts developing rapidly, with steel demand increasing also rapidly. So the establishing of an integrated steel industry is desirable when the economy reaches around the take off point.

This is quite true for almost all developing countries except for those whose population is too small. On the average it is applicable to those developing countries with 8 million inhabitants.

Usually the demand for non flat steel product is greater than flat product in the initial stage. This is to meet implementation of the infra-structure. The decision of the product-mix and production scale of an integrated iron and steel industry depends upon the market, taking into consideration the production capacity of the existing mills and the technological level. Scale-merit for the production of flat product is important and the control of size and dimensions are more restrict.

The following steps are usually followed by developing countries to implement iron and steel industry:

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* Prepared for the UNEP Workshop and entitled "Environmental Control in the Iron and Steel Industry".

First Step

Importation of semi-finished products or hot coil and transformation of them into rolled bar or cold rolled products or coated products.

Second Step

Importation of steel products and manufactured products.

Third Step

Importation of scrap and production of steel in the open hearth furnace or electric arc furnace.

Fourth Step

Start construction of integrated steelworks and start production of steel product or ingot or pig iron.

Fifth Step

Production of steel products and start the exportation.

In the decade of 1960 many developing countries whether owning iron ore sources or not, started showing great interest in establishing integrated or semi-integrated steelworks in order to:

a) Meet the domestic market (because steel is the most important basic material for development of other industries and replaces import of steel product) or

b) Export of semi-finished product or elaborate raw material (pellets) instead of raw iron ore which brings very small benefit.

The pattern (b) project was seen mostly in the developing countries that own iron ore resources and after the oil crisis by countries rich in Natural Gas. Some large projects have been studied involving Joint Venture with steel industries of developed countries on conditions of sharing a part of the production. The project that aims at the export of semi-finished product usually faces some difficult aspects:

a) Establishing production capacity and product mix;
b) Fluctuation of the world steel market;
c) Guarantee of dimensions and quality;
d) Reliability in supplies of coal, ferro-alloy and fuel (there are very few nations that own sources of all raw materials necessary for steel industries);
e) Disturbance - internal/external problem;
f) On-line process (rolling mill operating with computer);
g) Fixing price for semi-finished products;
h) Off standard materials, etc.

As the investment cost is high to produce semi finished product, it is desirable to integrate the steelworks with rolling mills. Because of the oil-crisis at the end of 1973, the growth of world economy slowed down (production of steel in 1974 and 1976 was 710 Mt and 693 Mt, respectively) so these kind of projects have been postponed or are under revision process.

These projects are capital intensive and investment so government is always involved and the participation of steel industries of developed countries is welcome.

The projection 85 prepared by IISI foresees the world steel demand of 1140 Mt/y in 1985 now under revision.

Many developed countries were considering to import steel for their future requirement by implanting steelworks in developing countries because of problems in the developed countries:

a) Area for new steel industry and high cost of land;
b) Pollution problems (retrofitting);
c) Expansion programme delayed to meet steel requirement;
d) Limitations to expanding existing steelworks;
e) Cost of transportation of raw materials etc.

However, in the wake of the oil crisis prices of equipment for new steelworks (greenfield) would be very high and the revision of Projection 85 are causing revision of expansion of existing works in developed countries. It is believed that this is a transitory situation and considering that the implementation of an integrated iron and steel industry takes from 6 to 7 years (site location, feasibility study, basic engineering, purchase of equipment, site preparation, infra-structure, construction and start-up), the developing countries with potentiality for steel production should start planning the establishment of steel industries.

The geographical distribution of major natural resources essential to steel production will be central determinants in the future development of the global iron and steel trade. Four of these resources relate to energy total coal, natural gas, oil and hydroelectric energy; and the others relate to raw materials - iron-ore, coking coal, charcoal, manganese ore and fluxes.

In the light of known reserves only, it is possible to identify those developing countries which are in a favourable position to establish an iron and steel industry. Some developing countries that own five resources are considered favourable for implementation of steel industry. Furthermore, taking into consideration the future shortage of oil those countries with availability of hydro-electric power and forestation area for charcoal production will be placed in the most favourable condition.

The low shaft furnace combined with direct reduction may be a good alternative for those countries rich in charcoal availability and hydroelectric power.

Anyhow, according to the Lima Declaration, the developing countries, in the year 2000 AD, will share 25 to 35% of overall world steel production that is to say that steel production in developing countries will have to be increased six to seven times in 20 years. This report covers current available technology for pollution abatement in the iron and steel industry and its benefits. It is less expensive to install pollution control equipment from the beginning than try to retrofit later.

In addition to natural resources it will be important to implement the infra-structure, including engineering, training of skilled workers, implementation of subsidiary industries such as firebricks, ferro alloys, spare parts, foundries, etc. It is very important to create engineers and specialists to manage and operate efficiently the pollution control equipment.

2 - SOURCES OF EMISSIONS AND CONTROL

a) This section describes very briefly the iron and steel production units indicating the sources of emissions of pollutants. The amounts of emissions which varies even for the same process depending on several different factors, such as the nature of raw materials, temperature, operating conditions, etc. are not indicated. Also the pollution control techniques are not described in detail because the currently used pollution control techniques, although satisfactory in various areas, are being improved or changed very rapidly envisaging the saving of energy and recovery of usable materials, in some cases envisaging the zero emission (coating lines), and abatement of noise and vibration. Studies are being conducted to recover waste heat to improve the working environment or to reduce the heat emissions to the atmosphere (for example, heat exchanger to recover the heat from the fume stacks to preheat the fuel or the combustion air).

b) The segment of pipe fabrication or rolling of pipes was omitted to avoid repetition.

c) As indicated in the section 5, it is assumed that all materials generated by the pollution control equipment are reused or sold, otherwise a large area is necessary, yearly, to dispose the wastes and in some places the cost of land is very high. It is logical, too, to reuse water treated at the waste water treatment plant. The treated water is a valuable by-product.

RAW MATERIALS

2.1 The main raw materials for an integrated iron and steel industry are: iron ore, coal, fuel, lime, silica, manganese, ferro-alloys, etc. Depending on the location of the steelworks, raw materials are transported to the steelworks by ships, barges, railroad, trucks or by conveyor belts and discharged by unloader or cardumpers, and are conveyed to the respective yards, which are open-air due to their great dimensions. Lime and charcoal, usually, are stored in silos. Raw materials are transported from yards to the processing units by conveyor belts.

a) Airborne Residuals

The mining, crushing and screening of raw materials arises some dust. a great amount of dust (fines of iron ore and coal) is lost during transportation (railroad and barges).

The unloading operation gives off some dust. As the piles of raw materials stored on the yards are very high, the wind can cause entrainment of fines of raw materials in the form of dusts (iron oxide, silica, calcium carbonate, manganese oxide, coal, etc.) which are transported to some extent.

Control: Spray of water. Sometimes adding chemicals to form a protective coat for long distance transport. All conveyor belts should be covered and conveyor junctions should be provided with dust collectors.

b) Waterborne Residuals

Drain water can carry a large amount of raw materials fines and contaminate the receiving stream with SS and other pollutants.

Control: Storm and drain water collection gutters should be provided along yards and pits with sufficient capacity to settle carried materials.

2.2 Sintering Plant

In the sintering process fines of iron ore, lime, mill scale, coke and recycled materials with due care to the BOF shop dust are mixed in drum mixers with addition of water.

Mixed materials are fed on the pallets and fired by burners. Then the fines of coke (or wood charcoal) contained in the mixture ignites and sinter is produced after 15 to 20 minutes. The sinter is then crushed and screened and cooled. The undersized material returns to the sintering plant while the remaining sinter is conveyed to the stock yard or to hoppers feeding the blast furnace.

a) Airborne Residuals

The sintering process uses a great amount of air for combustion and cooling. There are several emission sources of particulate residuals and gases (transport of blended materials, wind-box exhaust, crushing, screening, cooling and transport of sinter, etc.). The nature of particulate matters, will depend on the nature and size of raw materials and the gaseous emission on the content of S in the raw materials and coke breeze and fuel used for ignition.

Control: The arrestment of dust generated in the sintering machine is not difficult due to the structure of the building. There are several highly efficient equipment to arrest the particulate matter (cyclones, fabric filters and electrostatic precipitators).
However, the selection of fabric filter or EP must be studied carefully because of high temperature of gases and the nature of particulates (size, basicity and resistivity) which depends on the nature of raw materials and quality of sinter. There is also equipment to reduce the emission of SO_2 and NO_x.

b) Waterborne Residuals

In the modern sintering plant a great part of water is used for cooling the exhaust blower bearings crusher and in the drum mixer. Modern sintering plants are equipped with dry cyclones and fabric filters or electrostatic precipitators for cleaning the gas.

Control: Indirect cooling water in a sintering plant is contaminated with rise in temperature.
So it is sufficient to cool it and reuse.
Spray water used for cleaning purpose of sintering plant and cooling of pan conveyor (adequate control of combustion air eliminates the necessity of cooling on pan conveyor) and storm water must be collected in a pound to settle particulates. The settled water can be used to spray raw material piles or sent to the blast furnace water treatment plant.
Due to the composition of sinter dust in location where dry season and rainy season are distinct, sinter dust can solidify in the sewer mains and clog them.

c) Noise

The exhaust gas blower of sintering plant is very noisy. Special design of blower building may reduce the emission of noise to outside the building. Control room should be designed with the sound insulating materials.

2.3 Coke Making

Coke is widely employed as heat source and reductant, assuring good permeability to the burden in the blast furnace. There are different coal charging processes but in existing plants the larry car charging method is commonly used. Coal transforms into coke in 18 to 20 hours. Then it is discharged on to a quenching car through a guide car and usually coke is extinguished at quenching towers and dumped on a coke wharf.

a) Airborne Residuals

There are two forms of pollution emitted from a coke oven battery. There are continuous emissions that occur from doors and charging lids and there are the intermittent emissions that occur during the charging of the coal into ovens, and the pushing and quenching of coke.

Dust generated when coal is charged into coke ovens consists of fly ash from charged coal, gas and tar mists produced in the initial stage of carbonization, when charged coal comes into contact with the hot wall of the oven and soot produced by imperfect combustion.

The emission of SO_x into atmosphere depends on sulphur contained in coal. It can be estimated for each plant. Roughly 1.4 ton of coal is necessary to produce 1 ton of total coke (fines plus lump). During the coking process coke oven gas (COG) is produced and a part of gas (about 40%) flows to the combustion chamber of oven and the remainder being conveyed to chemical by-product plants to be cleaned and used as fuel in the steelworks.

Control: Intermittent Emissions
Charging of Coal

There are different types of smokeless charging systems: sequence charging; larry-car fitted with devices to collect and clean emissions; pipeline charging, etc. It is easy to provide coke ovens to be built with pollution control equipment. However, to retrofit the existing old coke ovens with pollution abatement equipment will depend on several factors which should be considered very carefully: foundation of coke oven batteries, quantity of collecting mains, cycle of coking time, capacity of tar decanter, etc.
Pipeline charging system offers advantages but it requires space for coal preheating installation and this will become a source of continuous emission of gases. Another consideration is that of change of pressure inside the ovens, from slightly negative pressure to positive.

Oven Pushing

Oven pushing is a source of emissions to the atmosphere that varies widely from plant to plant, depending upon many factors. Well coked-out ovens do not normally produce heavy emissions although there are certain amounts of particulate matter discharged by the coke as it falls into the quenching car. Three types of coke side emission control systems appear viable. These are firstly systems where the guide is enclosed and an associated hood provided with scrubbers and fans covers the coke car during pushing; secondly, systems where the hood and guide enclosure is connected to a duct which conveys emissions to a static washer and fan and thirdly, systems where the coke is pushed through an enclosed guide into a fully enclosed coke car, the washers and scrubbers travelling with the coke car. To retrofit any of the above systems to the existing coke ovens batteries should be studied very carefully taking in consideration the foundation of the battery, space for additional third rail, space for steam raising units, centralized treatment for scrubbers wastes or space for continuous quenching installation.

Coke Quenching

Quenching Tower

The quenching tower emits a large volume of water vapour to the atmosphere during the quenching operation and the vapour carries a significant amount of particulate matters. The emission of particulate matters can be reduced with the use of some type of mist suppressors in the quenching tower. Several different designs of suppressors are available such as wooden baffles, wedgewire screens, coke beds and back sprays. The continuous quenching and dry quenching systems solve many of pollution problems caused by quenching operation but retro-fitting them to the existing coke ovens batteries is very difficult and costly.

Continuous Emissions

When the oven charging hole lids become distorted by high temperature there occurs continuous emission of gas. The deformed lids must be replaced. Similarly dirty lids will not seal and cleaning is required.

Emission of gas can take place in the gooseneck lid too due to deformation of improper positioning.

Oven Doors

The gas leakage can be reduced to a very low level with good standard of operations in small size furnaces. For tall ovens a mechanical door cleaner is necessary.

Modern coke oven plants are equipped with mechanical door cleaners.

b) Waterborne Residuals

Water is used to cool equipment such as exhaust draft fan, gas pipe seal, spray water of dust catcher of coal crushing and blending and screening plant, coke wharf spray, coke quenching and dust catcher of coke crushing and screening.

The quenching tower and coke-wharf spray water is contaminated with cyanogen, phenol, ammonia, SS, etc.

Control: The coke oven waterborne residuals vary greatly in accordance with the cokemaking practices.

All waste water from the dust collector of the coal crushing, screening and blending, smokeless charging venturi scrubbers, coke pushing exhaust gas cleaning systems, quenching water, coke wharf spray water, etc. are collected in a sedimentation basin and clarified water, is reused. As the fine of coal or coke can be dewatered easily, no special dewatering equipment is necessary. Dewatered dust is sent to coal bin.

Waste from smokeless charge system (if the larry car is fitted with venturi scrubbers) and the wastes from coke guide and quenching car must be sent to the biological treatment unit. The effluent of biological treatment unit can be used as make-up water of the quenching tower. Special care must be taken as to the quality of the quenching tower make-up water because a part of residuals contained in the quenching water are transferred to further processes, mainly to the blast furnace.

2.4 Chemical By-Product

During the cokemaking process volatile matters are transformed into gas and there is formation of a liquid (vaporization of humidity contained in the coal) that condenses when the gas is cooled. This liquid contains water, phenol, cyanide, ammonia and sulphur compounds and tar. This liquid due to a strong smell of ammonia is usually called "ammonia liquor" and amounts to 10 to 12% of the charged coal. One ten of coal produces from 300 to 350 Nm^3 of gas with calorific value of 4,400 to 4,700 $Kcal/Nm^3$. Therefore, it is a very good fuel gas to be used inside the steelworks, after being adequately cleaned and treated at the chemical by-product plant.

Depending on coal quality and coke oven design, a great variety of by-product can be extracted from coke oven gas when it is treated and cleaned, such as tar, ammonia, benzene, toluene, xylene, naphthalene, creosote, phenolates, sulphate of ammonia, etc.

a) Airborne Residuals

The chemical by-product plant itself is not a source of airborne emissions unless there is some leakage in the piping or equipment. This can be avoided by a good maintenance programme. Chemical by-product plants emit a smell of benzol, toluol, ammonia, etc.

Control: A good maintenance service to avoid leakage of gases from the gas piping systems and equipments will reduce the emission of the airborne residuals.

b) Waterborne Residuals - Chemical By-Product

The most harmful of waterborne residuals is the ammonia liquor. Firstly the ammonia liquor must be treated to reduce the ammonia content by the Phosam process or Steam Distillation (pre-treatment).

Naphthalene must be removed in the final cooler because naphthalene is harmful to bacteria of the biological treatment.

Final cooler must be recycled and the blowdown water sent to the biological treatment plant.

Secondly the pre-treated ammonia liquor is treated in a biological treatment plant.

Basically the biological treatment plant comprises: neutralization tank, regulating tank, coke filter, agitation tank, aeration tank, sedimentation basin and sludge dewatering units.

To improve even more the quality of biological treatment effluent, it can be treated in an activated carbon unit.

The activated carbon can be regenerated in a regeneration tower.

2.5 Blast Furnace (Hot Metal/Pig Iron)
Charcoal

Production of pig iron; particularly in Brazil, where the wood charcoal is produced in large scale besides integrated iron and steel industry, there are many small blast furnaces just producing the pig iron for sale. This type of blast furnace usually have no hot stoves and air is heated in continuous heating facilities known as Glandons the heating fuel being a very small proportion of blast furnace gas. The air heated to about 500°C is blown into the blast furnace. Gas produced by the blast furnace is blown into the atmosphere except for a small portion which is used as fuel to heat air in the "Glandons".

Usually these furnaces are located close to wood charcoal and iron ore supply sources generally sinter is not used.

The particulate matters, emitted with the gas, is estimated at 16 to 30 g/Nm^3 of gas and are formed by the fines of charcoal iron oxide, and fines of fluxes (limestone and quartz).

The emission of dust laden gas being very small, because of the size of furnace and due to the location, apparently causes no environmental problem. Also there is no environmental problem in the cast house because the amount of hot metal (pig iron) produced per tap is very small. The slag is not granulated.

Although it doesn't constitute environmental problem it is necessary to study the utilization of ~~gas,~~ heat and the fines of charcoal because of significant economic aspect resulting from not using them. The charcoal blast furnace gas has a calorific value of 1100 $Kcal/Nm^3$, and from 10 to 16% of charcoal is lost as fines.

There are many semi-integrated or integrated steelworks, small to medium sized, producing hot metal using charcoal as heat and reductant source in the blast furnace.

The production capacity of furnaces varies from 100 to 500 ton/day. Greater blast furnaces are equipped with the dust collector and the gas cleaner.

A great part of the dust is formed by the fines of charcoal. Another source of charcoal fines emission source is the charcoal storage bins.

Depending on the charcoal storage bins and due to the charcoal low density, considerable amount of fines of charcoal is carried by the wind.

The emission of particulate matters takes place in the handling of raw materials and mainly in the burden screening, weighing and feeding operations.

Coke Based B.F.

The production capacity of blast furnace based on coke varies from some hundreds to ten thousand tons a day or more.

Depending on fuel ratio and oxygen injection, a blast furnace generates from 1400 Nm^3 to 1700 Nm^3 of gas (BFG) with calorific value around 700 to 900 $Kcal/Nm^3$.

It is a common practice to utilize BFG as fuel for the boiler, the thermoelectric power plant, and as mix gas for soaking pit and reheating furnaces.

BFG flows to the dust catcher and afterwards to the first and second venturi scrubber to EP and then to the gas holder. The dust content is reduced to 10 mg/Nm^3 or less.

This way there is no atmospheric pollution caused by the blast furnace gas, except when there is some leakage in the gas piping systems or trouble in the blast furnace and bleeders are open.

Around 200 to 300 kg of slag are produced per ton of hot metal, depending on nature of the burden.

The slag can be solidified in dry pit, granulated or transported to the slag disposal and treatment site by the slag ladle car.

a) Airborne Residuals

There is emission of some particulate matters on weighing and charging of burden and at the tapping time of hot metal. Pouring of hot metal into the ladle car or torpedo car can emit fume and kish.

The blast furnace slag granulation generates water vapour with slight odour of hydrogen sulphide.

The concentration of sulphur in the slag and washing of gas makes it almost zero the potential emission of SO_2 to the atmosphere. Slight emission of H_2S can take place is slag is exposed to humidity for a long time.

Control: The dust generated in the blast furnace cast house is collected by the hood surrounding the tap holes and runners for hot metal and slag covered by a heat resistant cast steel cover. A closed hood is provided to collect the fume emitted during pouring of hot metal and slag into respective ladles. If there is an unusual dust generation, the case has to be studied taking into consideration the dust generation frequency, dust volume, duration and blast furnace operating condition. The secondary dust collecting system depends on the geometry of the cast house. Usually the dust laden gas temperature is under 140°C and 10 to 15% of particulates are under 1 micron. A variable speed exhauster is desirable to control the draft according to the emission degree and fabric filter to clean the gas. Charging hopper and burden charging devices should be provided with dust collecting equipment. The gaseous emission can be avoided with a good maintenance programme. It is important to note that blast furnace gas has no colour and smell.

b) Waterborne Residuals

The great part of water in the blast furnace is used for cooling of equipment, such as: tuyeres, blast furnace body, bottom, hot stove valves, bearing oil of blower, steam condensation of steam turbine, etc. and it has no contact with materials, so the only contamination is the heat transferred.

The water requirement for the indirect cooling system is from 25 to 30 m^3 per ton of hot metal.

Another use of water is for cleaning the blast furnace gas, and the granulation of slag, and spraying.

The requirement of water for blast furnace gas cleaning varies from 2 to 4 m^3/ton hot metal and the effluent is contaminated with: temperature, pH, SS, phenol, oil, cyanide, sulphide, etc.

Control: In the past electrostatic precipitators were used to clean the blast furnace gas but nowadays the common practice is to clean the gas washing it with water in venturi scrubbers.

As the quantity of dust contained in the effluent of venturi scrubber number two is too small it is usual to collect this effluent in a pit and pump it to the venturi scrubber number one.

The effluent of venturi scrubber number one is pumped to a thickener where the water is treated and clarified.

Clarified water is cooled and recycled to the gas washing systems.

Spray water utilized to control dust in the burden feeding systems and dustcatcher is pumped to the thickener. The solid matters deposited in the thickener are pumped continuously to a vacuum or pressure filter for dewatering.

2.6 Lime Kiln

Limestone is transformed into lime in lime-kiln. Crushed limestone is washed to eliminate fines and stored in the limestone storage bins, and fed by vibrating feeder to the kiln through the top of preheater. The preheating is accomplished by counterflowing the kiln gas after dedusting it with the cyclone dust collector.

The gas temperature at the inlet of the preheater is around 1100°C. The lime kiln product is cooled by counterflow of cooling air, and discharged on a pan conveyor, then to a bucket conveyor and vibrating screen which is installed at the upper part of the product bins.

a) Airborne Residuals

Production of one ton of lime generates about 62 kg of dust and 23 kg of undersize materials. These figures vary with the chemical composition of the limestone and the undersize limit.

Usually low sulphur content fuel is used to avoid contamination of lime with sulphur.

Control: The lime kiln exhaust gas after transferring heat to the limestone is cleaned firstly in a multicyclone and secondly in a venturi scrubber.

The dust emitted by vibrating screens and other spots such as lime transferring sites is collected by hood and the contaminated air is ducted to a bag filter.

In this way the particulates emission is reduced to 0,1 to 0,2 g/Nm^3.

b) Waterborne Residuals

Water is used for washing of crushed limestone and lime kiln exhaust gas. The waste water is contaminated with SS and fines of lime.

Control: Cooling water of equipment is not contaminated. The crushed limestone wash and gas cleaning waste water are collected in a thickener and treated.

Clarified water is recycled and sludge is dewatered with vacuum filter, and semi-dry cake is deposited on bed and transported to the raw materials yard.

2.7 Blower for Blast Furnace

Basically there are three types of blower for blast furnaces: electric motor driven blower; gas turbine blower and steam turbine blower. The electric motor driven blower causes no pollution, except the noise. Gas or steam turbine blower may emit air pollutants. Water is used for the cooling of bearing oil or for steam condensation.

a) Airborne Residuals

Combustion of fossil fuels generates by-product materials. The principal emissions which could cause impact on the air environment are particulate matter, sulphur oxides, nitrogen oxides, hydrocarbons and carbon monoxide.

Usually a boiler for a steelworks is designed to use blast furnace gas, coke oven gas, tar or light oil generated in the steelworks and fuel oil. Emission of SO_2 vary with S content in the fuel. Imperfect combustion generates soot.

Control: It is advisable to use low S content fuel. SO_2 produced by 1% of S in fuel is approximately 570 to 600 ppm in flue gas. To reduce emission of soot it is necessary to control atomization of fuel, avoid excess, fuel, imperfect draft, control of viscosity, etc.

Emission of particulate matter may be controlled by cleaning the gas with electrostatic precipitators or venturi scrubbers. Noise can be reduced by silencers.

b) Waterborne Residuals

As water is used for indirect cooling purpose its only contaminant is the temperature rise. However, special attention must be paid to the effluent of the water demineralization plant.

Control: Indirect cooling water is cooled in a cooling tower and recycled. Venturi scrubber waste water, if used, is treated in a thickener and reused.

2.8 Steel Making

Hot metal (molten iron) produced in the blast furnace, scrap or sponge iron are transformed into steel in BOF or QBOF converters, or electric arc furnace or in open hearth furnaces.

Recent trend is to produce the most part of steel in the BOF converters although choice of process depends on raw materials, energy situation and envisaged quality of steel, due to the following advantages:

- equipment is quite simple;
- high purity oxygen is injected so there is no need for fuel;
- great range for hot metal quality variation, so dependence on scrap which is subject to wide fluctuation price is low;
- very short tap to tap time;
- flexibility as to quality of steel, etc.

(QBOP) may be the next generation of steel producing process).

LD Process:

Hot metal has a high content of carbon and also contains undesirable amounts of silicon, manganese and phosphorus. The hot metal is transported to the basic oxygen furnace shop, by ladel car or torpedo car. The converter is charged with scrap and hot metal, and then pure oxygen is injected through a water cooled lance. At the same time lime and fluorspar fluxes, mill scale are added. After about 15 minutes of operation carbon is oxidised to CO and other impurities are oxidised and are transformed into BOF slag. After checking the temperature and quality of the bath the steel is ready to be tapped. Liquid steel is poured into teeming ladles which in turn pour liquid steel into the ingot moulds in the teeming bay to produce ingot or the teeming ladle is transferred to the continuous casting shop, to produce continuous cast semi-finished products.

a) **Airborne Residuals**

When hot metal (molten iron) is transferred from the ladle or torpedo car into the hot metal receiving ladle, in the ladle weighing pit or to the hot metal mixer, some fume, dust and kish arise.

The charge scrap and hot metal into the converter, this is tilted to the receiving position, and some fume (fugitive) arises too. When the oxygen lance is lowered, lime, fluorspar fluxes and other additives are added. During the oxygen injection the hot metal temperature can go up to 1560°C and CO gas is emitted dragging dusts of fines of lime and iron oxides.

Basically there are two processes to cool the gas: installing half or full boiler. Half boiler reduces the temperature of gas, at the outlet of the boiler, to 1000°C and full boiler to 300°C. The choice between half and full boiler must be considered carefully taking in account thermal yield, investment cost, maintenance, operation difficulties, etc. Another alternative is the incomplete combustion of CO (BOF gas) produced during steelmaking. In this process, there is no combustion of CO. The advantages of this method are the following:

- gas temperature is low;
- the volume of gas to be treated is less.
- treated gas is good fuel (calorific value around 2000 kcal/Nm^3 without sulphur compounds), etc.

Very fine particulates are emitted during blowing operations. In the teeming yard operation, liquid steel is poured direct or indirectly (bottom pouring), into the ingot mould to produce ingot. Direct pouring emits some fume.

Mould cleaning, repairing and the base plate preparation bays are sources of particulates emissions.

Control: Hot metal receiving pit is equipped with a hood and dust is dragged to the bag filter.
Modern steelmaking shops are provided with a hood to collect emissions when even the converter vessel is tilted to receive scrap or hot metal. So there is almost no emission of dust to the inside of the steelmaking shop building (the installation of a hood has to be studied very carefully because of crane clearance). The cleaning of BOF converter gas is closely connected to the cooling of gas.

A) Combustion of Gas

1) Full boiler combined with venturi scrubber where the dust is washed out with spray water and collected in a pond for treatment.

2) Half boiler combined with electrostatic precipitator. There may be some difficulty due to high resistivity of dust.

B) Incomplete Combustion

Unburnt gas is cooled and cleaned. As there is no combustion (no draught of combustion air) the volume of gas to be treated is less. Gas is cleaned in two venturi scrubbers and waste water is conveyed to the sludge treatment pond and cleaned gas can be used as fuel or burnt at the flare stack. The trend is to recuperate the BOF gas instead of producing steam. As the BOF operation is intermittent, the production of steam is not continuous, requiring large steam accumulators and stand-by boiler for the emergency.

b) Waterborne Residuals

Water is used for cooling of oxygen lance, cooling of gas, cooling and cleaning of gas and miscellaneous use. The oxygen lance cooling water is free from contaminants, except for temperature. For BOF shop equipped with boiler (complete combustion) the gas is cooled by transferring heat to the boiler. Usually cooled gas is cleaned by a battery of venturi scrubbers. In the case of incomplete combustion, the gas is cooled by transferring the heat, by radiation, to water pipes protecting the inside and outside of the cooling zone, above the hood.

It is important to note that there are differences in sizes of particulate matter between the complete combustion of gas and the incomplete combustion.

Control: This report will describe the incomplete combustion of gas type BOF shop because it has several advantages over the combustion type. As the cooling water of the lance and hood has no contact with materials, there is no pollution problem except for rise of temperature. The closed circuit system is advisable. So the BOF shop water pollution problem is limited to cleaning the gas. The wash water effluent containing solid matters is collected in a pit where coarser matter, that settle rapidly, can be removed by screw conveyor and the overflow effluent flows to a thickner. The clarified water is cooled in a cooling tower and recycled. It must be noted that the incomplete combustion gas is explosive and the electrostatic precipitator is avoided. In the thickner, floculant and polymer are added to form flocs of sufficient size to settle easily overcoming the water counterflow due to the difference of temperature of wash water according to the oxygen blowing operation Settled matter in the thickener is pumped continuously to the vacuum or pressure filter for sludge dewatering and sludge is removed to a hopper and water returned to the thickener.

2.9 Open Hearth Furnace

Open hearth furnace is a very flexible steelmaking process. It can be charged with hot metal, scrap or lump ore. This process is based on the regenerative system to make good use of sensible heat of gas generated by the open hearth furnace. The gas flows through the regenerator and waste heat boiler and dust collecting system. The volume, chemical composition of gas and the dust content of gas generated in the furnace vary widely during steelmaking process.

The tap to tap time takes from 8 to 10 hours. With the injection of oxygen, the tap to tap time may be reduced from 5 to 8 hours. Many steelworks are replacing open hearth furnaces - OHF - by BOF or QBOP process, and keeping some OHF as stand-by unit for emergency.

It is anticipated that new steelworks will not be designed with open hearth furnace for steelmaking. Open hearth furnace utilizes heavy oil or coke oven gas as fuel.

a) Airborne Residuals

There is emission of dust in handling and charging the raw materials into the furnace. As the charging bay is very large, it is very difficult to collect the emission. The amount and size of particulate matters contained in the gas vary with oxygen injection.

The emission of SO_x varies in function of sulphur content in the fuel and raw materials. About 50% of sulphur contained in raw materials and fuel is emitted as SO_2 by stacks.

The open hearth furnace steelmaking process favours production of NO_x when oxygen is injected.

Control: The open hearth furnace steelmaking is one of the oldest steelmaking processes. So it is very difficult to try to control emissions and collect fumes in the charging bay. So the only alternative is to improve roof monitors to exhaust the fume to the atmosphere.
Fortunately, the open hearth furnaces are being replaced by BOF or QBOP converters. To reduce the particulates contained in the open hearth furnace it is necessary to clean the gas in an electrostatic precipitator or with venturi scrubber. For construction of cleaners it is necessary to utilize corrosion resistant construction

material. Bag filters have been used but without success. Installation of suitable collection devices would require major reconstruction of the open hearth furnace shop.

b) Waterborne Residuals

Water used for the cooling of equipment is not contaminated and can be reused after being cooled. Some old OHF's have no gas cleaning equipment.

When the gas is cleaned by dry precipitators, there is no water contamination. However, if the wet precipitators or venturi scrubbers are used for the gas cleaning, the waste water is contaminated with suspended solids, fluoride, nitrate and zinc, if zinc coated scrap is used. If there is oxygen injection, the size of particulates becomes very small.

Control: There is no waterborne residuals problem if a dry electrostatic precipitator is used for gas cleaning. However, if venturi scrubbers for wet electrostatic precipitators are used, the effluent water must be treated in a thickener with addition of flocculant and polymer because the size of particulates is very small, particularly when oxygen is injected into the open hearth furnace. Special care must be taken to control pH because the effluent has a very low pH (2,5 - 3). The treated water can be reused for furnace gas cleaning operations.

2.10 Electric Arc Furnace

Many steelworks are based on electric arc furnaces using scrap or sponge iron as raw material. Electric arc furnaces fit in regions or countries where natural gas is available to produce sponge iron which can replace scrap. An electric arc furnace is a shallow-depth, large diameter, cylindrical shell with removable cover. There are holes on the cover through which three electrodes are inserted.

The amount of emission depends on the quality of steel being produced, quality of scrap, melting temperature, the physical state of fluxing agent, oxygen injection, etc. Many steelworks are injecting oxygen into the electric arc furnace to reduce the tap to tap time.

a) Airborne Residuals

The amount of emissions varies whether oxygen is injected to some extent or not. It is estimated that if oxygen is injected, about 20% of total emission takes place during oxygen injection. As fuel is not utilized in the electric arc process the emission of SO_x is negligible. The emission of CO is very low, except when oxygen is being injected, but the CO produced is burnt.

The emission of fluorides varies according to the quality of steel being produced.

Control: 85% of emission of fume and particles occur during the melting and refining operation and the remaining 15% during the charging and teeming operations. There are three main alternatives to collect the fume of the electric arc furnace shop. The fume collection system which will collect all the fume produced during the complete cycle of the electric arc furnace operations installing a hood above the furnace. Installation of small size hood covering each hole of electrodes collecting fume exhausted through the ring of electrode holes. With this system fume arising during charging and teeming will not be collected. Installation of a collecting system which collects the fume of the interior of the furnace. In this system there is a fourth hole in the cover of the furnace through which the fume is sucked. In this system the emission during the charging and teeming operations and uncontrolled and there are emissions from the electrodes holes. All collecting systems described have advantages and disadvantages. The complete building evacuation system has the disadvantages of needing to collect a great quantity of air and is a danger to the health of the crane operator. For the new electric arc furnace shop it is feasible to design the complete evacuation of the building system, studying carefully the scrap charging method, crane operation cabin position, the building completely closed with doors that are opened only when necessary, etc. to reduce the amount of volume of air to be collected.

The choice of fume collecting system for existing electric arc furnace has to be studied very carefully because the collecting system depends also for the quality of steel to be produced. If the fourth hole system is adopted the system has to be shutdown sometimes when special alloyed steel is being produced. Usually fume collected in an electric arc furnace is cleaned with a fabric filter. So it is important to control the gas temperature to meet fabric filter working condition. The gas temperature can be controlled by the evaporation method, conduction-convection, or by dilution. The dilution system is better than the two other systems although it has to treat a great quantity of the mixture of air gas.

Cleaning of gas with venturi scrubbers is not commonly used, because its efficiency is low 65 to 75%.

b) Waterborne Residuals

The electric arc furnace has two main sources of waste water production. These are the cooling water system for the roof ring electrode ring and door cooling, and fume cooling and fume cleaning wastes. In the semi-wet system, a spark box or spray chamber conditions the hot gases for either a precipitator or a bag house. Usually a spark box is used with a precipitator system and a spray chamber is used with a bag filter. A water-cooled elbow connected to the furnace roof is used for the exhaust ductwork. It is not so common, but venturi scrubbers can be used for the cleaning of gas.

Control: Water is used for cooling of equipment and electrical components. This water is not contaminated and can be recycled after cooled in a cooling tower. When a venturi scrubber is used for cleaning the gas, waste water is contaminated with a high content of SS (around 5.000 ppm). As the size of the particles is extremely fine (50% < 10 micron) the waste has to be treated in a thickener with addition of polymer. The clarified water is reused and sludge is dewatered with a vacuum filter.

2.11 Continuous Casting

Continuous casting consists in producing slab/bloom or billet directly from the liquid steel produced in steelmaking shops. The teeming ladle is transferred from the steelmaking shop to the continuous casting shop and liquid steel is poured into a tundish and this feeds the liquid steel into moulds of the continuous casting machine. Mould and machine are water cooled and the solidified semi-finished product is gas cut at the end of the machine.

Some continuous casting shops are equipped with scarfing machines.

a) Airborne Residuals

Due to the nature of the machine and production process there is almost no emission of airborne residuals. Some fume can be generated in the gas cutting operation and in the scarfing machine and tundish heating. The addition of fluidizing agent causes no environmental problem.

Control: The fume generated in the scarfing machine is collected by a hood and cleaned in an electrostatic precipitator. The gas cutting operation generates some fume but as in an automatic operation it doesn't cause any harmful environmental problems.

b) Waterborne Residuals

Water is used for cooling the mould (indirect cooling), machine and semi-finished products. Spray cooling water is contaminated with scale and oil. Fume and particles generated in the hot or cold scarfing machine are cleaned in an electric precipitator and residuals conveyed to the continuous casting scale pit, to be treated.

Control: The mould cooling water has no contact with material, so it is sufficient to cool it in a cooling tower and reuse. The spray cooling water containing scale and oil is collected in a scale pit where coarse particles settle (particles larger than 100 micron).

From scale pit, water is pumped to a natural sedimentation basin where scales larger than 20 micron settle. Clarified water is filtered in on high rate pressure filter. This is to avoid clogging of spray nozzle. Oil is separated by an oil skimmer. Filtered water is cooled and recycled. This combination of natural sedimentation and high rate pressure filter is better than the use of chemical coagulants; the ion content of water is not changed so quickly and blowdown water is reduced.

The filter backwash water is collected in a thickener and the sludge is dewatered by a pressure or vacuum filter. Dewatered sludge is sent to the sintering plant. Oil removed by skimmer can be processed or used as fuel.

2.12 Hot Rolling

Steel ingots produced in the steelmaking plant are charged into soaking pits to be heated to the rolling temperature. Heated ingots are rolled to semi finished products (slab, bloom or billet), according to the size and dimensions specified in the further rolling schedule. Some rolling mills are equipped with hot scarfers. There is the crop shear that cuts the ends of products (tail fish). The semi finished products are cooled in cooling tanks, spray cooler or cooler banks. Automatic defect detectors and hot spot scarfers are being developed which will enable HC (hot charging) or HDR (hot direct rolling). The semi finished products are inspected and hand scarfed to remove defects. After these operations they are charged into a reheating furnace to be heated for rolling. Usually rolling mills are equipped with scale breaker, roughing mill, crop shear, finishing mill, down coiler for strips, hot and cold saw for shapes, etc. Some plate mills are equipped with shot blast, coating unit, and heat treating facilities.

a) Airborne Residuals

The airborne residuals are emitted from soaking pits, scarfing machine, hand scarfing and furnaces. The emission of pollutants depends on the fuel utilized. The modern trend is to use LPG or LNG in the soaking pit and furnaces. Some water vapour is formed during rolling operations around the scale breaker, rolling mills, hot run table and crop pit. Some fume can arise when plate is gas cut.

<u>Control</u>: The emission of residuals depends on the fuel used in the soaking pits, hot scarfer, reheating furnaces and heat treatment. Usually coke oven gas and blast furnace gas are used as mix gas, however, the modern trend is to use LPG or LNG to reduce emissions.

The fume generated by the hot scarfing operation is collected by a hood and treated with an electrostatic precipitator. The residuals from electrostatic precipitator are sent to the direct cooling water treatment plant.

b) Waterborne Residuals

The requirement of water in the hot rolling processes depends on the quality of steel and dimensions of material being rolled. There are two distinct uses of water: indirect cooling (oil cellars, motor room, reheating furnaces, control rooms, X or Gamma ray, industrial television, etc.) and direct cooling (scale breaker, scale flushing, cooling of roll, crop pit, slab or bloom cooling, scarfing machine, hot run table, down coiler, hot and cold saws, etc.).

2.13 Cold Process

The strip of coil rolled in the hot strip mill is treated in the pickling line to remove secondary scale formed during hot rolling process. Then the coil is rolled in a Cold Mill (reversing or tandem). Further processes are: annealing, ECL, double reduction, slitting, shearing and coating.

(i) Pickling Line:

Basically the pickling line comprises: uncoiler, welder, loop car, pickling tank, rinse tank, pre coat oil and coiler. A solution of sulphuric acid or hydrochloric acid is prepared in the pickling tank and steam heated to 80 to 95°C. After the scale breaker the strip is passed through the acid solution where scale is removed. Pickled strip is rinsed in the rinsing tank, and coated with oil to avoid reoxidation. The modern trend is to use hydrochloric acid which presents some advantages: high activity on Fe_3O_4, high pickling speed, lower temperature of solution, smaller facility, low reaction with the steel, feasible to regenerate HCL from the waste.

a) Airborne Residuals

There is generation of fume containing acid mist in the pickling tank which is collected by fume exhauster and water washed at the fume stack before being released into the atmosphere.

b) Waterborne Residuals

The sources of emissions are: discharge of weakened acid solution, overflow from the pickling tank, discharge from rinsing tank and effluent from the fume stack. The effluents from the pickling process are contaminated with acid, SS and temperature.

Control: There are several processes to treat the pickling waste water. The most usual procedures are neutralization and crystallising for the sulphuric acid solution and regeneration for the hydrochloric acid. The pickling waste treatment plant must be provided with storage tank lined with lead sheets to store the concentrated solution, when it is necessary to empty the pickling tank. There are different processes to regenerate the hydrochloric acid. The most common one is the Spray Roasting.

(ii) Cold Mills:

The Cold Mill reduces the thickness of steel strip by adding pressure and tension. This kind of Mill operates at a very high speed. A mixture of oil and water (emulsion) is sprayed on work rolls to dissipate heat and avoid pasting of the strip to the roll. The emulsion, after filtering is recycled. The nature of emulsion oil varies with the type of mill (animal fat, palm oils, etc).

a) Airborne Residuals

There is emission of emulsion mist which is collected by an exhaust hood and conveniently treated.

b) Waterborne Residuals

Although the emulsion is recycled, there is always leakage and condensation of mist of emulsion and during maintenance or cleaning of equipment the waste water is contaminated with emulsion and lubricating oil. Also the emulsion has to be renewed from time to time. The effluent is contaminated with high BOD, SS and free oil.

Control: There are different treatment processes, but all of them are based on the principle of breaking the emulsion (bubbling electrolysis etc.). The main equipment are: regulating tank, rapid agitation tank with addition of inorganic flocculant and control of pH, slow agitation tank with addition of organic flocculant, floatation tank, skimmer, neutralization tank etc.

(iii) Electrolytic Cleaning Line - ECL:

Depending on further processes the cold coil formed in cold mill is treated in the ECL to remove oil and clean the strip surface. The ECL comprises: uncoiler, welder, rinse tank, scrubbers, electrolytic tank with alkali solution, scrubber, hot rinse tank, dryer and coiler.

a) Airborne Residuals

During the cleaning process the formation of H_2 and O_2 takes place. As the production of hydrogen is twice that of oxygen, special care is necessary with ventilation of the building to avoid explosion.

b) Waterborne Residuals

The rinse tank solution is formed by 2 to 7.5% alkaline solution and temperature controlled between 70 and 100°C. The effluent from rinse tanks, overflow, splashes, etc. has high pH, oil, SS and high temperature.

Control: Neutralization, rapid and slow agitation tanks with addition of flocculants and polymers, floatation tank, scum skimmer and final adjustment tank. The scum, after dewatered is incinerated.

2.14 Coating Line

There are several different processes to coat cold formed strip or sheet with different materials. The most representative coated plates or strips are tinplate and galvanized strip or sheets. The modern trend is to use continuous coating lines.

(i) Tinning Line:

The main equipment are: uncoiler, welder, alkaline ECL, rinsing unit, pickler, rinsing unit, plating unit, rinsing unit, fusion unit, quench tank, chemical treating unit, rinsing unit, drying unit, oiling and coiler or shear.

(ii) Galvanized Line:

The entry equipment is quite similar to that of tinning line. There are annealing in line and annealing out of line types.

The main equipment are: alkaline ECL, rinsing unit, HCL pickler, bright annealing furnace, cooling units, coating bath, induction heating, premelt of zinc unit, coating furnace, cooling tower, water quench tank and coiler or shearing lines.

In the coating process each chemical solution must be used under a definitive condition. Therefore, the haulting of the chemical solution by strip from one process tank to the next one must be avoided by rinsing the strip adequately.

a) Airborne Residuals

There is almost no airborne emission in this process.

b) Waterborne Residuals

All coating process lines originate waterborne residuals from the claning of the strip surface dirty with oil, removal of rust, dust and from rinsing tanks containing diluted alkali, acid, diluted coating solution and from chemical treating line.

Control: The coating lines wastes could be treated in the pickling line waste treatment plant, but it is advisable to treat them independently. Also it is necessary to treat the chromium that comes from the final chemical treatment unit in the coating process. There are several processes to treat the waste containing chromium, such as: regeneration, neutralization, sedimentation, ion exchange and electrolytical treatment, and for wastes containing alkali or acid, reduction, oxidation of metals and neutralization.

2.15 Foundry

The foundry industry is a segment of iron and steel industry that produces cast iron or cast steel pieces. A foundry industry is constituted by following main sections:

- preparing and reconditioning of the mould sand;
- melting furnace;
- tapping;
- demoulding and deburring and cleaning of cast pieces.

All operations in a foundry emit airborne residuals such as fume dust and gases. Foundry industries are potential sources of high emission of airborne residuals. Even the production capacity is small, the pollution caused by foundry industries become critical because usually they are located in the urban area.

a) Airborne Residuals

Usually the melting furnace is charged with pit iron, return scrap. ferro-alloy, fluxes and coke. The rate emission of residuals depends on the cleanness of return scrap (scrap dirty with sand) and S contained in coke. The sand preparation and reconditioning section emits fines of silica, coke, "mogul" and sawdust. Dust and gases are emitted during the tapping and solidification of cast pieces. After demoulding, the cast pieces are cleaned with shot or sand blast and finally deburring of the cast pieces. All these operations cause emission of dust and particulates.

Control: The emission of particulates from cupola furnace can be reduced by: cleaning of scrap, by removing sand from surfaces: utilizing high strength coke, uniform granulation and without fines; using high thermal and mechanical strength fire bricks, etc. Hoods should be provided to collect dust in the sand or shot blasting area and deburring areas. All dust collected, including that of the cupola stack, can be cleaned with EP, bag filters or venturi scrubbers. EP and bag filters are more efficient than venturi scrubbers, but the last has the ability to remove SO_2 by adequately controlling the alkalinity of the washing water.

b) Waterborne Residuals

Water is used in a foundry for cooling of equipment and washing of sand.

If wet system is used to clean the gas and dust collected by hoods, then waste water will be contaminated, but mostly by silica.

Control: Water used for the cooling of equipment is contaminated with heat. If wet system is used to clean the fume stack and dust collecting systems, the waste water can be treated with that one from the sand washing.

2.16 Direct Reduction

Processes to produce pit iron without the blast furnace have been researched and developed since the end of last century, and there are more than 100 processes patented. However, the production of steel starting from direct reduction process was not successful because of high competitivity of the blast furnace process, although there are some steel plant operating successfully with direct reduction since the decade of 1950. However, many steel industries both developed and developing countries are considering the production of steel starting from direct reduction replacing coke ovens, sintering plant and blast furnace, due to the following factors: exhaustion of good quality metallurgical coal, development of technology to produce a large quantity of reducing gases with natural gas, development of UHP type electric arc furnace; handling of solid product instead of molten iron and finally to meet more and more severe pollution control regulations and improvement of the working environment. There are basically four direct reduction processes in industrial operation: rotary kiln; fluidized bed; shaft furnace and retort furnace.

Usually the capacity of each unit is limited to 400,000 t/year. The reducing fuel for rotary kiln process can be coal or coke breeze (solid fuel). When coal is used as reducing agent the volatile matter should be below 30%.

Other processes require gas as reducing agent and the content of H_2 + CO > 90%.

The selection of D.R. process will depend upon the quality of iron ore, pellet and available reducing fuel (solid or gaseous). It is a convenient process for the mini-steel plant, although there are integrated iron and steel plants being planned to produce 2,5 Mt/year based on the D.R. process. From a point of view the emission is less than the Coke Oven, Sintering and Blast Furnace process.

When natural gas is the reducing fuel the material yard contains only iron ore or pellets, so the emissions from yards are also very low.

When rotary kilns are used, the residual carbon is separated from the product by a magnetic separator and recycled as fuel. Almost all gas based on D.R. processes recycle gas for heating purposes, cooling or for refining, and the excess top gas can be used for other purposes, such as for sealing. As the product is solid there is no emission of flues or heat caused by hot metal and handling of product is easier, calling only for care to avoid reoxidation of product in the stòrage bins by injecting oxygen free gases (sealing gas).

a) <u>Airborne Residuals</u>

There is emission of dust from the furnace discharge, product handling and screening facility. The gases used for cooling or sealing purposes and top gas contain particulate matters.

<u>Control</u>: There are dust collection systems which consist of collecting hoods and ductworks for product discharge, handling and screening, and the dust laden air is conveyed firstly to the primary collectors and then to a venturi scrubber through special dusts.

Particulate matter is removed by the venturi scrubber and clean air passes through the fan and is discharged to the atmosphere.

The dust laden cooling gas and top gas are cleaned in separate venturi scrubbers because of their further use for cooling, heating, reforming or sealing.

b) <u>Waterborne Residuals</u>

Process water is used to scrub dust laden gases from product cooling, top gas and dust collection systems. So it is contaminated with particulate matters.

Cooling water for heat exchangers does not come into contact with the product and its only contaminant is the rise of temperature.

<u>Control</u>: Dust Laden Process Water is collected in a sump then pumped to the waste water treating plant which consists of thickners, cooling tower and vacuum filters. Treated water is reused and slurry after dewatered is sent to the crude pellet plant or for disposal. Machinery cooling water is collected in a separate system and reused after cooled. It may have some variations for gas cleaning and water reconditioning as well as volumes to the different kind of furnaces and raw materials used for production of direct reduction, but basically the principle is the same.

2.17 Ferro-Alloys Production

Usually ferro-alloys are produced in the blast furnace, electric reduction furnace, or electrolysis, thermile (silicon or aluminium) vacuum processes, etc., but the most common process is the electric reduction furnace.

There is emission of particulate matters during transportation, handling crushing and screening of raw materials but the emission can be controlled by conventional techniques without giving rise to pollution problems.

There are basically three types of electric furnace for ferro-alloys; open type, semi closed and closed type. The production of some ferro-alloys requires open type furnaces. (Some ferro-alloys need stocking during production to avoid blow out due to accumulation of gases), but whenever possible it is desirable to utilize closed furnaces. Depending upon the species for ferro-alloys being produced in a closed furnace it generates from 500 to 1.000 Nm^3 of gas per ton of product and the temperature of effluent gas varies from 250 to 600°C and the particulate content varies from 30 to 120 Nm^3 of gas. If an open furnace is used instead of a closed one, the gas generated will burn at the top of the furnace and will drag a great amount of air before reaching the stack. The volume of burnt gas can become 40 to 100 times that of the generated gas and the particulate content varies from 1 to 5 g/Nm^3.

a) Airborne Residuals and Control

Formerly a cyclone was used to clean the burnt gas generated by an open furnace. However, to meet more severe pollution control regulations wet venturi scrubbers were used but they require a great amount of washing water and its treatment. So the modern tendency is to use dry bag filters, although the requirement of power is very high. For cleaning the gas generated in a closed furnace, a venturi scrubber is commonly used because the volume of gas is less compared with that of open furnace.

As cleaned gas is rich in CO, it can be used as fuel, for pre-reduction of raw materials or for drying and heating of raw materials. The closed furnace offers advantages of improving the working environment besides the recovery of fuel gas.

b) Waterborne Residuals and Control

Water used for cooling of equipment (indirect cooling water) is not contaminated. It can be recycled after cooled in a cooling tower. However, wash water from venturi scrubbers is highly contaminated with dust and other matters so it must be treated as well as that water from the mist separator. Clarified water is reused and sludge is removed continuously from the bottom of thickener and reused as raw material after dewatered in a press or vacuum filter.

2.18 Charcoal Production

Charcoal:

Wood charcoal was the earliest fuel used in a blast furnace and its use has persisted and increased in countries where the right set of conditions is found. It is becoming increasingly important as metallurgical fuel as it is one of the few sources of carbon capable of regeneration (photosynthesis).

The energy crisis has highlighted the fact that world supply of fossil fuels and coking coals are limited and many countries are placing emphasis on development of alternative sources of carbon. The simplest alternative is the production of charcoal with a good forestation management programme. This is very convenient for those Southern Hemisphere developing countries with large areas which are not suitable for agriculture. There are variety of fast growing plants (eucalypts, ipil ipil, coconut tree, etc.). Charcoal can be obtained from any organic substance but wood is the usual raw material (production of charcoal from Babacu coconut shells is being considered in Brazil).

Governments must regulate the management of natural forest to avoid the indiscriminate destruction of natural forest, otherwise ecological problems will be created, including transformation of large regions into a desert. There are several processes to produce charcoal: some are very primitive where wood charcoal yield is very low besides losing all by products, and some modern industrialized processes offer better wood charcoal yield better quality of charcoal and allow the recovery of by products which are valuable for chemical industry or use as fuel.

Charcoal Manufacturing Plant:

The basic principle of carbonization of wood is common to the techniques and consists of distilling the wood in the absence of oxygen. The types of plant used to carry out the process are many and varied but may be broadly divided into the following groups:

- Meilers and kilns in which part of the charge is burned to initiate carbonization;
- Batch type retorts, in which the charge is heated in a container by means of an external source, either indirectly or by an oxygen free gas passed through the charge;
- Continuous rinsing gas retorts in which heat, carried by an oxygen free gas from an external source, is passed through the charge;
- Furnace in which the charge is mechanically driven through a furnace under controlled conditions using an external heat source.

As the cost of wood affects directly that of charcoal it is desirable to install charcoal manufacturing plant with by-product recovery facilities to minimize the cost of charcoal.

The distillation of the by product on the site will depend upon several factors: availability of oxygen free gas, species of wood, transportation facilities, power facilities, etc.

Usually this kind of project faces the problems of transport of wood against the transport of charcoal, but the cost of transport can be optimized by drying the wood, improving loading and unloading conditions, keeping the road system well maintained (usually unpaved) and thus decreasing the transport cycle.

The vertical continuous rinsing gas retorts developed in France by Lambiotte & Co., are operating successfully in Wundowie (Western Australia). There are two 35 ton per day units. The main species of wood carbonized by Wundowie is eucalyptus marginata and on carbonization it gives the following yield:

	Percentages (dry wood)	
Charcoal 10% V.M.	37.1%	
Non condensable gas	20.45%	
Acetic & homologous acids	2.80%	Pyroligens
Methanol	1.69%	Acid
Tar	9.75%	
Water of decomposition	28.21%	
TOTAL	100.00%	

The laboratory test conducted in Brazil with a mixture of twenty different species gave the following yield, on carbonization:

Charcoal	33.72%
Non Condensable gas	17.50%
Acetic acid	5.93%
Acetone + fenic acid	1.44%
Methanol	2.50%
Acetate of methila	0.56%
Ethylmethyl acetone	0.05%
Phenol + Creosol	0.75%
Guiacol	0.45%
Organic product	10.50%
Water of decomposition	26.60%
TOTAL	100.00%

These figures are indicative since the amount of by product will vary according to the species of wood and its dryness.

The investment cost for this type of charcoal production plant is high but the operation cost is low and charcoal produced by this method is of uniform and better quality than that produced in old batch furnaces without the recovery of by products.

Pollution Abatement:

On carbonization of wood without the recovery of by-product the acid effluents carried by gas will condense and deposit in the vicinity of working site affecting the working condition, which is already very severe (hot and dirty).

The production of charcoal with recovery of by-product will eliminate the source of pollution besides improving ecological protection because a rational road system network will act as a natural fire break.

The main advantages is that the charging, discharging and screening operations are made mechanically improving, in this way the working environment and the industrialization of the wood charcoal will contribute to improvement of social conditions.

There is almost no information regarding to the water pollution arising from charcoal production but it is believed that the condensation of by-product will affect the soil and storm water can carry the chemical substances into the stream, affecting the water quality.

3. CONTROL OF POLLUTION AT EXISTING STEELWORKS

Usually steelworks established before early 1960's are not provided with control equipment for air and waterborne residuals. Fortunately in the developing countries there are few integrated iron and steel industries based on the coke oven process. Most of them are semi-integrated or integrated based on charcoal blast furnaces or scrap electric arc furnaces.

Rapidly increasing steel demand in the developing countries is calling for the expansions of existing plants. Some steelworks are replacing existing open hearth furnaces by BOF converters equipped with pollution abatement installations. Expansion programmes are including air and water pollution control equipment, particularly when the source of financing is the World Bank.

The abatement of pollution caused by existing steelworks, where replacements are not planned, will require a thorough case by case study, taking into consideration the production flow, lay out, availability of space, condition of the structure and foundations etc., to install the dust collecting hoods, fabric filters, electrostatic precipitators or venturi scrubbers, the gas ductworks, pipings and the waste water treatment units. For example, to control emissions on the coal charging and coke discharging operations will need a very careful study to adopt the best solution. Small sintering plants are being replaced by large ones equipped with pollution control installations. The gas, heat and fines of charcoal recovery installations must be studies for those small charcoal based blast furnaces, that produce just pig iron in order to eliminate pollution and economize on the charcoal.

Some old boilers, designed to burn almost any kind of fuels (heavy oil, tar, light oil, gases and coal) give a large emission of particulates.

It will be necessary to treat the stack gas with venturi scrubbers.

Some measures to abate emissions:

a) Spray water for the raw materials yard;
b) covers for conveyors belts, reviewing structure and foundations;
c) dust collectors at conveyor belt discharge points, crushing and screening units;
d) smokeless charging and discharging of coal and coke, respectively;
e) improvement of dust collecting system in sintering plants, addition of bag filters or electrostatic precipitators;
f) dust collectors for the feeding, screening and weighing hoppers and skip car pit;
g) dust collector for the cast house;
h) gas cleaner for boiler fume;
i) dust collector for the lime kiln;
j) case by case study of steelmaking shops;
k) ditto of rolling mills;
l) use of low sulphur content fuel;
m) improved combustion system control - burner and temperature;
n) desulphurization of coke oven gas and sintering plant fumes;
o) the emission of NO_x can be greatly reduced by improving the combustion technique;
p) canvas cover for dump trucks transporting dusts, etc.

Measures for reducing waterborne effluents

Major integrated iron and steel plants started with the once through systems. These plants are introducing in-plant waste water treatment practice with expansion programmes. This practice is employed so as to avoid the construction of new water intake and supply mains and drainage.

Some techniques are already practiced by existing steelworks, such as:

a) waste water for coke quenching tower (this practice sometimes increases the emission of phenol and cyanide in the blast furnace);
b) recycling system for waste water from rolling mills;
c) neutralization of the pickling tank waste.

However, for total control of waterborne residuals it will be necessary to make a case by case study. Closed recycling systems may be an alternative (solves the problem of space) or tubular settling tank or vertical trickling filters to increase the efficiency and reduce the space requirements. It is believed that there will be a solution for each particular case.

4. PREVENTIVE POLICIES

No distinction should be made between developed and developing countries in relation to control of pollution arising from the iron and steel industry. Some countries are large, but population and industries are concentrated in a small segment of the country and pollution problems are sometimes much worse than those of the developed countries. For example, Brazil has a territory of 8,500,000 Km^2. The metropolitan area of the city of Sao Paulo is enclosed in a small area of 8,500 Km^2 and one third of Brazilian GNP is generated in that small area. This type of unbalanced development is taking place in many developing countries. On the other hand the implementation of a steel industry in an uninhabited region will require the expansion of facilities in the local town or the building of a new town to support the industry.

Considering a productivity of 150 ton/man/year, an integrated iron and steel industry with the production capacity of 6 million ton a year will require 40,000 workers. Considering their families, commerce, health centres, schools, recreation centres, auxiliary industries, public services, etc., the population of the town will increase rapidly by 300,000 to 400,000 inhabitants. The situation is made worse by the floating population that comes from distant regions dreaming of the opportunity of getting a good job in the town, where the large steel industry is being implemented in the developing country. So even in sites where the environmental consequences would be less severe, the situation could become more severe after a few years. Certain pollution control programmes are directed towards raw materials savings and energy economy programmes. With the development of new energy materials saving programmes, it is difficult to distinguish pollution control equipment from process equipment. For example:

> The coke dry quencher generates steam, improves the quality of coke, recovers the dust; the PHOSAM process recovers anhydrous ammonia; BOF shop gas recovery systems provides gaseous fuel of good quality etc.

So it will be necessary to create a new mentality regarding the pollution control equipment.

In the planning and designing of a new integrated or semi-integrated iron and steel industry, total pollution control installations or provisions should be considered. This factor is very important in planning the general and plant lay out.

As regards plant lay out in relation to a production unit, there are always ancillary installations such as unit office buildings, maintenance shops, stock houses, receiving sub-stations, railroads, utility pipelines; etc., and replacement of existing units to install additional equipment is very costly.

In plant pollution treatment equipment should be considered and a central sludge treating or processing plant and the use of waste water cascade should also be considered.

Space should be envisaged for installation of agglomeration and direct reduction plants, in order to use dusts, even though the basic production process relies on the blast furnace. The lay out should consider avenues and streets sufficiently wide to be lined with trees. These trees will contribute to the retention of fugitive dust and dampening of noise and afford a better working environment for employees.

It is important to note that the decision made in the planning stage of a new steel industry will govern the future of the steel industry. Any changes to the basic plan will be very costly. There is often hesitation on the part of many steel plant owners or boards of directors to install pollution control bases on existing laws which are likely to be replaced by more stringent regulations. It would consequently be wiser to adopt the more advanced worldwide pollution control standards existing, as a minimum requirement and in this way, having made provisions, step by step pollution control will be possible in order to meet the regulations of country or local governments. For example, even if a coke making plant is being planned on a site where the air can assimilate the emissions without causing environmental damage; the roof of the coke ovens should be designed with sufficient strength to receive the additional load of scrubbers, the foundation and structure of the coke guide car with sufficient space and strength to receive hoods for the guide car, and so on. However, it is advisable to install pollution control equipment at the very outset rather than to adopt remedial action at inordinate cost at a later stage. In most cases the investment cost for pollution control installations are small compared with those of overall steel production. Concerning environment management policy, the important thing is to afford to the plant workers the best working environment, reducing accidents and absenteeism from occupation disease.

Wherever possible, steel production should be based on processes with least sources of emission of pollutants - charcoal combined with the blast furnace or low shaft furnace, - direct reduction with electric arc furnace, - scrap with electric arc furnace, - continuous casting rather than slabbing or blooming mills, - direct hot rolling techniques to by-pass the reheating furnaces, etc.

There are new types of fire bricks and burners that reduce fuel consumption in the reheating furnaces, meaning less fuel combustion and less emissions of pollutants.

A pollution prevention policy is easier and less expensive than corrective action.

Examples of New Process Technology (Some are old technology)

Developing countries that are going to install new steel industries should consider thoroughly the sources of materials and energy available in their countries. The scale of steel production and range of products will vary according to the stage of development of each country. The distribution of steel products is usually half flat and half non flat products. The scale merit is greater for flat products than that for non flat products. Bearing in mind the size of the country and the costs of pollution abatement it is advisable to consider separately steelworks to produce flat products and those to produce non flat products so as to adapt them to the production scale-merit.

Direct Reduction

Depending upon the availability of natural gas, it is advisable to combine the direct reduction process, scrap and EAF so as to eliminate the cokemaking and sintering plant and reduce the sources of pollutants. There are different patents for the direct reduction process. In some of them a part of the reducing gas is recycled after being reformed, thus completing a closed system and avoiding the emission of pollutants.

There is a direct reduction process, which is a grate-kiln, where coke breeze or coal breeze are used as fuel and reducing agent. Sources of clean fuel are being developed from coal by gasification and liquification. It is believed that in the near future, even those countries without natural gas will be in a position to produce steel by the direct reduction process. The use of process heat from atomic energy to produce steel is also under research but there is some problem with the permeability of hydrogen and contamination of helium.

The capacity of direct reduction units are limited to about 400,000 ton/year, but a 1,000,000 ton/year unit is being considered, and by adding new units and using steel scrap, it is possible to produce 2 to 3 Mt/year of steel, or even more, by the direct reduction process.

Coke Blast Furnace

When the steelworks to be installed is to be based on conventional blast furnace to produce hot metal, the following alternatives should be considered:

- Coke dry-quencher to produce steam for general use, reducing the installation of conventional boilers and the surplus steam can be superheated to generate themal power:

- Use of formed coal or briquetted coal to improve coal to coke yield and coke quality;

- Improve the burden distribution mechanism of the blast furnace to increase the use of pellets which have higher degree of metallization;

- Blow in reducing gases into blast furnace;

- Installation of top pressure turbine generator to reduce the noise (septum valve);

- Q-BOP steel making instead of BOF. As Q-BOP eliminates oxygen lances, the building will be simpler and consequently the investment cost lower and control of pollution is easier than that of BOF steelmaking.
  Another alternative to produce hot metal is the low shaft furnace, where sintering or pellet plants are eliminated and top gas can be used for thermal power or as reducing gas to produce sponge iron.

- Use the surplus coke oven gas for direct reduction process.
- Replacement of the acid pickling process by the iron sand - water jet process, etc.

Continuous Casting

Depending on the steel quality, semi finished products should be produced in continuous casting machines, eliminating this way the ingot making operation at the steel making shop and slab/bloom mill, reducing the sources of emission of pollutants and improving the liquid steel to semi-finished yield. There are already continuous casting machines producing thick slabs and large size blooms and even beam blanks (dogbone) for heavy section mills. Techniques should be developed to allow the hot direct rolling of semi-finished produced by continuous casting machines, by passing the reheating furnace, reducing the consumption of fuel and consequently the emission of pollutants.

Waste-heat Recovery

Almost all reheating furnaces are equipped with the heat recuperator. However, the exhaust gas is still very hot. So the stack gas heat should be used to pre-heat slabs or blooms before being charged into the reheating furnace. Some steelworks are applying this procedure and are succeeding in reducing the fuel consumption. The slab or bloom pushing and extracting doors of reheating furnaces should be provided with the air curtain system to avoid the heat loss during the pushing and extracting operations. The waste heat recovery system is applicable for other areas: BF; Coke Ovens, etc.

Process Computer for Rolling Mill

The major working environment problem in the hot rolling mill area is the noise and radiation of heat. Usually the control rooms are well protected against the noise and heat, so there is no harm for the workers in the control room, but workers staying close to the mill equipment (rolling mill, straightener, leveller, movable or fixed hot and cold saw, cooling bed, marking, etc.) are subject to the noise and heat. If computer control is introduced, the need for workers in the rolling mill area will be reduced to a minimum, besides performing better control of fuel and reducing off-standard products.

Pickling Process

Hydrochloric acid should be used instead of sulphuric acid because although the hydrochloric acid is more expensive it is perfectly feasible to regenerate, reducing this way the pollution problem. There are other advantages such as recovery of residuals with good market value.

Furthermore reactivity of hydrochloric acid on Fe_3O_4 is better than that of sulphuric acid, eliminating this way the scale-breaking operation which is noisy and a source of emission of dust. Another advantage is the high-speed operation, due to the reactivity of hydrochloric acid and the pickling tank can be smaller for the same production capacity as compared to use of sulphuric acid.

Combustion Engineer

It is desirable that steelworks should be assisted by a competent combustion engineer to control fuel and combustion in order to reduce emission of fumes, soot and NO_x, besides the economy of fuel. There are very few engineers with this qualification, so probably steelworks should have a special programme to train engineers. In conclusion then, these are some techniques applicable to new steelworks to abate pollution in developing countries, besides economy of energy.

5. RESOURCE CONSERVING POLICIES

Iron and steel production involves great amounts of natural resources, such as: iron ore, coal, lime, fuel oil, manganese, ferro-alloys, electric power, air and water. Basically the hot metal (molten iron) production consists of heating the coal, cooling the coke, heating the raw materials mixture, cooling sinter and finally the production of hot metal by heating the blast furnace burden (coke, sinter, lime, etc.) with air heated in hot stoves. This way a large amount of fuel and energy are spent and all heat is lost in the cooling process.

Almost 3 tons of raw materials are necessary to produce 1 ton of hot metal and about 300 kg of blast furnace slag. This means that the remainder of the raw materials charged are transformed into gaseous residues or particulates that would be emitted to the atmosphere.

The pollution abatement programmes are always related to natural resources savings (saving of fuel, coal, raw materials).

Principal emission sources of NO_x and SO_x are furnaces and fuel combustion. There are two methods to reduce gaseous residues: use of low sulphur content fuels and control of the combustion. There are several resource conserving techniques, related to pollution abatement.

Reference is made to some:

a) spraying water on raw materials yards to reduce loss of particulates carried by the wind:

b) dry quenching systems: reduces water consumption, eliminates airborne residuals, makes good use of cooling heat, generating steam improves the quality of coke, eliminates coke wharf spray water, etc.

c) by-product: recovery of anhydrous ammonia, napthalene, light and heavy oils, reclaimed of S or sulphur compounds with coke oven gas desulphurization, etc.

d) sintering plant: recovery of dust, recovery of S or sulphur compounds (desulphurization of fume);

e) blast furnace: recovery of dust, top pressure turbine generator, low fuel ratio, dehumidification of blast air, etc.

f) BOF shop: recovery of dust, unburnt gas to be used as fuel, improved yield with ingot inner surface cleaning, reduction of loss of steel by splashes, removal of lime fine to reuse in sintering plant and to improve scrubber waste water quality, etc.

g) slab/blooming mill: to control track time and make the best use of sensible heat of ingot to reduce soaking time, eliminate fish tail to improve the yield from 87 to 96%, slab cooling boiler to recover waste heat;

h) continuous casting to increase liquid steel to slab or bloom yield;

i) changing in design of reheating furnace to reduce fuel consumption, suppressing the pre-heating zone, control of combustion;

j) direct hot rolling to by-pass reheating furnace;

k) substitution of sulphuric acid for hydrochloric acid (regenerating the hydrochloric acid);

There are many techniques or change in process that will result in savings of energy and increase in yield of liquid steel to ingot or semi-finished products. Improvement in yield of liquid steel to slab or bloom means less raw materials, less fuel, less emission of pollutants, less manpower, etc. to produce the same quantity of steel. In short, it means that pollution abatement policy generates as a benefit: reclaims dust and lost heat, less emission of gaseous residues, less energy consumption, less particulate residuals to be treated.

Dust generated in sintering plant, blast furnace and steelmaking shops may be reused to produce crude pellets using, as agglutinant agent, sludge containing oil generated in the rolling mills and in the continuous casting machine waste water treatment plant together with a binding agent.

Slags may be used as raw material for cement making, road paving aggregate, chemical paving of road (mixture of fines generated in the lime kiln, BOF shop dust and slag); construction material with a special granulation method; man made sand (slag treated to substitute the sand); etc. There is a slag granulation technique that allows the production of granulated slag of different sizes and strengths.

Desulphurization of coke oven gas and sintering plant emission generates S or gypsum or sulphuric acid. Sulphur may substitute 30 to 40% of asphalt in road paving and road paved with sulphur mixed with asphalt is resistance to heat and cold, no cracks or deformations caused by weather, lowest temperature for the asphalt preparation, etc. (This paving method has been tested in Alaska-cold and Iraq-hot and USA heavy traffic).

As mentioned before water and air are very important natural resources. With an effective pollution abatement policy air and water will be kept clean.

There are three integrated iron and steel industries based on coke in Brazil. All of them are installing the PHOSAM process to recover anhydrous ammonia. The investment cost is high but as there is shortage of fertilizers, the revenue will pay for the equipment in a few years, besides eliminating pollution of steams with ammonia.

Resource savings considerations were made for an integrated iron and steel industry based on coke-sinter-blast furnace processes.

For those countries rich in forestation areas, and hydropower charcoal low shaft furnace hot metal (molten iron) producing process should be considered.

As regards water, closed recycling systems should be used for indirect cooling water (bosh, tuyere, shaft, hot-stove, valves, steam condensers, BOF shop lance and hood cooling, oil cellars, heating furnaces, etc.). This system, besides saving of water, solves the space problem. The steel industry has given some consideration to resource saving policies and it may be concluded that there is a close relation between resource saving and pollution abatement policies.

In summary, if the pollution control management is effective, investment for pollution abatement installations will pay for themselves in a few years, besides making savings in natural resources.

6. SITING

Several factors must be considered in selecting the site (location) of a new integrated iron and steel industry.

6.a Raw Materials Sources

1. If all raw materials (including liquid combustibles and LPG) are going to be imported from abroad, it is quite natural that the best site be close to the import harbour. This port must be provided with unloading facilities and berthing of sufficient size to receive mammoth ore carriers and tankers to reduce the

transportation costs. Naturally the draft at the berth is an important factor. It is much more economical to transport one ton of steel instead of 2 to 3 tons of raw materials.

2. If the country owns a part or all of the raw materials, the selection of the site should be decided taking into consideration:

a) domestic consumption or export;
b) domestic market;
c) scrap resources;
d) raw materials sources;
e) transportation facilities;
f) availability of communications, power supply; social infrastructure, such as: housing, mass transportation systems, shopping centres, health centres, hospitals, schools, social services facilities, recreation centres, auxiliary industries, fire brick, foundry, forging, mechanical shops, etc. and the market for by-products such as: slag, light oil, heavy oil, tar, etc.

6.b Meteorological Conditions

As has been stated, steel industry transforms raw materials into steel and the raw materials are fines of iron ore, coal, lime, etc. and storage yards and piles are large and high. So the selection of site should consider the wind and storm conditions to avoid the loss of materials and causing of air and waterborne pollution problems.

The humidity of the air and temperature affects the fuel ratio and efficiency of cooling systems. But the most important consequence is on the worker and his family's comfort.

6.c Land Use

Flat land with good soil condition is desirable. Sufficient area has to be provided to allow for future expansions, the disposal of solid wastes, strip of green belt surrounding the steel plant and a buffer strip of land around the steel plant to avoid construction of industries or housings close to the steel plant. Generally the site for the greenfield steelworks is selected sufficiently away from urban areas to reduce the impact of the steel industry on the urban area from an environmental point of view. However, if the buffer zone is omitted the steel plant will be surrounded by housing developments and miscellaneous activities in a very short time.

6.d **Environment**

It is preferable to avoid selection of sites already polluted by existing local industries. Steelworks are usually the biggest industrial complexes followed by the petrochemical industry. So even when all emissions are under control in a steelworks, public opinion and criticism is bound always to be levelled against the steel industry if pollution problems arise. However, as the steel production cost is governed by the cost of raw materials, labour and transport, the additional environment protection cost must not be a governing factor.

6.e **Education Facilities and other Social and Urban Infrastructure**

The selection of a site for a new greenfield integrated steelworks is governed by the cost of transport of iron ore, coal, lime, fuel oil and finished products and therefore an uninhabited region could be selected the steel plant site. In this case it will be necessary to plan and implement the social and urban infrastructure. Amongst the public services required the most important are educational facilities, so that the steelplant workers and their families will settle for good. Otherwise, the turnover of workers will be high because of the problem of children's education and the formation of skilled manpower will be difficult.

6.f **Transportation System**

Good transportation facilities are required not only for operation of the steel plant but also for the construction of the steelworks. Reliable and safe transportation facilities are required because some equipment (Millstands for instance) may weigh 300 ton or more.

6.g **Power Supply**

The power required by an integrated iron and steel industry is around 350 to 400 Kwh per ton of steel. Instantaneous variation in power consumption is very big in an integrated iron and steel industry. So the power supply sources must have sufficiently large back up power (3 to 6 times).

6.h **Water Supply**

The integrated iron and steel industry will have to recycle and reuse wastewater to avoid pollution of the streams and water shortage. A good control of water quality in the in-plant waste water treatment installation allows the recycling of 93 to 96% of wastewater. Usually the investment cost of once through systems is higher than that for recycling systems. The in-plant recycling systems offer the following advantages:

a - Abatement of Pollution;

b - Smaller water supply mains and drainage systems;

c - Control of quality, pressure and temperature according to the requirement of each production unit;

d - Independent operation amongst production units;

e - Reclaim of reusable materials; etc.

In this way water is not a governing factor in the selection of site as it was in the past. A stream that can guarantee the supply of make-up water during the drought has become a good water supply source.

Usually in tropical regions water of rivers get muddy in the rainy season with high SS and turbidity. Therefore, sometimes, recycled water has better quality than river fresh water.

In summary, as investment cost for the pollution control equipment, (including waste water reuse system) in a new integrated iron and steel industry is low, about 6% of total investment; environmental cost must not be the governing factor for selection of the site for a new steel industry, since the pollution control cost is about 2% of the steel production cost.

Some Considerations on the Planning of a New Integrated Iron and Steel Industry:

Usually planners of an integrated iron and steel industry emphasize the process equipment, such as coke oven batteries, sintering plant furnaces, steelmaking shops and rolling mills, etc., and consider utilities or ancillary services, as well as working environment as of secondary importance. However, to abate the pollution problem and minimise the production cost, the following aspects should be considered on planning a new iron and steel industry.

a) lay-out to meet the long range production plan, considering the prevailing wind to decide the location of raw materials yards and height of fume stacks;

b) lay-out to facilitate the collection of sanitary sewage and industrial waste water (blow down) sewage into the central batch treatment plant, and reuse of waste water in a cascade system;

c) Arborization of streets and avenues - this matter should be studied very carefully otherwise the tree planting can impair illumination and damage utility piping and duct systems;

d) storm water collector and settling basin for raw materials yard;

e) office building of production units sufficiently far from noisy equipment such as: blowers, compressor rooms, exhaust fans, cooling towers, oxygen producing plants, etc;

f) production plan based on gas balance;

g) location of excess gases combustion towers at high place or well ventilated area to avoid accidents if the pilot flame is extinguished;

h) good ventilation for the exhaust gas blower rooms (CO is heavier than air);

i) incinerator with ash removal and gas cleaning systems for disposal of unusable wastes;

j) possibility for hot direct rolling - Continuous Casting Machine/ Slab/Bloom close to plate or Hot Strip Mill;

k) scrap cutting machine instead of gas cutting; (Kaiser steel - California);

l) good information system to keep all workers in the steelworks informed about the objectives and policies of the company loudspeakers installed in the offices, refractories, resting rooms, libraries, sport centres, etc., to achieve home public relation and training;

m) etc.

7. COST BENEFIT

When iron and steel industries in the developed countries started pollution control programmes, they had to install a lot of equipment to abate waterborne and airborne residuals, investing in the field of research and in the installation. Some new technologies have been developed as consequence of pollution abatement programmes, such as: PHOSAM process; CYAM process; Q-BOP shop unburnt gas recovery process; coal preheat and pipe charging system; on-strand cooler sintering machine; pickling process with hydrochloric acid; etc.

The majority of equipment developed to control pollution are bringing benefits, besides improvement of the working environment, by recovering reusable materials.

Therefore on the planning and designing of a new iron and steel industry some pollution abatement equipment should be considered as normal process equipment of the steelworks. This statement is reinforced particularly since the oil crisis in 1973, when the world started resource and energy saving campaigns. Existing technologies that had been considered unfeasible in the early times were recalled and are now being applied by some iron and steel industries, such as: dry-quenching of coke, blast furnace top pressure turbine generators, production of pellets or sponge iron with the dust generated in the steelworks, etc.

Usually the iron and steel industry lists the pollution control equipment just considering the investment cost, operating cost (energy man-power and maintenance) and capital cost but the return due to the recovery of valuable materials for reuse or selling is not considered. However, if recycling of valuable residuals, including waste water is taken into consideration for new steelworks to be installed in developing countries, the pollution control cost will not influence the final cost of steel products.

As regards to water, it is clear that treating and recycling the waste water is less expensive than once-through systems.

The airborne residuals control generates reusable materials. Envisaging the economy of energy, the use of blast furnace and BOF (Q-BOP) gases in fuel in steelworks must be common practice, so the gas cleaning equipment must be considered as process equipment.

Besides the considerations mentioned above the cost benefit of pollution control should be analysed on a regional basis. It is believed that the benefit generated by pollution control is greater than the cost of investment and operation, because there are several intangible benefits as consequence of pollution control, for example: less corrosion, painting of buildings, damage to equipment, etc.

8. WORKING ENVIRONMENT

(i) Workers in an integrated iron and steel industry are exposed to different working environmental conditions and some hazards in different areas are mentioned below:

- Raw materials yards: dust and noise and vibration if there are crushers and screeners;
- Cokemaking: fume, dust and heat;
- Chemical by-product plant: odour and vapour of benzene;
- Sintering plant: dust;
- Blast furnace: dust, heat and slight odour of H_2S;
- Blower: noise;
- Calcining plant: dust (sometimes injury with humidity);
- Steelmaking shop: fume, dust, heat and intense brightness;
- Continuous casting: heat for tundish operator;
- Hand scarfing: fume and dust;
- Foundry: gas, dust and noise;

- Oxygen plant: noise;

- Compressor rooms: noise and vibration;

- Hot rolling mills, noise and heat;

- Cold rolling mills: fume;

- Wastewater treatment plant: chemical agents;

- Degassing: noise, etc.

(ii) Due to the characteristics of equipment in steelworks and the production process, the working environment is not subject to toxic substances during normal operation, except in the chemical by product plant and in the foundry where workers are subject to the benzene vapour and gases, respectively. Other toxic substances such as CO, CO_2, NO_x, SO_x are emitted to the atmosphere through the flare or fume stacks and phenol, cyanides, ammonia, arsenic (if any) are emitted to the steams, with wastewater, creating air and water pollution problems rather than working environment problems unless there occurs some accident giving rise to a leakage of a toxic gas such as CO, H_2S polycyclic hydrocarbons, etc. Apparently the most dangerous area is the sewerage system (heavy gases can accumulate because of poor ventilation) so workers before entering into the sewerage area for inspection or cleaning should monitor the existence of dangerous gases with specific receiving instruments. The main working environment problems are caused by dust, heat, noise and intense brightness.

(iii) Occupational Disease:

a) The noxious action of dust and gases on man give rise to a great variety of effects, starting with olfactory troubles and continuous exposure can lead to chronic sickness and finally a severe intoxication. Certain chronic effects caused by low concentrations of dust and gases are as yet hardly known. Usually the noxious actions on the human organism are caused through respiratory system, and the main manifestations are irritation, allergy, cancer, etc.

b) Even before being concerned about pollution problems, steelworks had safety services to reduce the work accidents. Some measures were taken to protect the workers against hazardous environments such as the use of: eye protection glasses, ear protection; masks against dust and gases; protection masks and special clothing against the heat radiation; special food to compensate the loss of salt, etc. Therefore the incidence of work accidents was greatly reduced despite the increase in number of workers.

(iv) Occupational Disease in Steelworks in Developing Countries

There is almost no information about occupational disease. This fact is attributed to:

a) frequent turn-oven of workers from one working environment to another (from operation to maintenance, for example);

b) usually steelworks owns its own ambulances and hospital, but doctors working in them are not familiar with each working environment;

c) the worker himself is not familiar with hazards to which he is exposed;

d) diagnosis is made based on information given by the workers;

e) laboratory examination is performed only in special cases;

f) lack of periodical examination;

g) worker's colleagues should be examined too, etc.

(v) Conclusion:

Since there is little difference in the working environment in steelworks between developed and developing countries, where workers organisms are subject to different impacts (noise, vibration, dust, radiation, heat, chemical agents, etc.), it might be expected that the rate of occupational disease should be alike. Neurosis as a principal occupational disease is found to increase due to three shift operation of the steelworks, where sleeping and meal times are changing weekly. In order to control the occupational disease in the steelworks, effectively, it would be advisable to train doctors specialized in the different working environment of the steel industry.

9. POLLUTION CONTROL STANDARDS

Pollution has no frontiers. Local problems can be transformed into multi-regional problems. It is difficult to foresee the effects of pollutants which can be varied due to several influencing factors.

It is essential that the national Government establishes minimum pollution control standards throughout the country and each local Government or municipality should establish its own standards in consideration of the national standards. Otherwise bordering municipalties can adopt different pollution control standards for the same segment of industry prejudicing one and benefitting the other. This may happen in a developing country where the local authorities are interested in establishing industry in their municipalties which means: higher tax revenue and more job opportunity. To achieve it sometimes local authorities slacken the pollutant emission standards, without considering future consequences and impairing the industry established in neighbouring municipalties. For example, two municipalties separated by a river, or upstream and downstream where criteria are different.

Consequently the problem of pollution control and abatement must be evaluated in an integrated manner by the national government. The deterioration of the environment is a reflection of the population and industrial and urban growth. The preservation of environment is possible with application of several costs; investment cost, maintenance cost and operation costs. It is necessary to avoid unfair burden of costs on consumers and industries within the same environment, due to heterogeneous treatment.

Environmental Quality Control

Unless a nation has clearly defined environmental quality goals it becomes difficult to establish priorities and make intelligent policy decisions. The complexity of environmental problems requires sophisticated approaches. For economic, social and political reasons, goals for environmental quality control will vary among countries of the world.

Some developing countries are not sympathetic to the view that the economic growth should be curtailed to avoid environmental degredation. Some developing countries agree that environmental considerations should be incorporated into national development strategies in order to:

- utilize human and natural resources more efficiently;
- and enhance the quality of life of their people.

At the outset it is important to emphasize the importance and delineating goals and objectives and avoiding too hastily made policies and/or policies formulated after the fact. A National Policy for environmental quality control should be developed with specific goals and objectives which may be incorporated into a national development strategy.

Monitoring

With a goal as a base, an important consideration is to initiate monitoring programmes which will provide information on the current situation, and later, any change in environmental quality as affected by changes in natural resources use and development. A monitoring system will provide data on which to base regulatory action, determine the effectiveness of control programmes, and permit detecting hazards in advance of their reaching a critical stage. This requires establishing mechanisms for evaluating the data collected such as the use of environmental quality indices.

Criteria and Standards

A next step is agreeing on air and water quality for various uses. This is not too difficult because there is considerable data available on many of the significant parameters and their relation to prescribed uses. After a determination has been made on uses, based on available criteria, specific standards should be adopted, including legal mechanisms for enforcement, if any. The standard should be adopted on a national basis. There are also international economic consequences to establishing environmental quality standards. The consequences of any one nations action can affect its own international position as well as the position of other countries.

Institutions

Adequate institutional arrangements are necessary for effective resource management. Some of the principal factors to be considered are regulatory responsibilities, policy and technical advice to decision makers, and inter-agency coordination.

The national Government should retain overall responsibility for pollution control programmes, and local authorities some responsibilities for implementation.

Whilst many existing steelworks managers are conscious of pollution caused by their industries and are ready to take some kind of measures they are forced with shortage of human resources to solve control problems adequately. Technical institutions or Technological Centres should be created by the government to give orientation to the industries as well as to the manufacturer of pollution control equipment.

Economic Development

Economic development must include industrial development as part of a national policy on environmental quality control. In order to stimulate industrial growth a country may be willing to minimize the investment in the environmental pollution problems early in the developing programme, viewing the problem on short term basis. However, this may not be the wiser nor the more economical course, if viewed long term. A more practical approach in the case of new construction would be to encourage industry to incorporate the most technically and economically feasible pollution control equipment available. This is not an excessive financial burden. In most cases the efficient use of pollution control equipment enables the recovery of usable materials with sufficient value to off-set some of the treatment costs.

Manpower

Manpower is a very important factor in developing an effective pollution control programme. An integrated iron and steel industry requires about one to two men/150 ton year, and many of skilled workers have to be trained at the plant and most of the unskilled workers come from agricultural areas, having no experience with electrical, mechanical, and chemical equipment. So it is important to create training centres at the initiation of steelworks construction and prepare workers for the operation. If workers are aware of operating condition of the steelworks, many pollution problems can be eliminated at the source with good housekeeping practice.

Technology

The designing and manufacturing of pollution control equipment for the iron and steel industry require sophisticated and advanced technology. As pollution becomes a boom many equipment manufacturers start manufacturing pollution control equipment without the background know how. Some industries install pollution abatement equipment just to satisfy the local authorities, purchasing less expensive equipment which sometimes is completely ineffective and thus wasting money.

Governments should facilitate the importation of know-how to allow local manufacturers to fabricate pollution control equipment with a solid background.

The manufacturer of pollution control equipment should provide good technical assistance and maintenance service for users.

Monitoring Systems

As air and water are important natural resources it is mandatory to control pollution for their preservation. The ideal situation would be that where all emissions were eliminated at the emission sources. But there are always fugitive emissions and in some cases it will be too costly to eliminate all emissions such as NO_x and SO_x, therefore it becomes a duty to care about pollution and its effects, sometimes involving specialized research institutes.

The study of pollution problems should be performed following a legal prescription with the cooperation of iron and steel industries, sanitary, agricultural and meteorological departments in order to establish the extent and effects of pollution outside the industry and to avoid harmful effects caused by pollution.

Air Pollution Monitoring Systems

a) In-plant Measurement:

Measurement of pollution inside the plant must be achieved by all steel industries regardless of its size and site because it interests directly the steel industries. It gives information as regards to:

- The working environment: which will establish a guideline to improve the working condition by suppressing the source of nuisance and will allow the establishment of the cause and frequency of occupational disease if there is a periodical medical examination;

- Measurement of the exhaust gases (CO_2 content) in the gas duct will assess whether combustion is complete or not and the corrective action can result in less emission and a fuel economy;

- To check the performance of pollution control equipment already installed and to take corrective action if necessary;

To estimate the amount of pollutant being emitted. This is particularly important if the steel industry is located in an industrialized area or close to urban areas (emission by motor vehicles), etc.

Each steel industry should be provided with a meteorological station to record all weather conditions, mainly the ambient temperature, humidity, direction and intensity of the wind and, if possible, to measure the height of the thermal inversion level which will be helpful to design the fume stacks.

b) Measurement Outside the Industry:

It is difficult to establish a standard for monitoring systems outside the steel industry because the extent and distribution as well as the type of pollution depends upon several variable factors such as size of plant and steel production processes, topographical condition of the area surrounding the steel industry, existence of buildings and most importantly the meteorological conditions; the plume path, its extension and diffusion vary greatly. The thermal inversion levels must be determined. This will allow after some analysis, to foresee the possible degree of concentration of pollutants at ground level and the counter measures which could be taken by steel industry.

The monitoring systems outside the steel plant could be performed by the local pollution control authorities. However, although there are several automatic apparatus for measuring pollutants, the establishment of monitoring requires highly specialized personnel to identify where apparatus must be located (extension and diffusion of plume path), interpretation of the results, because it is believed that each particular steel industry site will require a particular solution and it will be impracticable to study each site condition in a wind tunnel model. A monitoring programme should be established and tentatively try to cover the whole area under the influence of the emissions.

In the developing countries the government could create a national or state institute to perform the monitoring tasks outside the steel plant or encourage the creation of specialized consultant and engineering firms to do it. The monitoring systems required to assess the extent to which a contaminant is carried and the degree of variation of pollutants in space and time often call for use of a computer to obtain results as quickly as possible and, where possible to foresee the development of a pollution phenomenon.

The frequency of measurements can be reduced after sufficient data are obtained since it will be possible to foresee the pollution condition based upon emission data from the steel plant. Usually more frequent measurement is required in winter weather.

Water Pollution Monitoring System

Monitoring water quality is simpler than that of air pollution. Since the tendency of steel industries is to reuse the waste water, it is necessary to have the make-up water, recycled water and blow-down water quality under control for the best use of the water. So each steel industry should be provided with a central water laboratory to perform water analysis.

The operation of analytical apparatus is quite simple. The intake water and downstream water after the waste discharge point (after sufficient diffusion) must be analysed. This is important to avoid unfair penalties if there are pollution sources upstream or downstream. There are automatic analysers that can be mounted on a vehicle making it easy to perform some analyses.

ANNEX

Scrap Based Steel Industry - Recycling of Scrap

The iron and steel industry transforms the raw materials to prime material for industrial development (mechanical, electrical, transportation, construction, etc.) and constitutes 95% of the metallurgical industry.

There are several sources of steel scrap; steelworks circulating scrap; prompt industrial scrap; process scrap; obsolete scrap - capital scrap; import scrap; etc.

The approximate distribution of scrap generation is:

- Scrap generated in steelworks: 77.8%
- Scrap generated in transformation industries: 20%;
- Scrap generated in chemical and non ferrous industries.

The contribution of scrap to the world steel production in 1974 was 40.3%:

- steel production............ 704,9 Mt/year;
- hot metal.................... 585,0 Mt/year;
- scrap........................ 395,0 Mt/year;
- scrap ratio = $\frac{395}{395 + 585}$ = 40.3%

There are some unrecoverable scraps, such as: marine structures destroyed by corrosion; foundation; warships; etc.

Steelworks based on steel scrap in developing country will have to import scrap at the initial stage of development and substitute gradually the import for domestic generated scrap.

When a steelworks envisages to produce bars and light sections (medium to mini steelworks) it can be constructed in modules to utilize the regional scrap. One module would consist of:

- Scrap yard/Handling equipment;
- EAF shop (1 furnace and completely enclosed building to facilitate the collection of fume and dust);
- Continuous Casting Machine;
- Billet Yard;
- Ultra High Voltage Transformers;
- Small Capacity Oxygen Plant (optional);
- Shape/Bar Mills, and
- Water Systems.

To increase production of steel, construction of new modules may be more economical than expanding of existing steelworks.

To estimate the production cost, the following factors should be considered:

a) Consumption of Primary Energy:

Conventional Process		Scrap EAF
Coke Making	881,000 Kcal/ton	EAF 1,261,000 Kcal
Sinter	617,000 Kcal/ton	
Hot Metal	2,631,000 Kcal/ton	
BOF	312,000 Kcal/ton	
Total	4,441,000 Kcal/ton	1,261,000 Kcal

meaning that steel scrap keeps within it 72% of energy necessary to produce liquid steel.

b) Comparative cost with hot metal : hot metal - demerit of scrap (cold scrap requires more energy + handling cost).

c) Scrap recycling cost; handling and transportation costs of capital scrap, automobile scrap and manufacturing scrap.

d) Cost of steel product:
Cost of scrap = cost of steel product = fabrication cost (EAF operation + rolling mill + other expenses).

e) Cost of refractory bricks (17 kg/ton), electrodes (5 kg/ton) power (480 kWh/ton).

f) Quality of hot metal is known while that of scrap is unknown.

g) Pollution abatement is easier because the sources of emission are limited to the scrap yard, EAF shop and rolling mills, etc.

So scrap has a higher value than sponge iron for production of common steel, but when production of special steel is envisaged, sponge iron offers the advantages of its uniform quality.

Conclusion

Usually, the developing country envisages the production of non-flat (bar and light sections) steel products at the initial stage and the combination of scrap with EAF is applicable since the supply of scrap is guaranteed, because the world's scrap trade is very active, and where there are sources of hydroelectric power, or low cost energy, because undoubtedly the investment cost is lower, pollution control is easier and steelworks implementation time is shorter than for the conventional iron and steel industry.

Depending upon the availability of natural gas, D.R. offers similar advantages.

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IRON AND STEEL INDUSTRY IN EASTERN EUROPE AND POLLUTION CONTROL

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1. Introduction

The problem of environmental protection in which man lives and works became - particularly in the recent years - the subject of great concern of society, governments, social and political organizations and specialized and international agencies. This problem is also investigated in specialistic scientific centres and institutes.

The most destructive factor for the environment is the progressive urbanization and industrialization that are particularly intense in large developing industrial centres. Such a situation arises in all parts of the world independently of the existing economic and social systems. But the sharpness of its occurrence may depend on the level of social and economic development and on the goals to which priorities are ascribed.

In the Central and East Eurpoean countries, great importance is attached to the problems related to environmental protection, including the work safety and hygiene and the environmental protection within and outside the working site. However, the problems of working conditions were already treated in the period between the two World Wars. On the other hand, the problems of environmental protection that surrounds man became the subject of important interest within the last 20 year period.

The production of steel and of the materials that are necessary for its manufacture is accompanied by emission of large amounts of dust, harmful gases, heat, noise and radiation. These elements usually cause damage to man's environment, that is, air, water and soil. They are harmful for the health and well-being of people and animals, and for the growth of plants.

Until the Second World War the steelmaking industry in Eastern Europe was centered, with the exception of the Soviet Union, around densely populated urban areas and this fact largely worsened the already difficult environmental situation. After the Second World War, the steel industry, and especially its raw material branches, has been developed outside urban areas and, thus, it has been possible to avoid its undesired impacts on the living conditions in towns. The old/urban/raw material industry for steelmaking has been or is being now rebuilt into the processing industry which is much less harmful for the environment.

The present report describes the environmental protection problems and related harmful impacts occurring in coking, sintering, steel-making, steel rolling and steel forging plants. It is also discussed what efficient remedies should be taken to further improve the working conditions in the iron and steel plants and the living conditions near them, and, at the same time, to reduce different kinds of losses.

To focus attention the present report is restricted only to main problems. For more detailed data, the reader is referred to the full text of the report.

2. Air and Water Pollution and Working Conditions in Steel Plants

a. Coal coking plants are one of the most important sources of contamination of the atmosphere, water and soil. The pollutants emitted from the coking plant are hazardous and harmful for health. An additional unfavourable circumstance is that the emitting installations are usually of small height and, thus, the pollutants settle in the close vicinity of the coking plant. It should be stated that coking plants are still serious sources of hazard in spite of use of modern technologies and highly efficient facilities that collect dust and neutralize harmful gases. Much hope is attached to the fluidal method employed for coke production. The emission rate of pollutants from coking plants into the air are given in Tables 11 to 22. (The full set of tables are found in the original report). Coking plants are also the source of considerable contamination of water that is used for preparation of chamber charge material.

b. Ore Sintering

Sintering plants involve large numbers of points at which pollutants arise, mainly dust, sulphur dioxide and carbon monoxide.

The emission rates of the pollutants are given in the report for particular production stages and facilities in Tables 23 to 36.

The ore sintering plant and charge preparation department consume water designed for: charge moistening, sinter cooling, cooling of burners, bearings and breakers and dust collection from gases. Main pollutants of water are suspended solid particles and alkalies (calcium hydroxide).

The main problems in ore sintering plant are: pollution of air by dust and gases, noise and heat radiation.

c. Blast Furnace Process is, in East European countries the basic method employed for producing pig iron from iron ores and it is expected to remain so for the immediate future. Following general technological progress, the blast furnace process has been modified improved and intensified. This affected the mechanism of production of dusts and gases and, thus, the quantity and quality of emitted pollutants. Among the impurities emitted into the atmosphere, cyanides are most harmful. The content of cyanides grows as the zones of high temperatures move towards the furnace throat and this takes place when the coke consumption rate increases. The content of other gases, including SO_2 is low.

Blast furnace gases have a high calorific value, that is, they are valuable fuels. Before being used, they must thoroughly be cleaned from dust usually in three stage installations, namely: static dust collector - scrubber - electrofilter.

The blast furnace department is also the greatest consumer of water in two major recirculation systems, namely: the surface cooling system for the blast furnace and heating blast stoves equipment, and the non-surface cooling system for blast furnace gas. Moreover, water is used for moistening of charge materials, granulating of slag and cooling pigs in the cast machine.

The specific problem in the recirculating systems of the blast furnace as cleaning equipment is the appearance of cyanides (C_2H_2, HCN).

In view of the high toxic properties of cyanides, the water can be neither disposed outside the plant nor supplied to other recirculating systems without being purified. It is not easy to solve the problems occurring in the purification plants of blast furnace and this requires major financial investments. Details of this problem have been described in Sub-sections 11.2.2 11.5 to 11.8 of the report.

d. Steelmaking Plants. Most often steel is produced in open-hearth, tandem, electric arc and induction furnaces, in oxygen converters and by employing electroslag smelting. The concentration of pollutants arising in the open hearth furnace process depends on many factors from which the most important are: kind of charge materials, kind of processes employed, design and condition of the furnace, kind of fuel and amount of oxygen used for intensifying the smelting process and for refining. The pollutants emitted into the air include: dust, sulphur dioxide and nitrogen oxides. The emission rates of the pollutants are given in Tables 49 and 50 of the report.

A version of the open hearth technique is the tandem process which is characterized by its higher heat efficiency and productivity. Its emission rate is lower than that of the open hearth process.

The emission rate of pollutants and their quality can be different for furnaces of the same size. This depends on the way of conducting the process, grade of steel, smelting time, etc. The main pollutants emitted into the air are dust and nitrogen oxides. The remaining constituents e.g. SO_2 appear in smaller or trace amounts.

The electroslag steel smelting process is more and more often introduced into steelmaking plants. It is intended almost exclusively to obtain special grades of steel. This process is related with emission of dust, fluorine, sulphur dioxide and nitrogen oxides. The emission rate depends on, first of all, the grade of slag.

The principal growth in the steel production was obtained by the use of converters and oxygen. In Table 66, is given data on the quantity and quality of flue gases. In Table 62 is presented the emission rate of dust from converters with gas after burning. If the dust saturated gases are not after burnt, they are dedusted, stored and used in other facilities of the steel plant. Pollutants include here: nitrogen oxides and small amounts of fluorine and sulphur dioxide.

e. Ferroalloys. The production process of ferroalloys is one of the most intense sources of pollutants emitted into the air. The main contaminants are: dusts, nitrogen oxides, small amount of sulphur dioxide and traces of other pollutants, depending on the charge material. The emission rates of these pollutants are presented in Tables 69 to 95.

f. Rolling Mills, forge shops, hammer forging departments and stamping plants emit less pollutants into the air but they consume a lot of water for: cooling of heating stoves, rolling machines, drawing machines and for conveying scales rinsing products and preparing solutions for pickling products. Effluent water from these departments is contaminated mainly by suspensions and oils. Most working sites are subject to a few effects at the same time, predominant among which, is heat radiation, mainly, from heating stoves, hot ingots, sheet metal and billets during conveying rolling and storing. Most operations performed in the rolling mills, forge shops, hammer forging departments and stamping plants produce noise of a high level and, a number of working sites, especially the finishing departments are subject to excessive vibration both general and local.

g. Iron and Steel foundries emit dust, nitrogen oxides, sulphur dioxide and smaller amounts of other pollutants. Water is used for cooling installations and for technological process(preparation of raw materials, cleaning of cast iron products, etc.). Between the departments of iron and steel making plants, foundries can be included as minor consumers of water. The main pollutants are strongly concentrated dust with a high content of silica, and noise. Additional harmful effects are: periodically excessively hot microclimate, heat radiation, gaseous contamination and vibration

Methods for Pollution Abatement

3.1 Air Pollution

a. In coking plants, there are different sources of pollutants. It is usual to enclose the facilities that produce pollutants for the purpose of cleaning. Systems of cyclones and fabric filters with an efficiency of 99% are used in coal treatment, batching and stamping plants and in coke sorting plants.

Dust emission during coke chamber charging is reduced by sealing the installations and cutting short the charging time.

During coke pushing, the emission is reduced by installing exhaust and cleaning equipment mounted on the continuously travelling carriage.

Over the entire coking cycle, impurities leak through untight points of the doors and whole ceramic body of the stove. This emission is reduced mainly by technological means.

Soot and sulphur dioxide are the basic pollutants emitted into the air through chimneys that release the exhaust gases arising from firing coke batteries. This emission is reduced by applying appropriate technological process, firing sulphur free gas and installing dust cleaning equipment.

During coke quenching, the radical reduction of emission is obtained by replacing the wet quenching by a dry one. The emission rate of pollutants during the wet quenching of coke is decreased in the quenching tower through its appropriate design and mounting suitable shutters.

b. Reduction of the emission rate of pollutants in the sintering process

The quantity and quality of pollutants is different in particular process operations. The emission of pollutants from storage yards of charge materials can be reduced mainly by employing technological means such as: water moistening of materials, maintaining a high humidity of materials during their ageing, and protecting storage yards against wind action. Wet dust collectors are used for dust removal as materials are unloaded from the wagon tipper. The sintering process itself is protected by multicyclones, often by electrofilters and recently by Venturi scrubbers. The working site of the breaker is also protected by the use of multicyclones, wet dust collects and, in the newest designs, the gases are fed into the enclosure under the sintering conveyor. In this technique the layer of the material mixture being sintered performs the function of a filter. The feeders of back sinter are usually equipped with wet dust collectors. Sinter is cooled in the cooling facilities fitted with multicyclones or fibre filters.

c. Blast furnace gases are cleaned usually in three stages, namely: dust catcher - scrubber, Venturi scrubber or electrofilter. In this method, the collection efficiency ranges from 99.5 - 99.95% and the amount of gaseous contaminants are decreased.

d. Cleaning of flue gases from steelmaking furnaces is strictly connected with their cooling. In open-hearth furnaces, the exhaust gases are cooled either directly by means of additional air stream or water injection, or indirectly in the utilization boiler or water jacketted pipes. Dedusting takes place in wet dust collectors, electrofilters or fabric filters. Attempts to apply bed filters and multicyclones have ended in failure. It is possible to encounter open-hearth furnaces without any cleaning equipment.

Flue gases from tandem furnaces are easily cooled because their temperature is not higher than 600 - 630 K. Dust is caught by means of Venturi scrubbers fabric and electrostatic collectors. Most frequently, the first stage of dedusting is a foam washer that not only collects dust and part of gaseous contaminants but also cools the gas down to 370 K. The cooled and steam saturated gases flow to Venturi scrubber. The efficiency of such an installation is of an order of 99% and even more.

In electro-steelmaking plants, the problem is how to collect gases and feed them to cleaning equipment. In modern installations use is made of two methods. One of them consists in direct installation of the exhaust member that enters the furnace chamber through its ceiling; in the other method, gases are exhausted through a hood that is tightly built on the ceiling. There are several versions in practice of each method. Before being cleaned, gases are first cooled. Contaminants are removed from gases by means of fabric filters, wet collectors and electrofilters having a collection efficiency up to 99%.

Flue gases from the electroslag steel smelting are cleaned in wet dust collectors. Fabric filters and electrofilters proved to be unworkable in view of aggressive properties of the exhaust gases.

Two methods are now employed for cleaning flue gases from converters. One consists in collecting the gas with after-burning, the other - without afterburning. In the first method, CO is afterburnt to obtain CO_2; much heat is here evolved but its amount is, unfortunately, variable. The heat is used in utilization boilers. Fluctuations in the amount of the supplied heat are balanced by additionally firing the boilers with coke or mixed gas. The negative feature of collecting converter gases with afterburning and utilizing are high costs of the installation amounting to 10 - 13% of the whole steelmaking plant. The method without afterburning is cheaper.

The collected gases are stored and used for a variety of purposes. Their calorific power is 8,000-10,000 kJ/m^3. The installation is small in size because only 20% of nonlatent heat is captured as compared to the method with afterburning.

The whole cooling and cleaning system can be relatively small in size since the amount of flue gases is small and their temperature is low. But this system is rather hazardous in view of the fact that an explosive mixture may arise from the leaking gases. In some cases, the flue gases are burnt out in the flare but this is an obviously wasteful approach.

Before being cleaned, the flue gases are cooled in two stages. The first stage includes either a utilization boiler or a tube jacketted boiler, the second stage - scrubbers. Depending on the way of collecting and cooling gases, use is made of different cleaning systems, the most frequent facilities being wet fabric or electrostatic dust collectors.

e. In the production of ferroalloys, the cleaning methods of flue gases are the same as those in electric furnace steelmaking plants, that is, they are cooled and cleaned in fabric filters or electrostatic precipitators. Foam washers are replaced in view of the high hardening tendency of dusts and their unfavourable wetability. Since the emitted dusts are highly commercially valuable, the efficiency of the installation must exceed 99%.

3.2 Water and Its Purification

Sewage is now treated in particular departments of steelworks and in sewage treatment and disposal plants, including general origin sewage in the steel works.

The fundamental method consists in the mechanical removal of suspended matter in sedimentation tanks.

The chemical effluents from coking processes are cleaned by biological methods in layers sprayed with active sediment in oxidation chambers or ditches. In spite of the high reduction (even up to 95%) of phenols, cyanides, rhodantes, etc., the sewage contains, after biological treatment, a great deal of different non-decomposable contaminants and salt.

General effluents from steel plants are cleaned by coagulation with iron salts in multi-functional reactors and this enables the removal of suspensions, oils and part of the organic pollutants (approx. 50 - 60%).

3.3 Working Sites

In the iron and steelmaking industry man at his working site is subject to numerous hazardous effects. And since in the central and Eastern European countries man is an object of a special care, all hazardous working sites are adequately protected. Namely, the production, emission and dispersion of air pollutants at working sites are reduced in their intensity by employing sealed enclosures, local exhaustion devices, gas dedusting and neutralizing installations or, in unfavourable conditions, high stacks are erected to release the pollutants into the high atmospheric strata, and thus, contribute to their dispersing over long distances. In extreme and economically justified instances, stacks may be 400 m high.

A very important factor that is very unpleasant, not only for the workers employed in the iron and steelmaking plant, but also for the residents of the nearby regions, is excessive noise. Noise is prevented from penetrating into residential areas by curtains of tall trees planted around the plant, and by a protective zone. Numerous steelmaking machines and equipment units are fitted with noise suppressing devices. The achievements of a satisfactory situation requires a long time although even now sporadic major successes can be noted in rolling mills, forging shops and other departments. Workers exposed to excessive noise are equipped with ear protection equipment units. Hazardous infrared (heat) radiation is reduced by the use of protective clothing and fast flowing air streams. A very important factor of working conditions in the iron and steel industry is the microclimate characterized by temperature, humidity and air speed. The required parameters of the microclimate are obtainable by the complete air-conditioning of working sites and even whole production workshops. These conditions are, of course, possible in newly erected installations or in old ones that are subject to re-building and modernizing. All staff members employed in the iron and steel industry are subject to routine medical examinations. It should be noted that in all iron and steelmaking plants, the free of charge and widely developed industrial health services take care of the current health condition of the personnel. Sanatoria and rest houses administered by particular iron and steel producing plants are helpful for all staff members in recovering their good health.

4. Regulations and Standards

Man and his environment are protected by the consititutions of particular countries. Regulations describe the quality of air that is necessary for the further development of man and that is unharmful for animals and plants. Legislation in particular countries provides details on the permissible concentrations of air pollutants.

The quality of air is investigated by sanitary institutions and, in some countries including Poland, also by the local administrative organs the so-called environmental protection departments. Apart from that, industrial laboratories test air in the so-called protective zones around production plants. To start the construction of new steel works or plant or to enlarge the existing plants it is necessary each time:

1. To determine the existing background of pollutants (emission) in the atmosphere.

2. To predict the future and emission rate of pollutants, their dispersion and the concentration occurring in space and time for a given production plant.

3. Drawing the lines of equal concentration levels of particular pollutants and their excess in space and time (for a given production plant).

4. Drawing the lines of equal levels of the resultant concentrations (that is the background + new source), their concentrations and excesses in space and time.

It is obvious that this scheme will be modified in a particular country but the principle is similar.

In some cases, the known hazardous coefficients for particular pollutants are utilized to determine one resultant coefficient. The most usual practice is to assume one initial coefficient SO_2 = 1 and then NO_x = 2, dust = 0.1 depending on the degree of harmfulness, etc.

If a newly projected plant does not cause excess of the permissible air pollutants, it obtains permission for its construction, rebuilding, etc.

If a newly projected plant or a department is predicted to exceed the permissible levels of pollutants described by standards, then it must either reduce the emission rates of pollutants from other departments or to modernise the technology.

In water supply, it is the unquestionable principle that the disposed water must not be worse than that admitted to the system. For this reason, water must always be disposed above the admission point from the flow stream. In this way, iron and steel plants must build sewage-treatment installations so as to have water of the required quality. The parameters of effluents are prescribed by regulations and standards.

Regulations require that the workers in the iron and steel plant must be protected against harmful effects at their working site. Observation of these regulations and standards is supervised by sanitary inspection and the trade unions. The measurement of the environmental conditions at working sites are performed by State Sanitary Inspection, specialized laboratories and physicians employed at the plant.

Standards prescribe the requirements related with the highest permissible concentrations and intensities in view of health protection in iron and steelmaking plants.

5. Conclusions

Summing up, it should be stated that the iron and steel industry is one of the more important sources of harmful effects acting on the external environment and the environment of working sites. It is obvious that much can be done in preventing and reducing losses. This is possible by utilization of the experience already collected in particular countries and centres, exchange of information, training activities and informing general public as to the necessary steps to be taken. This does not mean that all possibilities of technology have already been utilized. It is necessary to continue efforts in specialised research and scientific centres.

TABLES

This collection of tables, referred to in the summary are taken from the original report.

Table 11

Dust Emission Rates From Coal Storing Yards

Item No	Type of storing yard	Efficiency of dust arrestment device %	Fugitive convection rate of dust kg/t of coal	Emission rate of dust kg/t of coal
1	2	3	4	5
1	Open storing yard	0	0,8	0,8
2	Pit-type storing yard	0	0,3	0,3
3	Coal bunkers	0	0,2	0,2

Table 12

Dust Emission Rates From Coal Processing Plants

Item No.	Type of enclosure facility, extraction technique of dust laden air and kind of dust arrestment device	Efficiency of dust arrestment device %	Fugitive convection rate of dust kg/t of charge	Emission rate of dust kg/t of charge
1	2	3	4	5
1	Non-enclosed facility	0	1.0	0.1
2	Tightly enclosed facility, no air extracting device	0	0.5	0.05
3	Tightly enclosed facility, air extraction by fan, no dust arrestment devices	0	0.5	0.5
4	Tightly enclosed facility, air extraction by fan, dust arrestment by cyclone	70	0.5	0.15
5	Tightly enclosed facility air extraction by fan, dust arrestment by cyclone and fabric filter	99	0.5	traces

Table 13

Data Concerned With Dust Emission From Charging Machine (Coal Proportioning From Tower and Stamping of Layers)

Item	Type of enclosure equipment, drop height of coal, dust arrester	Efficiency of dust arrester %	Fugitive rate of dust kg/t of charge	Emission rate of dust kg/t of charge
1	2	3	4	5
1	Unenclosed facility, long dropping height	0	0.2	0.2
2	Unenclosed facility, short dropping height	0	0.1	0.1
3	Tightly enclosed facility, short dropping height, no dust arresters	0	0.05	0.05
4	Tightly enclosed facility, short dropping height	80	0.05	0.01
5	Tightly enclosed facility, short dropping height, dust arresters: cyclone and fabric filter	99	0.05	traces

Table 14

Dust Emission Rate From Coking Battery During Oven Charging

Item No.	Oven charging system, exhaust and dust arrestment device	Efficiency of dust arrester %	Fugitive rate of dust kg/t of charge	Emission rate of dust kg/t of charge
1	2	3	4	5
1	Stamped system, no exhaust and dust arrestment device	0	0.9	0.90
2	Stamped system, roof exhaust hood with forced draught and gas combustion	30	0.9	0.63
3	Stamped system, gas extraction by use of steam ejection	80	0.9	0.18
4	Stamped system, gas extraction by fan, dust arrestment in foam washer	90	0.9	0.09
5	As in item 1, gravity system	0	0.6	0.60
6	As in item 2, gravity system	30	0.6	0.42
7	As in item 3, gravity system	80	0.6	0.12
8	As in item 4, gravity system	90	0 6	0.06

x. Under assumption that charging time is 5 min.

Table 15

Dust Emission Rates From Coking Battery During Coke Pushing

Item No.	Type of extraction of dust laden gases kind of dust arrestment device	Efficiency of dust arrester %	Fugitive rate of dust kg/t of charge	Emission rate dust kg/t of charge
1	2	3	4	5
1	No extraction and dust arrestment devices	0	0.1	0.10
2	Extraction and dust arrestment devices mounted on continuously moving carriage, dust arrestment in settling chamber, gas flow forced by natural convection	20	0.1	0.08
3	Extraction and dust arrestment devices mounted on continuously moving carriage, dust arrestment in cyclone, gas flow forced by fan	70	0.1	0.03

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Table 16

Dust Emission Rates From Quenching Tower During Coke Quenching

Item No.	Method of coke quenching kind of dust arrestment device	Efficiency of dust arrester %	Fugitive rate of dust kg/t of charge	Emission rate of dust kg/t of charge
1	2	3	4	5
1	Dry quenching no dust arresters	0	0.01	0.01
2	Wet quenching no dust arresters	0	0.9	0.90
3	Wet quenching wooden baffles installed	60	0.9	0.36
4	Wet quenching spray washer is installed	90	0.9	0.09

Table 17

Data Concerned With Dust Emission From Screening Plant

Item No.	Type of equipment enclosure, extraction technique of dust laden air, dust separator	Efficiency or dust arrester %	Fugitive rate of dust kg/t of charge	Emission rate of dust kg/t of charge
1	2	3	4	5
1	Unenclosed facility	0	1.0	0.1
2	Tightly enclosed facility, no air extraction	0	0.5	0.05
3	Tightly enclosed facility, air extracted by fan, no dust separator	0	0.5	0.5
4	Tightly enclosed facility, air extracted by fan, dust separation by cyclone	70	0.5	0.15
5	Tightly enclosed facility, extracted by fan, dust extracted by cyclone and fabric filter	99	0.5	

Table 18

Data Concerned With Emission of Some Gaseous Pollutants From Coking Battery During Oven Charging

Item No.	Oven charging system chambers, kind of extraction and dust emission control technique	Constituent	Efficiency of emission control technique %	Fugitive rate of gaseous pollutant kg/t of charge	Emission rate of gaseous pollutant kg/t of charge
1	2	3	4	5	6
1	Stamping system, no extracting and control equipment	tar substances	0	0.100	0.100
		aliphatic hydrocarbons	0	0.120	0.120
		carbon monoxide	0	0.040	0.040
		benzene	0	0.007	0.007
		phenol + homologues	0	0.001	0.001
		pyridine + homologues	0	0.001	0.001
		ammonia	0	0.002	0.002
		hydrogen sulphide	0	0.002	0.002
		hydrogen cyanide	0	0.001	0.001
		nitrogen oxides	0	0.010	0.010
		sulphur dioxide	0	0.002	0.002
		chlorine	0	0.001	0.001
2	Stamping system, roof extractor with forced exhaustion and gas combustion	tar substances	30	0.100	0.070
		aliphatic hydrocarbons	30	0.120	0.084
		carbon monoxide	30	0.040	0.028
		benzene	30	0.007	0.005
		phenol + homologues	30	0.001	0.001
		pyridine + homologues	30	0.001	0.001
		ammonia	0	0.002	0.002
		hydrogen sulphide	30	0.002	0.002
		hydrogen cyanide	30	0.001	0.001

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Table 18 continued

1	2	3	4	5	6
		nitrogen oxides	0	0.010	0.010
		sulphur dioxide	0	0.002	0.002
		chlorine	0	0.001	0.001
3	Stamped system gas extraction by steam ejection	tar substances	80	0.100	0.020
		aliphatic hydrocarbons	80	0.120	0.024
		carbon monoxide	80	0.040	0.008
		benzene	80	0.007	0.001
		phenol + homologues	80	0.001	traces
		pyridine + homologues	80	0.001	traces
		ammonia	80	0.002	traces
		hydrogen sulphide	80	0.002	traces
		hydrogen cyanide	80	0.001	traces
		nitrogen oxides	80	0.010	traces
		sulphur dioxide	80	0.002	0.002
		chlorine	80	0.001	traces
4	Stamped system, gas extraction by fan, wet washer and after burning of gas	tar substances	80	0.100	0.020
		aliphatic hydrocarbons	80	0.120	0.024
		carbon monoxide	80	0.040	0.008
		benzene	80	0.007	0.001
		phenol + homologues	80	0.001	traces
		pyridine + homologues	80	0.001	traces
		ammonia	0	0.002	0.002
		hydrogen sulphide	80	0.002	traces
		hydrogen cyanide	80	0.001	traces
		nitrogen oxides	0	0.010	0.010
		sulphur dioxide	0	0.002	0.002
		chlorine	0	0.001	0.001

Under assumption that charging time is 5 min.

Table 19

Data Concerned With Emission of Some Gaseous Pollutants From Coking Battery Over the Whole Coking Process

Item	Kind of Extracting and emission control technique	Constituent	Fugitive rate of gaseous pollutant kg/t of charge	Emission rate of gaseous pollutant
1	None	tar substance	0.360	0.360
		aliphatic hydrocarbons	0.820	0.820
		carbon monoxide	0.255	0.255
		benzene + homologues	0.088	0.088
		phenol + homologues	0.011	0.011
		pyridine + homologues	0.007	0.007
		ammonia	0.028	0.028
		hydrogen sulphide	0.032	0.032
		hydrogen cyanide	0.003	0.003
		nitrogen oxides	0.007	0.007
		sulphur dioxide	0.002	0.002
		carbon disulphide	0.001	0.001
		chlorine	0.003	0.003

Table 20

Fugitive Convection Rates and Emission Rates of SO_2 From Coke Oven Battery When it is Fired

Item No.	Battery firing technique and kind of emission control facility	Efficiency of control facility %	Fugitive convection rate of SO_2 kg/t of charge	Emission rates of SO_2 kg/t of charge
1	2	3	4	5
1	Coke gas firing, no control device	0	2.2	2.2
2	As in item 1, blast furnace gas	0	0.2	0.2
3	Coke gas firing, treated in wet washer	40	2.2	1.32
4	As in item 3, blast furnace gas	40	0.2	0.12

Table 21

Fugitive Convection Rates and Emission Rates of Some Gaseous Pollutants of Coke Oven Battery During Coke Pushing

Item No.	Extraction technique of dust laden gases arrestment device	Description of constituent	Fugitive convection rate of gaseous pollutant kg/t of charge	Emission rate of gaseous pollutant kg/t of charge
1	2	3	4	5
1	No extraction and dust arrestment devices or gas extraction by fan and dry-process dust separation	tar substances carbon monoxide sulphur dioxide	0.010 0.005 0.007	0.010 0.005 0.007

Table 22

Fugitive Rate and Emission Rate of Some Gaseous Pollutants From Coke Oven Battery During Coke Quenching

Item No.	Quenching medium	Constituent	Fugitive rate of gaseous pollutant kg/t of charge	Emission rate of gaseous pollutant kg/t of charge
1	2	3	4	5
1	Industrial water	tar substances	0.010	0.010
		carbon monoxide	0.007	0.007
		hydrogen sulphide	0.030	0.030
		sulphur dioxide	0.015	0.015
2	Coke oven effluents	tar substances	0.010	0.010
		carbon monoxide	0.007	0.007
		phenol + homologues	0.158	0.158
		ammonia	0.114	0.114
		hydrogen sulphide	0.077	0.077
		hydrogen cyanide	0.010	0.010
		sulphur dioxide	0.015	0.015

Table 23

Data Concerned With Dust Emission From the Storage Yard for Charge Materials

Item No.	Operation, type of storage yard and humidity of materials	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Unloading of ore and limestone by means of wagon tippler, moisture content materials approx. 4%	0	0.005	0.005
2	Unloading of ore and limestone by means of wagon tippler, moisture content of materials approx. 8%	0	0.002	0.002
3	Material blending, storing yard is serviced by bridge crane with bucket, materials are intensively water sprayed	0	0.050	0.050
4	Material blending, storing yard is serviced by belt conveyors, materials are intensively water sprayed	0	0.030	0.030

Table 24

Data Concerned with Dust Emission From Equipment for Crushing, Screening and Transporting of Limestone

Item No.	Operation and data on dust arresters	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Transporting raw (lumped) limestone by belt conveyors, no dust arresters	0	0.050	0.050
2	As in item, dust arrestment in foam worker washer	90	0.050	0.005
3	Crushing of limestone in hammer mills, no dust arresters	0	0.40	0.40
4	As in item 3, dust arrestment in foam washer	90	0.40	0.04
5	Screening of limestone through vibrating sieves, no dust arresters	0	0.10	0.10
6	As in item 5, dust arrestment in foam washer	90	0.10	0.01
7	Transporting of milled limestone by belt conveyors, no dust arresters	0	0.30	0.30
8	As in item 7, dust arrestment in foam washer	90	0.30	0.03

Table 25

Data Concerned with Dust Emission From Equipment for Crushing and Transporting of Coke Breeze

Item No.	Operation and data on dust arresters	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Transporting of raw (uncrushed) coke by belt conveyors, no dust separators	0	0.01	0.01
2	Crushing of coke in four-roll crushers, no dust separators	0	0.05	0.05
3	Crushing of coke breeze in four-roll crushers, dust arrestment in multi-cyclone	80	0.05	0.01
4	Transporting of coke breeze by belt conveyors, no dust separators	0	0.03	0.03
5	Transporting of coke breeze by belt conveyors, dust arrestment in multi-cyclone	80	0.03	0.006

Table 26

Data Concerned with Dust Emission From Equipment for Crushing, Screening and Transporting of Iron Ore

Item No.	Operation and data on dust arresters	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Crushing of ore in cone crusher, no dust separators	0	1.40	1.40
2	Crushing of ore in cone crusher, gas arrestment in foam washer	90	1.40	0.14
3	Crushing of ore (siderite) in hammer mill, no dust separators	0	0.70	0.70
4	Crushing of ore (siderite) in hammer mill, dust arrestment in foam washer	90	0.70	0.07
5	Screening of ore, no dust separators	0	0.50	0.50
6	Screening of ore, dust arrestment in foam washer	90	0.50	0.05
7	Transporting of ore by belt conveyors, no dust separators	0	0.20	0.20
8	Transporting of ore by belt conveyors, dust arrestment in foam washer	90	0.20	0.02

Table 27

Data Concerned With Dust Emission From Equipment for Dolomite Crushing and Transporting

Item No.	Operation and data on dust arresters	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Transporting of raw (lumped), dolomite no dust arresters	0	0.01	0.01
2	Crushing of dolomite in hammer mills, no dust arresters	0	0.05	0.05
3	Crushing oi dolomite in hammer mills, gas arrestment in foam washer	90	0.05	0.005
4	Transporting of crushed dolomite by means belt-conveyors, dust arrestment in foam washer	0	0.03	0.03

Table 28

Data Concerned with Dust Emission From Strand Type Sintering Machines

Item No.	Extraction technique for gases and data on dust arrestment devices	Efficiency of dust separators %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Gas extraction from machine and crusher, dust arrestment in multicyclone	65	3.80	1.330
2	Gas extraction from machine and crusher, dust arrestment in multicyclone and electrofilter	99	3.80	0.038
3	Gas extraction only from machine dust arrestment in multicyclone	65	2.20	0.770
4	Gas extraction only from machine dust arrestment in multicyclone and electrofilter	99	2.20	0.022

Table 29

Data Concerned With Dust Emission From Sinter Crushers

Item No.	Extraction technique for gases and data on dust arrestment devices	Efficiency of dust separators %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Gas extraction from crusher, no dust separators	0	0.20	0.20
2	Gas extraction from crusher, dust separation in foam washers	90	0.20	0.02
3	Gas extraction from crusher and sintering machine discharge end	0	0.90	0.90
4	Gas extraction from crusher and sintering machine discharge end	90	0.90	0.09
5	Gases from crusher are directed under strand, pollutant extraction at point at which sinter is discharged from crusher, no dust separators	0	0.10	0.10
6	Gases from crusher are directed under strand, pollutant extraction at point at which sinter is discharged from crusher, dust separation in foam washers	90	0.10	0.01

Table 30

Data on Dust Emission From Sinter Screening by Shaker Screens

Item No.	Conditions of sorted coke, dust arresters	Efficiency of dust separator %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Screening of hot sinter no dust arresters	0	0.60	0.70
2	Screening of hot sinter, dust separation in foam washer	90	0.70	0.07
3	Screening of cooled sinter (after passing through cooler) no prescreening, no dust arresters	0	0.40	0.40
4	Screening of cooled sinter (after passing through cooler), no prescreening, dust arrestment in foam washer	90	0.40	0.04
5	Screening of cooled sinter (after passing through cooler) and after prescreening no dust arresters	0	0.20	0.20
6	Screening of cooled sinter (after passing through cooler), after prescreening, gas arrestment in foam washer	90	0.20	0.02

Table 31

Data Concerned With Dust Emission From Shute During Carrying of Sinter to Wagons

Item No.	Extraction technique of gases, dust arresters	Efficiency of dust separators %	Fugitive rate of dust kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Natural ventilation, no dust arresters	0	0.10	0.10
2	Gas extracted by fan, dust separated in multicyclone	70	0.10	0.03
3	Gas extracted by fan, dust separated in foam washer	90	0.10	0.01

Table 32

Data Concerned With Dust Emission From Belt-Type Cooler

Item No.	Condition of cooled sinter, dust separators	Efficiency of dust separators %	Fugitive rate of dust kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Sinter screening, no dust arresters	0	0.20	0.20
2	Cooling of unprescreened sinter, no dust arresters	0	0.50	0.50

Table 33

Emission Rates of Dust From Reprocessed Sinter Feeders

Item No.	Method of feeding reprocessed sinter data on dust arrestment devices	Efficiency of dust arrester %	Weight of dust generated kg/t of sinter	Emission rate of dust kg/t of sinter
1	2	3	4	5
1	Continuous feeding of wet reprocessed sinter, no dust arresters	0	0.07	0.07
2	Continuous feeding of moistened reprocessed sinter, no dust arresters	0	0.20	0.20
3	Continuous feeding of moistened reprocessed sinter, dust arrestment in foam washer	90	0.20	0.02

Table 34

Data Concerned With SO_2 Emission From Strand Type Sintering Machines

Item No.	Method of gas extraction, data on SO_2 removal equipment	Efficiency of SO_2 removal %	Weight of SO_2 generated kg/t of sinter	Emission rate of SO_2 kg/t of sinter
1	2	3	4	5
1	Gas extraction from sintering machine and crusher, no SO_2 removal equipment	0	1.45	1.45
2	Gas extraction from sintering machine and crusher, SO_2 removal in wet-process Venturi separator	60	1.45	0.58
3	Gas extraction only from sintering machine, no SO_2 removal equipment	0	1.25	1.25
4	Gas extraction only from sintering machine, SO_2 removal in wet-process Venturi separator	60	1.25	0.50

Table 35

SO_2 Emission From Sinter Crushers and Screens

Item No.	Gas extraction point, data on SO_2 removal devices	Efficiency of SO_2 removal %	Weight of SO_2 generated kg/t of sinter	Emission rate of SO_2 kg/t of sinter
1	2	3	4	5
1	Extraction of gases from crusher no SO_2 removal device	0	0.0020	0.0020
2	Extraction of gases from crusher SO_2 removal in foam washer	40	0.0020	0.0012
3	Extraction of contaminants at point at which sinter is poured out from crusher	0	0.0010	0.0010
4	Extraction of gases from hot sinter screen, no SO_2 removal device	0	0.0010	0.0010

Table 36

Emission Rate of CO From Strand Type Sintering Machine

Item No.	Method of gas extraction	Amount of CO generated kg/t of sinter	Emission rate of CO kg/t of sinter
1	Gas extraction from both machine and crusher	5.0	5.0
2	Gas extraction from machine only	5.0	4.0

Table 49

Dust Emission Rates From Open-Hearth Furnaces

Item No.	Capacity of Furnace	Fuel	Process	Data on waste heat boilers and dust arrester	Efficiency of dust arrester %	Average amount of dust in chimney duct kg/t of steel	Average dust emission rate kg/t of steel
1	2	3	4	5	6	7	8
1	185-370	natural gas with fuel oil (30% of supplied heat) oxygen intensification of combustion (20Nm^3/t)	scrap and ore	waste heat boiler is operated, no dust arrester	0	1.75	1.5
2	185-370	as in item 1	scrap and ore	waste heat boilers and highly efficient dust arresters are operated	99	1.75	0.05
3	180-230	fuel oil	scrap	boiler is operated, no dust arrester	0	3.0	3.0
4	180-230	fuel oil	scrap	no waste heat boiler, highly efficient dust arresters are operated	99	3.0	0.03
5	100-130	fuel oil	scrap and ore	no waste heat boiler is operated, no dust arrester	0	3.0	3.0

Table 49 continued

1	2	3	4	5	6	7	8
6	100–130	fuel oil	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	99	3.0	0.03
7	100–130	gas with fuel oil addition	scrap and ore	no waste heat boiler no dust arrester	0	2.9	2.9
8	100–130	gas with fuel oil	scrap and ore	no waste heat boiler, highly efficient dust arresters are operated	99	2.9	0.029
9	100–130	fuel oil	scrap	no waste heat boiler, no dust arrester	0	2.6	2.6
10	100–130	fuel oil	scrap	no waste heat boiler, highly efficient dust arresters are operated	99	2.6	0.026
11	100–130	natural gas with fuel oil (30% of supplied heat) oxygen intensification of combustion (up to 40 nm^3/t)	scrap and ore	no waste heat boiler, highly efficient dust arresters are operated	0	1.9	1.9
12	100–130	as in item 11	scrap and ore	no waste heat boiler no dust arrester	99	1.9	0.019

Table 49 continued

1	2	3	4	5	6	7	8
13	70-100	natural gas with fuel oil (30% of heat supplied)	scrap	no waste heat boiler, highly efficient dust arresters are operated	0	1.4	1.4
14	70-100	natural gas with fuel oil (30% of heat supplied)	scrap	no waste heat boiler	99	1.4	0.014
15	60-100	mixture of producer and coke oven gases	scrap and ore	no waste heat boiler no dust arrester	0	2.2	2.2
16	60-100	mixture of producer and coke oven gases	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	99	2.2	0.022
17	60-80	mixture of producer and coke oven gases with fuel oil addition	scrap	no waste heat boiler no dust arrester	0	1.4	1.4

Table 49 continued

1	2	3	4	5	6	7	8
18	60-80	mixture of producer and coke oven gases with fuel oil addition.	scrap	no waste heat boiler highly efficient dust arresters are operated	99	1.4	0.014
19	50-80	fuel oil	scrap and ore	no waste heat boiler no dust arrester	0	2.0	2.0
20	50-80	fuel oil	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	99	2.0	0.02
21	45-80	producer gas	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	0	3.2	3.2
22	45-80	producer gas	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	99	3.2	0.032
23	50-75	fuel oil	scrap	no waste heat boiler no dust arrester	0	1.5	1.5
24	50-75	fuel oil	scrap	no waste heat boiler highly efficient dust arresters are operated	99	1.5	0.015
25	50-70	producer gas	scrap	no waste heat boiler no dust arrester	0	2.5	2.5
26	50-70	producer gas	scrap	no waste heat boiler highly efficient dust arresters are operated	99	2.5	0.025

Table 49 continued

1	2	3	4	5	6	7	8
27	50-70	mixture of producer and natural gases with tar addition	scrap	no dust arrester	0	2.1	1.8
28	50-70	mixture of producer and natural gases with tar addition	scrap	waste heat boiler and highly efficient dust arresters are operated	99	2.1	0.018
29	50-70	mixture of producer and natural gases	scrap	waste heat boiler is operated no dust arrester	0	1.7	1.5
30	50-70	mixture of producer and natural gases	scrap	waste heat boiler and highly efficient dust arresters are operated	99	1.7	0.015
31	50-70	coke oven gas with fuel oil addition	scrap and ore	no waste heat boiler no dust arrester	0	1.5	1.5
32	50-70	coke oven gas with fuel oil addition	scrap and ore	no waste heat boiler highly efficient dust arresters are operated	99	1.5	0.015
33	35-50	natural gas	scrap	no waste heat boiler no dust arrester	0	1.0	1.0
34	35-50	natural gas	scrap	no waste heat boiler highly efficient dust arresters are operated	99	1.1	1.1

Table 49 continued

1	2	3	4	5	6	7	8
35	25-50	natural gas with tar addition	scrap	no waste heat boiler no dust arrester	0	1.1	1.1
36	25-50	natural gas with tar addition	scrap	no waste heat boiler highly efficient dust arresters are operated	99	1.1	0.011
37	15-40	mixture of producer and natural or coke oven gases	scrap	no waste heat boiler no dust arrester	0	1.7	1.7
38	15-40	mixture of producer and natural or coke oven gases	scrap	no waste heat boiler highly efficient dust arresters are operated	99	1.7	0.017

Table 50

Data on the emission rate of SO_2 from open-hearth furnaces

Item No.	Capacity of furnace	Fuel	Process	SO_2 removal	Efficiency of SO_2 removal	Average amount of SO_2 in chimney duct kg/t of steel	Average emission rate of SO_2 kg/t of steel
1	2	3	4	5	6	7	8
1	100-370	natural gas with fuel oil (30% of heat supplied)	scrap and ore	none	0	0.08	0.08
2	100-370	natural gas with fuel oil (30% of heat supplied)	scrap and ore	wet-process dust separators	40	0.08	0.05
3	180-230	fuel oil	scrap	none	0	0.017	0.17
4	180-230	fuel oil	scrap	wet-process dust separators	40	0.017	0.10
5	100-130	fuel oil	scrap and ore	none	0	0.22	0.22
6	100-130	fuel oil	scrap and ore	wet-process dust separators	40	0.22	0.13
7	100-130	producer gas with addition of fuel oil	scrap and ore	none	0	0.20	0.20

Table 50 continued

1	2	3	4	5	6	7	8
8	100-130	producer gas with addition of fuel oil	scrap and ore	wet-process dust separators	40	0.20	0.12
9	100-130	fuel oil	scrap	none	0	0.13	0.13
10	100-130	fuel oil	scrap	wet-process dust separators	40	0.13	0.08
11	70-100	natural gas with fuel oil	scrap	none	0	0.04	0.04
12	70-100	natural gas with fuel oil	scrap	wet-process dust separators	40	0.04	0.02
13	60-100	mixture of producer and coke oven gases	scrap and ore	none	0	0.11	0.11
14	60-100	mixture of producer and coke oven gases	scrap and ore	wet-process dust separators	40	0.11	0.07
15	60-80	mixture of producer and coke oven gases with addition of fuel oil	scrap	wet-process dust separators	0	0.09	0.09
16	60-80	mixture of producer and coke oven gases with addition of fuel oil	scrap	wet-process dust separators	40	0.09	0.05

Table 50 continued

1	2	3	4	5	6	7	8
17	50-80	fuel oil	scrap and ore	none	0	0.18	0.18
18	50-80	fuel oil	scrap and ore	wet-process dust separators	40	0.18	0.11
19	45-80	producer gas	scrap and ore	wet-process dust separators	0	0.17	0.17
20	45-80	producer gas	scrap and ore	wet-process dust separators	40	0.17	0.10
21	50-75	fuel oil or producer gas	scrap	none	0	0.10	0.10
22	50-75	producer gas or fuel oil	scrap	wet-process dust separators	40	0.10	0.06
23	50-70	mixture of producer and natural gases with tar addition	scrap	wet-process dust arresters	0	0.10	0.06
24	50-70	mixture of producer and natural gases with tar addition	scrap	none	40	0.11	0.07
25	15-70	mixture of producer and natural gases	scrap	none	0	0.07	0.07

Table 50 continued

1	2	3	4	5	6	7	8
26.	15-70	mixture of producer and natural gases	scrap	wet-process dust arresters	40	0.07	0.04
27	50-70	coke oven gas with fuel oil addition	scrap and ore	none	0	0.05	0.05
28	50-70	coke oven gas with fuel oil addition	scrap and ore	wet-process dust arresters	40	0.05	0.03
29	35-50	natural gas	scrap	none	0	0.03	0.03
30	35-50	natural gas	scrap	wet-process dust arresters	40	0.03	0.02
31	25-50	natural gas with tar addition	scrap	none	0	0.06	0.06
32	25-50	natural gas with tar addition	scrap	wet-process dust arresters	40	0.06	0.04

Table 65

Data on the Emission of Gaseous Fluoride From the Electroslag Steel Remelting Process

Item No.	Grade of slag	Weight of Fluoride evolved kg/t of steel	Data on dust separators (x)	Emission rate of fluoride kg/t of steel
1	2	3	4	5
1	A	0.09	NDA WPS	0.090 0.027
2	B	0.24	NDA WPS	0.240 0.072
3	C	0.02	NDA WPS	0.020 0.006

(x)

NDA - No Dust Arresters

WPS - Wet-Process Separators that Arrests Approx. 70%

Table 66

Flow Rate of Waste Gases as a Function of Converter Capacity
(Low Phosphorus Content Pig-Iron With C Content of 4%)

Item No.	Converter Capacity	Approximate duration, min.		Oxygen consumption m^3/min	Flow rate of gases m^3/h	
		refining	all process		average	maximum
1	2	3	4	5	6	7
1	20	10	20	90	9600	13000
2	50	16	38	180	14000	22000
3	75	20	40	220	16500	27000
4	100	23	47	250	19000	33000
5	130	24	50	300	23000	40000
6	250	27	65	350	39000	75000
7	300	28	70	700	47000	100000

Table 69

Emission Rates of Dust From Electric Arc Furnaces Producing FeSiMn

Item No.	Characteristics of furnace and data on dust arrestment devices	Efficiency of dust separator %	Weight of dust emitted from furnace kg/t of FeSiMn	Emission rate of dust kg/t of FeSiMn
1	2	3	4	5
1	Furnace supplied from 2000 kVa transformer, no dust arresters	0	84	84.0
2	Furnace supplied from 2000 kVa transformer, dust arrestment from waste gases in multicyclone	60	84	33.6
3	Furnace supplied from 2000 kVa transformer, dust arrestment from waste gases in foam washer	90	84	8.4
4	Furnace supplied from 2000 kVa transformer, dust arrestment from waste gases in highly efficient dust separators	99	84	0.84
5	Furnace supplied from 5000 kVa transformer, no dust arresters	0	94	94.0
6	Furnace supplied from 5000 kVa transformer, dust arrestment from waste gases in multicyclones	70	94	28.2
7	Furnace supplied from 5000 kVa transformer, dust arrestment from waste gases in foam washer	95	94	4.7
8	Furnace supplied from 5000 kVa transformer, dust arrestment from waste gases in highly efficient separators	99	94	0.9

Table 70

Emission Rates of SO_2 From Electric Arc Furnaces Producing FeSiMn

Item No.	Characteristics of furnace and data on SO_2 removal devices	Efficiency of SO_2 removal device	Weight of SO_2 emitted from furnace kg/t of FeSiMn	Emission rate of SO_2 kg/t of FeSiMn
1	2	3	4	5
1	Furnace supplied from 2000 kVA transformer, no SO_2 removal device	0	1.25	1.25
2	Furnace supplied from 2000 kVA transformer, SO_2 removal in foam washer	40	1.25	0.75
3	Furnace supplied from 2000 kVA transformer, SO_2 removal in Venturi-type separator	65	1.25	0.44
4	Furnace supplied from 5000 kVA transformer, no SO_2 removal device	0	1.35	1.35
5	Furnace supplied from 5000 kVA transformer, SO_2 removal in foam washer	40	1.35	0.81
6	Furnace supplied from 5000 kVA transformer, SO_2, removal in Venturi-type separator	65	1.35	0.47

Table 71

Size Composition of Dust From Electric Arc Furnace Producing FeMn

Item No.	Particle size range µm	Percentage by weight %			
		Charging and melting	slag tapping	metal refining and tapping	average for whole melting process
1	2	3	4	5	6
1	20 - 40	-	28.5	18.0	3.4
2	10 - 20	12.5	9.0	12.0	12.2
3	5 - 10	10.5	29.4	26.5	13.0
4	2 - 5	37.5	17.6	21.5	34.9
5	1 - 2	15.6	6.9	9.5	14.5
6	0.5 - 1	11.1	2.8	5.5	10.1
7	0.2 - 0.5	8.4	4.2	4.7	7.8
8	0.1 - 0.2	3.3	1.4	1.6	3.1
9	0.05 - 0.1	1.1	0.3	0.7	1.0
10	0.05	-	-	-	-

Table 72

Dust Emission From Electric Arc Furnaces Producing FeMn

Item No.	Description	Melting Stage			
		Charging and melting	Slag tapping	Metal refining and tapping	Whole process
1	2	3	4	5	6
1	Waste gas flow rate thousand nm^3/h	33	36	34	
2	Dust concentration in waste gases g/nm^3	0.24	0.09	0.05	
3	Flow rate of dust kg/h	7.92	3.24	1.70	
4	Melting process time, h	1.60	0.35	0.60	2.55
5	Weight of dust emitted, kg	12.67	1.13	1.02	14.82
6	Tonnage of FeMn produced during one melting process	2.50	2.50	2.50	2.50
7	Emission rate of dust, kg/t of FeMn	5.07	0.45	0.41	5.93

Table 73

Emission Rate of Dust From Electric Arc Furnaces Producing FeMn

Item No.	Characteristics of furnace and dust separators	Efficiency of dust separator %	Weight of dust generated in furnace kg/t of FeMn	Emission rate of dust kg/t of FeMn
1	2	3	4	5
1	Furnace supplied from 4500 kVA transformer, no dust arresters	0	6.0	6.0
2	Furnace supplied from 4500 kVA transformer, dust arrestment in multicyclone	65	6.0	2.1
3	Furnace supplied from 4500 kVA transformer, dust arrestment in foam washer	95	6.0	0.3
4	Furnace supplied from 4500 kVA transformer, dust arrestment in highly efficient dust arresters	99	6.0	0.06

Table 74

SO_2 Emission Rates From Electric Arc Furnaces Producing FeMn

Item No.	Characteristics of furnace and SO_2 removal device	Efficiency of SO_2 removal device %	Weight of SO_2 generated from furnace kg/t of FeMn	Emission rate of SO_2 kg/t of FeMn
1	2	3	4	5
1	Furnace supplied from 4500 kVA transformer, no SO_2 removal device	0	0.36	0.36
2	Furnace supplied from 4500 kVA transformer, SO_2 removal in foam washer	40	0.36	0.22
3	Furnace supplied from 4500 kVA transformer, SO_2 removal in Venturi-type dust arrester	65	0.36	0.13

Table 75

Size Composition of Dust From Electric Arc Furnaces Producing FeSi

Item No.	Particle size range µm	Percentage per weight %			
		Furnace supplied from 7500 kVA transformer	Furnace supplied from transformer with power 2 x 7750 kVA		
			Chimney 2.5 x 0.9m	2 Chimneys 4.0 x 1.0m	Total for 3 chimneys
1	2	3	4	5	6
1	20 - 40	-	-	30.1	25.00
2	10 - 20	14.7	-	23.9	19.90
3	5 - 10	17.1	11.4	17.0	16.0
4	2 - 5	27.7	18.0	9.2	10.70
5	1 - 2	15.3	21.5	5.5	8.22
6	0.5 - 1	9.5	17.1	4.3	6.45
7	0.2 - 0.5	8.7	17.3	4.6	6.75
8	0.1 - 0.2	4.2	10.5	3.5	4.52
9	0.05 - 0.1	1.8	4.2	2.1	2.46
10	0.05	0.1	-	-	-

Table 76

Dust Emission Rate From Electric Arc Furnaces Producing FeSi

Item No.	Characteristics of furnace and dust separator	Efficiency of dust separator %	Weight of dust generated in furnace kg/t of FeSi	Emission rate of dust kg/t of FeSi
1	2	3	4	5
1	Furnace supplied from 2 x 7750 kVA transformer, no dust arresters	0	144	144.0
2	Furnace supplied from 2 x 7750 kVA transformer, dust arrestment in multicyclone	70	144	43.2
3	Furnace supplied from 2 x 7750 kVA transformer, dust arrestment in foam washer	95	144	7.2
4	Furnace supplied from 2 x 7750 kVA transformer, dust arrestment in highly efficient dust arresters	99	144	1.2
5	Furnace supplied from 7500 kVA transformer, no dust arresters	0	52	52.0
6	Furnace supplied from 7500 kVA transformer, dust arrestment in multicyclone	60	52	20.8
7	Furnace supplied from 7500 kVA transformer, dust arrestment in foam washer	90	52	5.2
8	Furnace supplied from 7500 kVA transformer, dust arrestment in highly efficient dust arresters	99	52	0.5

Table 77

SO_2 Emission Rates From Electric Arc Furnaces Producing FeSi

Item No.	Characteristics of furnace and SO_2 removal device	Efficiency of SO_2 removal device %	Weight of SO_2 generated from furnace kg/t of FeSi	Emission of rate SO_2 kg/t of FeSi
1.	Furnace supplied from 2 x 7750 kVA trans-former, no SO_2 removal devices	0	1.8	1.8
2	Furnace supplied from 2 x 7750 kVA trans-former, SO_2 removal in foam washer	40	1.8	1.8
3	Furnace supplied from 2 x 7750 kVA trans-former, SO_2 removal in Venturi-type dust arrester	65	1.8	0.6
4	Furnace supplied from 7500 kVA transformer, no SO_2 removal devices	0	8.7	8.7
5	Furnace supplied from 7500 kVA transformer, SO_2 removal in foam washer	40	8.7	5.0
6	Furnace supplied from 7500 kVA transformer, SO_2 removal in Venturi type dust arrester	65	8.7	3.0

Table 78

Size Composition of Dust From Electric Arc Furnace Producing Technically Pure Silicon

Item No.	Particle Size µm	Percentage by weight % (average values for whole melting process)
1	2	3
1	20 - 40	9.8
2	10 - 20	3.6
3	5 - 10	7.0
4	2 - 5	15.9
5	1 - 2	18.5
6	0.5 - 1	16.3
7	0.2 - 0.5	17.3
8	0.1 - 0.2	9.2
9	0.05 - 0.1	2.3
10	<0.05	0.1

Table 79.

Dust Emission Rates From Electric Arc Furnace Producing Technically Pure Silicon

Item No.	Characteristics of furnace and dust separator	Efficiency of dust separator %	Weight of dust generated in furnace kg/t of Si	Emission rate of dust kg/t of Si
1	2	3	4	5
1	Furnace supplied from 3000 kVA transformer, no dust arresters	0	174	174
2	Furnace supplied from 3000 kVA transformer, dust arrestment in multicyclone	65	174	60.9
3	Furnace supplied from 3000 kVA transformer, dust arrestment in foam washer	95	174	8.7
4	Furnace supplied from 3000 kVA transformer, dust arrestment in highly efficient dust arresters	99	174	1.7

Table 80

Emission Rates of SO_2 From Electric Arc Furnaces Producing Technically Pure Silicon

Item No.	Characteristics of furnaces and SO_2 removal devices	Efficiency of SO_2 removal devices %	Weight of SO_2 generated in furnace kg/t of Si	Emission rate of SO_2 kg/t of Si
1	2	3	4	5
1	Furnace supplied from 3000 kVA transformer, no SO_2 removal device	0	1.35	1.35
2	Furnace supplied from 3000 kVA transformer, SO_2 removal in foam washer	40	1.35	0.81
3	Furnace supplied from 3000 kVA transformer, SO_2 removal in Venturi-type arrester	65	1.35	0.47

Table 81

Size Composition of Dust From Electric Arc Furnace Producing FeCaSi

Item No.	Particle Size μm	Percentage by weight, (average values for whole process)
1	2	3
1	20 - 40	-
2	10 - 20	7.5
3	5 - 10	13.6
4.	2 - 5	28.4
5	1 - 2	18.5
6	0.5 - 1	13.5
7	0.2 - 0.5	12.3
8	0.1 - 0.2	4.6
9	0.05 - 0.1	1.6
10	~0.05	-

Table 82

Dust Emission Rates From Electric Arc Furnaces Producing FeCaSi

Item No.	Characteristics of furnace and dust arrester	Efficiency of dust arrester	Weight of dust emitted from furnace kg/t of FeCaSi	Emission rate of dust kg/t of FeCaSi
1	2	3	4	5
1	Furnace supplied from 7750 KVA transformer, no dust arrester	0	197	197.0
2	Furnace supplied from 7750 KVA transformer, dust arrestment in multicyclone	60	197	78.8
3	Furnace supplied from 7750 KVA transformer, dust arrestment in foam washer	90	197	19.7
4	Furnace supplied from 7750 KVA transformer, dust arrestment in highly efficient dust arresters	99	197	2.0

Table 83

SO_2 Emission Rate From Electric Arc Furnaces Producing FeCaSi

Item No.	Characteristics of furnace and SO_2 removal device	Efficiency of SO_2 removal device	Weight of SO_2 emitted from furnace kg/t of FeCaSi	Emission Rate of SO_2 kg/t of FeCaSi
1	2	3	4	5
1	Furnace supplied from 7750 KVA transformer, no SO_2 removal device	0	5.0	5.00
2	Furnace supplied from 7750 KVA, SO_2 removal in foam washer	40	5.0	3.00
3	Furnace supplied from 7750 KVA transformer, SO_2 removal in Venturi-type separator	65	5.0	1.75

Table 84

Size Composition of Dust From Electric Arc Furnaces Producing FeW

Item No.	Particle Size µm	Percentage by weight %			
		furnace starting	thermal silicon reduction	slag tapping	average for whole process
1	2	3	4	5	6
1	20 - 40	-	18.0	-	13.9
2	10 - 20	11.5	12.0	15.5	11.9
3	5 - 10	9.0	13.8	21.7	12.8
4	2 - 5	33.7	30.1	31.4	31.0
5	1 - 2	16.2	12.2	15.9	13.1
6	0.5 - 1	12.6	6.4	7.6	7.7
7	0.2 - 0.5	12.1	5.5	5.8	7.0
8	0.1 - 0.2	4.2	1.5	1.4	2.1
9	0.05 - 0.1	0.7	0.5	0.7	0.5
10	0.05	-	-	-	-

Table 85

Dust Emission Rates From Electric Arc Furnaces Producing FeW

Item No.	Characteristics of furnace and separators	Efficiency of dust separator %	Weight of dust emitted from furnace kg/t of FeW	Emission rate of dust kg/t of FeW
1	2	3	4	5
1	Furnace supplied from 2000 kVA transformer, no dust arrester	0	68	68.0
2	Furnace supplied from 2000 kVA transformer, dust arrestment in multicyclone	60	68	27.2
3	Furnace supplied from 2000 kVA transformer, dust arrestment in foam washer	92	68	5.4
4	Furnace supplied from 2000 kVA transformer, dust arrestment in highly efficient separators	99	68	0.7

Table 86

SO_2 Emission Rate From Electric Arc Furnaces Producing FeW

Item No.	Characteristics of furnace and SO_2 removal device	Efficiency of SO_2 removal	Weight of SO_2 emitted from furnace kg/t of FeW	Emission rate of SO_2 kg/t of FeW
1	2	3	4	5
1	Furnace supplied from 2000 kVA transformer, no SO_2 removal	0	6.8	6.80
2	Furnace supplied from 2000 kVA, SO_2 removal in foam washer	40	6.80	4.08
3	Furnace supplied from 2000 kVA transformer, SO_2 removal in Venturi-type separator	65	5.0	1.75

Table 87

Size composition of dust from electric arc furnaces producing FeCr

Item No.	Particle range	Percentage by weight						
		Furnace supplied from 5200 kVA transformer				Furnace supplied from 3800 kVA transformer		
		charging and melting	refining	metal tapping	average value from all process	charging and melting	metal tapping	average value from all process
1	2	3	4	5	6	7	8	9
1	20-40	27,5	30,0	-	27,1	28,0	23,5	28,0
2	10-20	16,2	9,0	41,0	16,0	11,0	13,0	11,0
3	5-10	27,1	28,0	34,3	27,4	23,0	22,0	23,0
4	2-5	15,3	12,1	13,4	14,7	18,4	18,5	18,4
5	1-2	5,3	9,1	4,3	5,9	8,3	9,5	8,3
6	0,5-1	3,9	6,0	3,2	4,2	6,5	7,1	6,5
7	0,2-0,5	3,5	4,2	2,4	3,5	4,1	5,2	4,1
8	0,1-0,2	1,0	1,3	0,8	1,0	0,6	1,1	0,6
9	0,05-0,1	0,2	0,3	0,6	0,2	0,1	0,1	0,1
10	<0,05	-	-	-	-	-	-	-

Table 88

Dust Emission Rate From Electric Arc Furnaces Producing FeCr

Item No.	Characteristic of furnace (power of supply transformer), grade of ferrochrome produced, dust separator	Efficiency of dust separator %	Weight of dust emitted from furnace kg/t of FeCr	Emission rate of dust kg/t of FeCr
1	3800-5200 KVA, low carbon ferrochrome (FeCr 006-FeCr 015), no dust arrester	0	5.8	5.8
2	3800-5200 KVA - FeCr 006-FeCr 015, multicyclone	65	5.8	2.0
3	3800-5200 KVA - FeCr 006-015, foam washer	96	5.8	0.3
4	3800-5200 KVA - FeCr 006-015, highly efficient dust arrester	99	5.8	0.06
5	3800-5200 KVA - medium carbon ferrochrome (FeCr 025 FeCr 400), no dust arrester	0	9.8	9.8
6	3800-5200 KVA - FeCr 025 - FeCr 400 - multicyclone	65	9.8	3.4
7	3800-5200 KVA - FeCr 025 - 400 - foam washer	95	9.8	0.5
8	3800-5200 KVA - FeCr 025 - FeCr 400 - highly efficient dust arrester	99	9.8	0.1
9	3800-5200 KVA - high carbon ferrochrome (FeCr 650 - FeCr 800), no dust arrester	0	12.5	12.5
10	3800-5200 KVA FeCr 650 - FeCr 800 - multicyclone	65	12 5	4.4
11	3800-5200 KVA - FeCr 650 - FeCr 800 - foam washer	95	12.5	0.6
12	3800-5200 KVA - FeCr 650 - FeCr 800 - highly efficient dust arrester	99	12.5	0.12

Table 89

SO_2 Emission Rate From Electric Arc Furnaces Producing FeCr

Item No.	Characteristics of furnace (power of supply transformer) grade of ferrochrome produced, SO_2 removal device	Efficiency of SO_2 removal %	Weight of dust emitted from furnace kg/t of FeCr	Emission rate of dust kg/t of FeCr
1	2	3	4	5
1	3800-5200 kVA low carbon ferrochrome, no SO_2 removal	0	3.0	3.0
2	3800-5200 kVA low carbon ferrochrome, foam washer	40	3.0	1.8
3	3800-5200 kVA low carbon ferrochrome, Venturi-type separator	65	3.0	1.1
4	3800-5200 kVA medium and high ferrochrome, no SO_2 removal	0	1.0	1.0
5	3800-5200 kVA medium and high ferrochrome, foam washer	40	1.0	0.6
6	3800-5200 kVA medium and high carbon ferrochrome, Venturi-type separator	65	1.0	0.35

Table 90

Size Composition of Dust From Metallic Thermal Furnace Producing FeTi

Item No.	Particle Size µm	Percentage by Weight, %
1	2	3
1	20 - 40	27.60
2	10 - 20	40.70
3	5 - 10	19.15
4	2 - 5	5.65
5	1 - 2	2.35
6	0.5 - 1	2.10
7	0.2 - 0.5	1.75
8	0.1 - 0.2	0.56
9	0.05 - 0.1	0.13
10	to 0.05	0.01

Table 91

Dust Emission rates from FeTi Production Process

Item No.	Production facility and dust arrester	Efficiency of dust separator %	Weight of dust emitted through chimney kg/t of FeTi	Emission rate of dust kg/t of FeTi
1	2	3	4	5
1	Reaction chamber with moving crucible, no dust arrester	0	3.6	3.6
2	Reaction chamber with moving crucible, dust arrestment in multi-cyclone	65	3.6	1.26
3	Reaction chamber with moving crucible, dust arrestment in foam washer	95	3.6	0.18
4	Reaction chamber with moving crucible, dust arrestment in highly efficient separator	99	3.6	0.04
5	Metallic-thermal crucible, stationary or moving, no dust arrester	0	2.5	2.50
6	Metallic-thermal crucible, stationary or moving dust arrestment in multicyclone	65	2.5	0.88
7	Metallic-thermal crucible, dust arrestment in foam washer	95	2.5	0.13
8	Metallic-thermal crucible, stationary or moving, dust arrestment in highly efficient separator	99	2.5	0.03

Table 92

SO_2 Emission Rate From FeTi Production Process

Item No.	Production unit and neutralization device. SO_2 removal device	Efficiency of SO_2 removal %	Weight of SO_2 emitted kg/t of FeTi	Emission rate of SO_2 kg/t of FeTi
1	2	3	4	5
1	Reaction chamber of metallic-thermal crucible, no SO_2 removal	0	0.10	0.100
2	Reaction chamber of metallic-thermal crucible, SO_2 removal in foam washer	40	0.10	0.060
3	Reaction chamber of metallic-thermal crucible, SO_2 removal in Venturi-type separator	65	0.10	0.035

Table 93

Size Composition of Dust Emitted From
Electric Arc Furnaces Producing Corundum

Item No.	Particle size µm	Percentage by weight, %	
		high quality corundum (A)	standard corundum (B)
1	2	3	4
1	20 - 40	29.20	20.80
2	10 - 20	25.40	13.10
3	5 - 10	30.40	26.60
4	2 - 5	6.35	20.70
5	1 - 2	3.10	9.00
6	0.5 - 1	2.80	5.20
7	0.2 - 0.5	2.26	3.79
8	0.1 - 0.2	0.43	0.69
9	0.05 - 0.1	0.06	0.12
10	to 0.05	-	-

Table 94

Emission Rates of Dust from Electric Arc Furnaces Producing Corundum

Item No.	Characteristics of furnace (power of supply transformer), grade of corundum produced, dust separator	Efficiency of dust separator %	Weight of dust emitted from furnace kg/t of corundum	Emission rate of dust kg/t of corundum
1	2	3	4	5
1	1200 kVA - corundum A no dust arrester	0	23.0	23.0
2	1200 kVA - corundum A multicyclone	65	23.0	8.1
3	1200 kVA - corundum A foam washer	95	23.0	1.2
4	1200 kVA - corundum A highly efficient dust arrester	99	23.0	0.2
5	1200 kVA - corundum B no dust arrester	0	34.0	34.0
6	1200 kVA - corundum B multicyclone	65	34.0	11.9
7	1200 kVA - corundum B foam washer	95	34.0	1.7
8	1200 kVA - corundum B highly efficient dust arrester	99	34.0	0.3

Table 95

SO_2 Emission Rates From Electric Arc Furnaces Producing Corundum

Item No.	Characteristics of furnace (power of supply transformer), grade of corundum produced, SO_2 removal	Efficiency of SO_2 removal %	Weight of SO_2 emitted from furnace kg/t of corundum	Emission rate of SO_2 kg/t of corundum
1	2	3	4	5
1	1200 kVA - corundum A no SO_2 removal	0	0.45	0.45
2	1200 kVA - corundum A foam washer	40	0.45	0.27
3	1200 kVA - corundum A Venturi-type separator	65	0.45	0.16
4	1200 kVA - corundum B no SO_2 removal	0	0.52	0.52
5	1200 kVA - corundum B foam washer	40	0.52	0.31
6	1200 kVA - corundum B Venturi type separator	65	0.52	0.18

IMPACT ON THE ENVIRONMENT OF VARIOUS NEW POSSIBLE METHODS TO PRODUCE IRON AND STEEL MATERIALS

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THIRD PART

INTRODUCTION

It has been reported, in a number of meetings (1), books (2) and various papers (3) that "environmental problems are of considerable interest (for the iron and steel industry) and, also, complex and interdisciplinary". It could be added that they are costly and, sometimes, so costly and so difficult to solve that it can be wondered if the so called "classical" iron and steelmaking processes can survive in the long term.

If the growing tendencies to conserve the raw materials and to decrease energy consumption are added the main question becomes:

- How can steel be produced?
  - with minimum quantity of raw materials, specially to avoid wastes and the problem of re-using by-products or co-products;
  - with as little energy as possible, in quantity and quality;
  - with as limited effect as possible on the environment (air, water pollution, noise, etc..);
  - and with the best working conditions for people who will have to operate and maintain the plants.

This was the question put by UNEP within the scope of a survey about the impact on the environment of the iron and steel industry. To answer it, the various methods of producing steel, (existing, being developed, or just being considered), must first be looked at: this is done in the first part of this report.

The second part of this report, attempts to compare the newest methods from the point of view of the environment.

Then, in the third part, a number of concrete cases are given as possible examples.

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FIRST PART

TENTATIVE CLASSIFICATION OF VARIOUS METHODS TO PRODUCE STEEL

I - 1 - PRELIMINARY CONSIDERATIONS

The subject has to be divided in two different problems:

- the production of the necessary grades of metal (iron or steel) which needs a large amount of energy and raw materials and produces many by-products and possible nuisances.

- the transformation of the crude metal (ingots, blooms, billets or slabs) into commercial shapes such as sheets, bars, etc. as needed for further utilization; these operations consume less energy and create less nuisances than the preceding one.

As mentioned before, this part of the report concentrates on the first problem. However, this problem should not be seen only as related to the existing processes, as developed and elaborated as they are, but must incorporate all the possible systems which can be used to produce iron and steel. Figure 1 gives a kind of possible generalized representation of such methods. All the possible systems have, indeed, to be considered, starting from:

- iron bearing materials (iron ore, also scrap and other possible sources)

using:

- necessary energy
- appropriate equipment
- and manpower for:

operation,
maintenance,
control, etc.

producing:

- steel
- with the minimum of by-products and possibly none by suitable recycling
- and avoiding nuisances.

I - 2 - CLASSIFICATION OF THE VARIOUS POSSIBLE SCHEMES TO PRODUCE STEEL

As pointed out by Professor EKETORP (4):

"- the iron is to be reduced from the ore in a selective reduction process. In today's blast furnaces, the very low potential prevalent near the bottom of the shaft causes silicon and phosphorus to be reduced and dissolved into the raw iron. It is thermodynamically quite possible to achieve the reduction of iron oxide with greater precision.

- any materials normally leaving a plant, gas, hot water, slags, dusts, etc., should either be recycled within the processes or leave the plant in such condition that it can be sold at an attractive price. The time of unrestricted dumping of slags and other various and sundry wastes with dubious influences on the environment are over.

- concerning the consumption of energy, the objective is not only achieving a low specific gross consumption, but rather using forms of energy that are relatively cheap and available for a foreseeable future. Besides, it is by no means certain that a low specific energy requirement is optimal. The main point is that the energy used should pass through the chain of processes with a high degree of utilization. The blast furnace requires the world's most expensive fuel - admittedly in moderate amounts - but it also produces the poorest of industrial gases."

Returning to existing processes, they can be figured out in a simplified way in figure 2, where it can be seen that there are:

a) - always two stages in the route from iron ore to steel

b) - and two different kinds of flow sheets:

- the first one, the most classical, is based on a first stage where there are both reduction and melting, often called a reduction smelting process

- the second one, which is now expanding, is based on a first stage which is only reduction in solid state.

On the other hand, possible idealized simple systems are visualised, two basic flow sheets can be designed starting from pure iron oxide and these are given in material balances in figures 3 and 4. They show clearly the minimum amount of reagent (assumed to be pure hydrogen) needed. Table 1 gives the minimum heat required.

I - 3 - TWO STAGE SYSTEMS BASED ON SMELTING REDUCTION

All these systems are briefly described in figure 5 where the main features can be seen:

- the first stage combines reduction with melting of the metal (and of the slag); this system is, thus, based on a smelting reduction process;
- the second stage, starting from a liquid primary metal, can be an oxidizing process, more or less important depending on the reducing potential in the smelting reduction process. If, as in the blast furnace, conditions are strongly reducing, the liquid metal is highly carburized and may have an important content in various metalloids such as Si, P, etc. or metals like Mn, etc.

Therefore, the various possible stages of this system must be looked at more in detail to describe them.

A - General description

Figure 6 gives a general description of such schemes and they can be divided between the two or even three stages described below:

A - 1 - Smelting reduction

From the usual "classical" blast furnace process, a number of existing or possible ways can be listed (see Table II and Table III).

It is outside the scope of this paper to describe such processes in detail but this review shows clearly that these "primary processes" are by far the most important in the whole steel producing system, regarding:

- raw materials consumption, especially, energy.
- gas production with the consequences in regard to possible pollution.

The expression of this in quantitative terms in the material balances is attempted below.

A - 2 - Steelmaking

Starting from liquid hot metal, only oxygen refining processes are considered and figure 7 summarizes these methods which, in round figures

require about 60 Nm^3 oxygen per ton of steel

and produce 70 Nm^3 of primary gases ($CO - CO_2$)

which can lead to various volumes depending of the degree of combustion of these primary gases.

A - 3 - Ladle metallurgy, grading processes

For completeness, mention is made here (as suggested in figure 8) of a separate unit starting from crude steel from the preceeding state to get the exact grade of steel required both for chemical content (C, Mn, Si, O, S, P, etc.) as well as temperature for casting or homogeneity and inclusion content (cleanness).

B - Material and energy balance

To comment more in detail on the various systems, especially the aspects connected with environment (i.e. gas evolution and water consumption) it would be necessary to carry out detailed material and heat balances. A typical example only is given later (see section III). Figure 8 shows schematically the various raw materials to be added and the by-products generated at each level.

I - 4 - TWO STAGE SYSTEMS BASED ON SOLID STATE REDUCTION

Such systems are briefly described in figure 9 and their main features are as follows:

- the first stage is a reduction operation without melting: it is a solid state reduction process which can be called prereduction, reduction, sometimes sponge iron production or, incorrectly, direct reduction (it is not truly "direct" as opposed to the processes described in chapter I - 5; in this case reduction, without melting, has to be followed by another unit operation, i.e. melting and adjustment to required grade)

- the second stage being a melting process is completely different from the one described in the preceeding chapter(I - 3).

A - General description

Figure 10 gives a general description of all these schemes and, as for the preceeding one (see I - 3), they can be divided in the two and even three stages described below.

A - 1 - Solid state reduction

This is what is improperly called "direct reduction" or "sponge iron" processes and Table IV gives, in a simplified way, the references to the main processes existing or being developed.

A- 2 - Steelmaking

In this case, starting from solid metal (with possible preheating), the steelmaking furnace has to be a melting unit. Figure 11 gives a schematic description of the usual processes.

A - 3 - Ladle metallurgy, grading processes

As in the "classical" scheme and as indicated in figure 9, there is a tendency to make a separate operation of this final grading in a different vessel.

B - Material and energy balance

The idealized balance is shown in figure 10 and, comparison with figure 8 shows that even though it is a two-stage process it is a very attractive scheme in that it needs less additions and produces less exhaust gases and by-products than the so-called conventional processes.

Caution is, however, necessary because a number of operations could still be necessary which are not represented on figure 9. To mention some of them:

- some are related to the fact that such high grade ore can be found but more generally it must be produced (natural sized ore or natural pellet ore, pellets, etc...).
  For this reason, some extra concentration steps could be needed... This is not always needed... The same applies to pelletizing.
  These are commented on in section II - 2.

- some other operations are linked with the fact that hydrogen (or other reducing agent) has to be produced and is sometimes not included in the scheme, although the established "direct reduction" processes always include a reforming operation

- large electrical energy supply can be needed and could demand extra power plant.

I - 5 - POSSIBLE "DIRECT" SCHEMES

These correspond to the old dream of making iron or steel directly from iron ore. This looks simple but has to be described with precision the design of such a system is attempted.

The starting point is clear: it is iron ore i.e. oxidized iron. The end product is not so clear; there is, indeed, a possible choice between several alternate possibilities (see Table V):

a) the first one is to produce, as in the scheme covered in the two-stage processes (section I - 3 and I - 4), a primary metal which is not yet a finished product; it is clear that this leads back to the two-stage processes. However, it must be appreciated that if the primary metal, solid or especially liquid, has a chemical composition very near to that of the precise grade of steel needed, the second state will be more of a grading operation:

- in this way, it will be a simplified and less costly operation not giving rise to too many problems regarding the environment

b) the second one is to produce very pure metallic products by processes identical or similar to so-called "direct reduction" processes and starting from very pure iron ores; such products could be used directly i.e. without melting, by technologies similar to those of powder metallurgy.

- in this way, directly finished iron products could be made. The simplification of the scheme leads to a very good situation regarding environment.

c) the last one is to operate only at room or, at least, low temperature to deoxidize iron ores by various methods such as:

- electrolysis

- chemical processing

- biological methods

There are quite a number of possibilities in these fields but the methods are still in the research stage and it is difficult to make any appraisal about their impact on the environment.

In summary, it appears there are quite a number of possible research and development subjects but their outcome is very difficult to predict.

Some of them could lead to a better situation regarding the environment than the "classical processes"; on the other hand, some others could lead to quite different and, possibly, difficult problems due to interaction with chemical reagents or biological methods.

SECOND PART

TENTATIVE EVALUATION OF IMPACT ON ENVIRONMENT OF SEVERAL NEW PROCESSES

II - 1 - PRELIMINARY COMMENTS

What has been said about the metallurgical processes in the first part of this report shows clearly three facts:

- the evolution of the classical method of producing steel in two main stages has led to rather efficient, especially for heat utilization and recovery, and large scale plant; unfortunately, this has also resulted in large scale complicated plants which give rise to a number of issues regarding environment;

- the revolution to produce steel directly from iron ore in one continuous process has not yet taken place and, indeed, it is not clear if such a method can be found and developed in the future;

- in between these, the combination of solid state reduction of iron ores with subsequent melting of this product (sponge iron, prereduced pellets or briquettes etc...) will play a more and more significant role.

As classical processes are covered elsewhere and as it is difficult to comment much on future direct processes, the present evaluation is centered on the combination of:

- solid state reduction of iron ores

- melting of prereduced iron ores

Before commenting on these two unit operations, the first section of this part is devoted to iron ore processing including agglomeration. All these comments will be made primarily from the point of view of the environment.

To analyse these different possibilities, a number of criteria must be used. These are:

- volume of gases evolved which will be indicative of possible air pollution problems; this has, of course, to be modified by taking in account the nature of the gases and their possible contamination by solid or liquid particles.

- volume of used water discharged from the system

- quantities of by products, taking in account the possibilities of recycling

II - 2 - IRON ORE PROCESSING

A first statement has to be made: except for steel produced from recycled scrap (see section II - 4), the whole production of steel originates from iron ores, thus, all constituents of the iron ore as shipped from the mines will be found in the iron and steel plants and will increase the environmental problems with production of gases, dusts, by products etc...

It would, therefore, seem logical to reduce all these constituents (often called the "gangue") as much as possible and leave them at the mine site. For this reason, the first comments are devoted to "superconcentration".

a - Superconcentration of iron ores

It is felt that this will be a growing trend in the future for at least three reasons:

- the first one is that for the "prereduction - melting" route it is a definite advantage to have as little slag as possible in the steelmaking operation: the best way to achieve this is to reduce the gangue content of the feed...

- the second one is that we shall have to rely more and more in the future on low grade ores for other metals as well as for iron; as soon as benefication of iron ores results, as a consequence of this, it is worth while considering superconcentration to decrease the gangue and various impurities content as much as possible; it must be noted that the limits to such an operation are belonging to two different orders:

- the physical nature of the ore and its liberation characteristics regarding the iron oxide

- the economic factors and especially the proposed use of the concentrate

- the third one is, of course, the environmental point of view: this idea of leaving the gangue elements at mine site as much as possible and shipping an iron oxide to the iron and steel plant with the minimum level (depending of physical, metallurgical and economic considerations) of gangue must be emphasised, especially:

- silica or alumina which requires more or less equal amounts of lime and magnesia to be slagged off

- impurities such as sulphur or phosphorus which lead to costly and often polluting operations to deal with in the plants.

b - Pelletizing

With a fine grained concentrate or superconcentrate, the normal way of conditioning is to use the pelletizing process. From the environmental point of view, it seems to lead to a definite advantage over the more conventional sintering process. However, both sintering and pelletizing are developing and improving and there are many considerations in the comparison of these two agglomeration processes.

Table VI gives a schematic comparison between the two processes of sintering and pelletizing. Some comments should be made:

- if higher grade concentrates are used for pelletizing, especially to feed direct reduction processes, than for sinter feed, the ratios of gases and dust per ton of Fe are further improved.

- many constituents of the gases, especially S, F, Cl are dependent of the ore feed; when solid fuel is used, especially for sintering but also sometimes in pelletizing, they can contribute to the S content.

c - Future of agglomeration of iron ores

More generally, it should be considered what physical forms should be aimed at for the iron ores in the future, especially the concentrates or superconcentrates already described. It is clear that shaft furnaces, either blast furnaces or "direct reduction" furnaces, need sized raw materials. Thus, two different problems should be considered.

- what sized materials are needed for shaft furnaces?

- are there any other furnaces to be developed specially avoiding the need of the usual sized feed?

Future of sized feed for shaft furnace

Outside of the two classical processes of sintering and pelletizing, some other possibilities should be mentioned:

- the first one is to use natural sized iron ores and it must be remembered that a rather large tonnage of such products is used, both in blast furnaces and in "direct reduction" shaft furnaces.

- the second one is to develop new agglomeration processes; although there does not appear any bright new schemes, especially for blast furnace feed, there are certainly possibilities with briquetting (either with binder or at medium temperature) for "direct reduction" processes.

Regarding the smelting reduction processes, there are a number of possibilities to avoid the necessity of a very stable, strong, sized feed. A number of researches, mentioned briefly in section I - 3, are aimed at using fine ores directly.

On the other hand, the electric smelting furnaces, although requiring a sized feed, are not so demanding as the blast furnaces as regards strength and physico-chemical characteristics of the feed.

Direct use of fine ores or concentrates:

- either in new smelting reduction processes

- or in solid state reduction processes such as the one using fluidised bed techniques

could replace to some extent the conventional high temperature agglomeration processes and suppress the corresponding pollution problems associated with production of large volumes of waste gas.

II - 3 - SOLID STATE REDUCTION OF IRON ORES

These processes, as described in section I - 4, are not yet very well assessed from the environmental point of view.

An illustration of this is given in figure 12, taken from a study by UNIDO.

a - Simplified schemes

The first point to be made is related to the fact that the limits of the system have to be clearly defined, as some of the problems could well be transferred to other areas!

In fact, this is not entirely absurd and one could envisage restricting the system of iron and steel production to the use of high grade iron bearing materials and treat them with high purity reagents.

As an example, figure 4 shows what could be done by reducing very pure iron ores with pure hydrogen in a theoretical way. This could be a practical way (as we shall see later in section III - 7) if hydrogen were available in the future in large volumes and distributed in pipes through a grid.

However, for the time being, we shall try to assess existing "direct reduction" processes from the point of view of impact on the environment.

b - Assessment of several "direct reduction" processes

As it is not very well appreciated, it should be emphasized that these processes, as they exist now, are replacing both coke ovens and blast furnaces. They are indeed:

- starting from a primary fossil fuel, especially natural gas for the main existing processes but also from fuel oil or coal for some processes.

- converting it to a suitable reagent, if necessary, usually by reforming

- reducing the iron ore to sponge iron, prereduced pellets or briquettes stage.

Material and energy balances have been published and are given as a typical example in section III - 3. Figure 13 shows some typical gas based reduction processes stand from the environmental point of view.

Table VIIa gives a number of figures for two processes i.e. MIDREX and ARMCO, regarding exhaust gases and dust and also more generally all dust emission from such plants.

Table VIIb gives similar data about effluent water and noise.

A number of remarks can be made:

- waste gases are always the exhaust gases from the reformer unit; all the process gases are recirculated and the excess is used as fuel for the reformer unit; waste gases appear fairly clean

- particulate emission is small

- noise level looks reasonable at least at some distance from the compressors which are the main source of noise

Regarding coal-based direct reduction processes, figure 14 and Table VIII (related to the Krupp process) show how they compare with gas-based processes. The main differences, as might be anticipated, are:

- virtually no water pollution: water is used mainly as spray water and evaporates as steam at the external cooling of sponge iron

- but, conversely, a more difficult problem associated with gases and dust

II - 4 - MELTING OF PRIMARY METAL

As indicated in the first part, especially section I - 4, this is practically always made in electric arc furnaces. Environmental problems associated with this type of furnace are the subject of many studies and are not summarized here. Comment should be made on the fact that in the future:

- all the growing recovery of scrap will be melted in this way

- this will be enhanced by the melting of a large part of the "sponge iron" or other reduced iron ores produced in growing tonnages in the world

This explains why world electric arc steelmaking capacity is now growing from say 100 Mt/year to 200 Mt/year in the near future.

a - <u>Improvements of the electric arc furnace</u>

It is not intended to comment here on what is considered as the classical improvements of the electric arc furnace, as it now exists, from the point of view of environmental control and management. It might be noted however that a number of metallurgical research and development studies could lead to a better situation of this process regarding the environment. Among such studies, we can list:

- continuous operations beginning to become "classical" for the charging of sponge iron but perhaps extending in the future to the continuous tapping in a grading furnace or ladle

- direct current operations

- better control and automation of the process, etc...

b - <u>New methods of melting a primary metal</u>

However, beyond improvement of the classical arc furnace, it may be possible to devise other melting processes and furnaces. Other possible examples are:

- induction furnaces

- oxygen-liquid (or gaseous) fuel furnaces

- plasma furnaces
  etc...

It is not at all clear if such processes will improve the situation regarding the environment: they will, at least, raise different problems and could lead to different solutions.

THIRD PART

SURVEY OF A POSSIBLE SCENARIOUS

III - 1 - INTRODUCTION

After describing the metallurgical processes and their environmental implications, the wider issues can be discussed in terms of:

- space i.e. in the different regions of the world
- time i.e. according to the necessary delays in developing new processes (and sometimes in creating them at the basic research level)

It is clear that, in contrast with the situation of the iron and steel industry in the first half of the century, a single universal process line is no longer applicable for the whole world. Indeed in the past everybody (just a few countries at the beginning of the century) was using a single flow sheet which has, schematically, evolved along the lines of figure 15.

Later, as mentioned before, two other schemes, along or in combination, have been developed:

- the ones based on "direct reduction" or the so-called sponge iron processes
- the mini-steel plant concept.

Needless to say, the so-called "classical schemes" described in the first part of the review will still be used in the future, especially in areas where energy supply is adequate. Thus, these will be considered first before coming to "direct reduction" and mini-steel plant.

Three other possible cases will be considered later concerning:

- the tropical countries

- the use of large amounts of electrical energy

- the possible utilization of hydrogen

III - 2 - FUTURE EVOLUTION OF THE CLASSICAL IRON AND STEEL PLANT (blast furnace and oxygen converter)

As already indicated, such plants, especially very large plants of that kind will continue to exist and develop particularly for flat products (sheet and strip).

III - 2 - 1 - Main hypothesis for this case

Such plants are not critical from the point of view of the grade of iron ore and, although they operate better with high grade iron ores, they could be designed for medium or even low grade ores.

The main point concerns energy, as shown in more detail below in that they mainly use coking coal as an energy supply. Thus such plants can be built:

- ~~either in areas where there is plenty of coking coal (see as an example)~~ world coal resources of figure 16 and Table IX

- or in a sea coast location, such as many Japanese or West European plants where coking coal can be imported in the cheapest way.

III - 2 - 2 - Features of the large "classical" iron and steel plants

The "classical" flow sheet was described earlier (see especially Part I - 3), and comments here are limited to:

- material and energy. Tables X and XI are given as an example (without the coking plant, unfortunately, from the IISI study about energy in the Steel Industry (5)).

- scale of operations. The most efficient way is to build very large plants in the range of 10 to 20 Mt/year.

III - 2 - 3 - Main issues regarding the environment

As is very well known, such large plants give rise to many issues regarding the environment. As this is covered by another report to UNEP it is sufficient here only to emphasize the point that great improvements can be made, at a cost of course, as has been demonstrated in a number of plants, especially in Japan.

A recent report at the ROMA 1977 IISI Conference (6) shows, as an example, how many by-products, dust, sludge, etc. can be recovered (see figure 17 and Table XII).

III - 3-FUTURE EXPANSION OF THE IRON AND STEEL PLANTS BASED ON "DIRECT REDUCTION" PROCESSES

The so-called "direct reduction" processes are developing in a way which can be illustrated by the data in Table XIII and figure 18. Although this is still relatively small, expansion is fairly fast. Within ten or fifteen years, 100 Mt of Fe could be produced by these processes.

Such processes can use different kinds of iron ores but, for the efficient operation of the steelmaking furnaces using "directly reduced" iron ores, they have, practically, to operate with high grade natural ores or concentrates. This is not thought to be a severe limitation and could even be looked on as an operational trend in that iron ores would be increasingly beneficiated at the mine site in the future. This would tend to decrease the problem raised by the by-products or co-products as shown in the first part of this survey.

It looks quite appropriate to produce, at least when it is not too difficult, a concentrated iron ore with as little gangue as possible from the mines.

III - 3 - 1 - Main hypothesis for this case

As previously indicated, the major expansion, at least in the short or medium term, is for gas-reduction processes established or being developed. Thus, the main development will be made in gas and oil rich countries, such as those indicated on figures 19 and 20. A look at Tables XIV and XV gives confirmation of this.

However, development could also be anticipated in areas where imports of gas are easy and relatively cheap. In the more distant future, such processes could use gases produced either from solid fuels or from water (hydrogen).

Considering the longer term future again, there is a probability that there will be further developments regarding coal based reduction processes, due to the large amount of coal reserves in many countries of the world.

III - 3 - 2 - Features of the "direct reduction" - based iron and steel plants

From the principle of such processes and such flow sheets (see first part of this survey) several possible cases arise:

- the first one is the "merchant" direct reduction plant i.e. selling the product to distant steel plants; as example, HIB and FIOR plants of Venezuela are delivering their products either to steel plants in Venezuela or shipping them overseas

- the second one is the integration, partial or total, of a ministeel plant such as those described in the following part (III - 4). Such is the case of HAMBURGERSTAHLWERKE (Federal Republic of Germany) or PUEBLA (Mexico)

- the third one is the medium or large size plant based on "direct reduction".

This is a growing trend with larger plants such as :

SIDBEC at CONTRECOEUR (Canada) for 1 Mt/year

NISIC at AHWAZ (Iran) for about 2.5 Mt/year

SIDOR at MATANZAS (Venezuela) for about 4 Mt/year

and a number of similar projects especially in gas-rich areas.

As previously mentioned, such plants are, practically, restricted to the use of high grade natural ores or concentrates as otherwise, operations of the subsequent electric arc steelmaking shops would be complicated and far more expensive due to the excessive amount of slag.

In regard to energy, the IISI study (5) can be quoted which gives average data for such a plant in two tables (see Tables XVI and XVII).

III - 3 - 3 - Main issues regarding the environment

Compared to a "classical" plant of the same size, such "direct-reduction-based" plants have a definite advantage from the fact they have eliminated coal and coking plants, at least for those which are using processes starting from gas.

As far as is known, the complete comparison of the whole flow sheets has not yet been made, regarding:

- total volume of gases

- dust content and analysis of these exhaust gases

- water consumption and effluents

- noise, etc...

However, taking in consideration all that has been done over a long time to improve the situation for the classical steel plants, it is noticeable that the direct reduction plant, especially those based on natural gas or fuel-oil, are developing with a number of favourable features regarding the environment. For example:

- they are using a smaller quantity of raw materials (high grade iron ores, no fluxes at the reduction stage, no ash ....) per ton of liquid steel

- they tend to decrease the environmental problems at the plant site by placing some operations at the mine site (concentration, especially super-concentration and, possibly pelletizing when needed).

- they are producing an intermediary product ("sponge iron", or directly reduced iron in lumps, pellets or briquettes) which is solid and easier to handle than liquid pig-iron ("hot metal").

III - 4 - FUTURE OF THE "MINI-STEEL PLANT"

The first thing to do when coming to this subject is to define it. As pointed out in a number of recent papers (7) (8), the concept of "mini-steel plant" is not clear and can for example cover:

- a small scale plant using scrap in electric furnaces and producing bars of similar "merchant" products (small profiles)

- a medium scale plant again using scrap in electric furnaces and producing more sophisticated products (wire rod, pipes, even strip or plates)

- or in theory at least any type of small plant designed to produce one single product efficiently or, at least, a very limited range of products.

From this last definition, it is possible to conceive different types of mini-steel plants and indeed this has actually been done, for example:

- those based on a small coke blast furnace like ELFOULADH in Tunisia

- those covered later (para. III - 5) using charcoal.

III - 4 - 1 - Main hypothesis

The "classical" mini-steel plant (i.e. the one based on scrap and electric arc furnaces) especially suited for developed areas where:

- a lot of steel products are being used, leading to a large local supply of scrap; it should be added that there is a real need to dispose of this scrap...

- a market exists for bars (and also the "merchant" products).

However, due to its size and the limited requirement in terms of investment costs and energy supply, it is often considered and built in developed areas. The market of such an area appears specially adapted, in tonnages and product-mix for such a plant. As one can imagine, the main problem is the supply of scrap which will often be inadequate. To solve it, there are only three solutions:

- import it from industrialized countries with all the risks of the cost and ofthe difficult supply at certain periods

- replace it by sponge iron which leads back to the solution described in para. III - 3

- design a mini-steel plant based on local raw materials such as the one described later (para. III - 5)

III - 4 - 2 - Main features of the mini-steel plants

Considering the "classical mini-steel plant" based on scrap and electric furnaces, it should be emphasized that they are simple and cheap plants compared to the integrated plants described previously.

Again, there is the advantage of using scrap which is a metal and has only to be melted to produce steel without any energy (and reagent) requirements for the reduction.

Regarding material and energy balances, Tables XVIII and XIX show from the same IISI study (5) how they appear, and they can be compared to those mentioned previously for large integrated classical plants (para. II - 2) and direct reduction (para. II - 3) on figures 21 and 22. Although all the data can be discussed, scrutinized and modified, the conclusion is very clear: such mini-steel plants use far less raw materials and energy than the integrated plants.

III - 4 - 3 Main issues regarding environment

From what has been said, it is clear that the mini-steel plants are giving rise to only limited problems regarding the environment. We can mention:

- a first advantage arising from the fact that, by definition, mini-steel plants are small, compact and handle limited amounts of materials

- a second advantage coming from the fact that scrap needs no reagent (as it is already a metal) and limited amount of fluxes for melting and slagging off the gangue materials

The main problems will come from the electric furnace where there are:

- limited, but, however, unavoidable gas emissions with dusts, especially containing metalloids or non-ferrous metals incorporated in scrap

- noise problems associated with the arc.

III - 5-POSSIBLE IRON AND STEEL SYSTEMS IN TROPICAL COUNTRIES

In this case, a number of tropical and subtropical countries are considered which can be characterized by rainy seasons which lead to:

- agricultural possibilities
- hydroelectric power

It must be remembered that such activities are directly related to solar energy and hence represent renewable sources of energy.

Examples of such cases are a number of Latin American countries including part of Brazil, Argentina, Bolivia, Paraguay, Uruguay etc...
In Africa, a number of the Western, Eastern and Central parts of the continent, and in Asia and the Far East many areas in Thailand, Malaysia, Philippines etc...

The world capacity of pig-iron production through the use of charcoal is around 4 Mt/year as it is indicated in table XX.

In the case of Brazil, the anticipated development is shown on table XXI.

III - 5 - 1 - Main hypothesis for this case

A number of agricultural products, mainly from forest trees, can be used to produce a kind of solid carbon product, such as charcoal which could be the main energy source. This is the case of:

- many forest trees as currently being used, mainly in Brazil
- planted trees such as eucalyptus (or, maybe, other kinds like ipil-ipil) as, again in Brazil
- rubber trees like in Malaysia
- nuts such as the one from Babacu currently under study in northern Brazil.

In addition, hydroelectric energy could be produced and be available.

III - 5 - 2 - Possible Iron and Steel Systems

From what has been said in regard to

- primary energy as - charcoal
  - hydroelectrical energy
- various iron ore resources

there are three basic flow sheets as shown in figure 23.

- flow sheet 1 (charcoal blast furnace)

- flow sheet 2 (charcoal electric smelting furnace) which can use medium and even low grade iron ores

- the flow sheet 3 (charcoal rotary kiln) needs high grade ore, not for the process itself but for an efficient use of the subsequent electric arc furnace

On the other hand, there are differences, as indicated in figure 24 in the quantity and nature of energy used. It may be added that the blast furnace is, of course, due to the shaft, requiring more regard to be given to the mechanical strength of charcoal.

Considering the possible scale of such plants, there are not too many problems from the technological point of view as charcoal blast furnaces and electrical smelting furnaces are currently built; up to 600 and 300 t/day respectively. Units are being built or designed for the 1000 t/day capacity. In this connection we can mention the Monlevade plant of the Cia Belgo Mineira (Brazil) which has a capacity exceeding 500000 t/year (9) (10).

The main problem is the supply of charcoal which may be subdivided between

- the large area needed to produce the wood which leads to problems of logistics in transporting of wood or charcoal

- the choice between various types of furnaces to produce charcoal. Table XXI and figures 25 to 29 show a number of examples.

III - 5 - 3 - Main environmental issues

The most important issue is related to ecology and the practical possibility of producing sufficient carbon from the specific areas, taking into consideration:

- the land requirements for other uses, such as food or other agricultural products

- the logistics of production, carbonisation and transportation of the wood and charcoal (or similar products).

III - 6-POSSIBLE IRON AND STEEL SYSTEMS BASED ON ELECTRICAL ENERGY

This is the case where electrical energy is plentiful:

- either from hydroelectric power, which is a variation on the preceding theme but where hydro-power is more abundant than the case of tropical countries; the Northern countries, such as Canada or Norway, could be examples.

- or from another generating system such as nuclear electric power.

In this context direct use of electrical energy is referred to; the use of nuclear heat or of derived products (by electrolysis or thermal cracking) such as hydrogen will be covered in the next chapter.

III - 6 - 1 - Main hypothesis for this case

It is assumed that there is a large supply of electrical energy at a low cost, i.e. a relatively low cost compared to fossil fuels.

However, as will be seen in the following section (III - 6 - 2) this situation can be associated with many different contexts. The following can be mentioned as possible examples:

- areas (like in several equatorial or tropical countries) where there is large hydro-electric potential. Again, this could be associated with various resources of fossil fuels

- areas where large scale production of electrical energy, by one way or another (conventional thermal power generation or nuclear or any other future new methods) is intended to be developed and made available.

III - 6 - 2 Possible iron and steel systems

In this case, it is logical to try and design systems incorporating maximum usage of electrical energy. However several possible situations could arise depending of the supply of iron values: (14).

- in a developed industrial area there will be plenty of scrap and its recycling will be useful and necessary

- in some other areas there could be high grade iron ores (i.e. natural high grade ores or high grade concentrates from lower grade ores)

- in still different places, there could be local low grade iron ores, difficult (or expensive) to concentrate.

Three different kinds of systems according to such situations can be envisaged:

a) the first one will again be the mini-steel plant described previously. There are also some possibilities of using electrical energy to reheat the semi products, billets and especially slabs (see Table XXIII) and, in this way, it could be quite possible to design such a mini-steel plant or even a medium size plant utilizing only electrical energy. It could be assumed that with around 1000 kWh, it is possible to produce one ton of steel, in rolled product, from scrap.

b) the second one will be the direct reduction plant connected with electric arc steel making as described previously. But here, fossil fuels are required at least for the time being and the various solutions have been mentioned in the chapter III.

Looking to the future, there is another solution in that with an ample supply of cheap electrical energy, it is possible to product hydrogen by electrolysis.

c) the third one will be based on the low shaft electric smelting furnace briefly described previously. But, again, a reducing agent is required which can be:

- either a fossil fuel, coal or, more frequently coke

- or charcoal which is the most interesting possibility for equatorial and tropical countries (see chapter III).

III - 6 - 3 - Main issues regarding the environment

Such schemes look very attractive in that use of electrical energy means a "clean energy". Compared to fossil fuels, this means no gases (or less gases) so less problems of air pollution. It explains, in part, development of a number of processes already mentioned such as:

- electric arc furnace

- use of electrical energy in reheating furnaces especially for slabs.

However, such developments and further development of other processes such as electric smelting or completely new methods such as electrolysis of iron ores can only take place if:

- firstly cheap and abundant electrical energy is available on a long term basis

- secondly problems of generating electrical energy especially the environmental aspects, are not larger than the ones associated with more conventional iron and steel making processes.

III - 7-POSSIBLE IRON AND STEEL SYSTEMS BASED ON HYDROGEN

Coming to this case, it is necessary to try and predict what the consequences of the so called "Hydrogen Civilization" (the subject of a number of researches and congresses (11) (12) (13)) might be to the iron and steel industry.

III - 7 - 1 - Main hypothesis for this case

It must be clear, as a first comment, that the main types of nuclear reactors already built and in operation can only produce electrical energy (and, possibly, steam).

So, for the iron and steel industry, the present state of nuclear industry can only provide an ample supply of electrical energy: this is only a special situation in the general case where the iron and steel industry is to be based on electrical energy (III - 6).

It must, anyhow, be remembered that there is always the possibility of producing hydrogen by electrolysis of water and even, at the present stage of development of nuclear reactors, some hydrogen could be generated and this could constitute the beginning of large scale hydrogen utilization.

However, if high temperature nuclear reactors are considered, there are additional possibilities:

As soon as nuclear heat (generally in the form of hot helium under pressure) is generated at 700°C and preferably, 800, 900°C (or more...), it can be used in processes to produce reducing gases

- either from solid, liquid or gaseous fossil fuels

- or even, through complex cycles, from water.

It must also, be emphasized that hydrogen is not necessarily linked with nuclear energy produced by one type, or another, of nuclear reactor. It could be produced:

- by electrolysis, as already indicated, from any source of electrical energy, hydroelectricity, solar energy, etc...

- from fossil fuels

- from "biomasses" or any agricultural products or by products.

III - 7 - 2 - Possible iron and steel systems

These have been described in a number of conferences and publications.

As possible examples, the following two flow sheets might be mentioned:

- figure 30 which shows from the now classical route of direct reduction steelmaking (figure 31) how a high temperature nuclear reactor can be associated to produce reducing gas; in practical terms, this gas will be hydrogen and could be produced at some distance (from a few kilometres to even more distant locations), and even feed a grid where ironmaking could be one of many users

- figure 32 which indicates a close association of the high temperature nuclear reactor with the ironmaking facilities. The thermal efficiency of the whole system would be very much improved but there are complications of difficult problems due to the necessity of using tight regulation and security procedures for the whole nuclear reactor - ironmaking complex. It can, however, be pointed out that the steelmaking facilities and the rolling mills can be located at some distance and need not be closely associated.

Returning to the first case (figure 30) it must be emphasized again that the iron and steel plant is entirely separated from the hydrogen-producing plant.

In other words, from the point of view of iron and steel industry, it is an easy solution to get energy supply through a hydrogen grid (at least, if this hydrogen is available in large quantities at reasonable cost) and the way this hydrogen is produced, does not matter...

III - 7 - 3 - Main issues regarding the environment

This case illustrates one of the most controversial issues:

- on one hand, hydrogen-based iron and steel plant could lead to simpler problems regarding the environment due to low amount of feed gas (and thus exhaust gases)

- on the other hand, production of hydrogen with the complex high temperature nuclear reactor and heat exchangers raises a number of well known problems. It can be wondered, if that part of the scheme is not raising more problems than the use of hydrogen in the iron and steel industry solves.

CONCLUSIONS

From this survey, it seems that a number of conclusions can be drawn and these are listed as follows.

1 - From the past, it is apparent that the iron and steel industry is continually changing and evolving, especially in regard to the main processes. It can thus be expected that this trend will continue and that there will be a number of processes and routes available to produce steel from the various iron ores available.

2 - However, no real direct and continuous single process has yet been devised and "direct steel" is still a dream...
On the other hand, it is difficult to predict the results of research in progress and maybe, some day a new revolutionary way of producing steel could appear...

3 - Anyway, account must be taken of the long delay needed to develop a new process and to expand it to the large scale of operations of the iron and steel industry in the world. Although this is certainly going faster and faster, account has to be taken of this delay which can be very well illustrated by the development of say, "direct reduction", oxygen steel-making or continuous casting.

4 - Furthermore, a new dimension is gradually coming clear: the same route and the same processes do not apply everywhere in the world: this is the regional approach mentioned in the last part of this report. It is likely that different processes and different plants will be found in the future in the various parts of the world; this will of course be linked with:

- the market for the miscellaneous steel products

- and especially, the various iron ores and energy supplies.

5 - Then, one might predict that the iron and steel industry will be more and more, associated with other industries and will not be considered isolated from the whole industrial and even agricultural context. Outside of the well known link with "downstream" industries (i.e. using the steel products) the growing association must be emphasised with the "energy" industry, mainly the coal industry but, also, now oil and gas, hydroelectricity and, in the future, nuclear energy, hydrogen production, forest and agricultural activities, etc...
This is a very important aspect regarding the environment as it shows the implications especially when some activities are transferred from one industry to another.

6 - As a last conclusion, it must be stressed that predictably there is no single solution solving all the problems associated with the environment: each route, each process have advantages and disadvantages. Some have less impact on the environment but they have other implications regarding sources oi energy or types of iron ores which are needed.

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LIST OF TABLES

Table I

MATERIALS AND ENERGY NEEDED FOR A SIMPLE "TWO STAGE" IRON AND STEELMAKING SYSTEM

(see figure 4)

per ton of liquid Fe

Pure iron oxide (supposing Fe_2O_3)		1 430 kg
Hydrogen	or	51 kg 571 Nm^3
Energy		
for the reduction stage	or	206×10^3 kcal 239 kWh
for the mel:ing stage	or	320×10^3 kcal 372 kWh

Note: all these figures are theoretical and do not take in account any yield, heat efficiency etc...

Table II

CLASSIFICATION OF IRONMAKING PROCESSES

PROCESS	IN COMMERCIAL UNIT		IN PILOT PLANT OR RESEARCH SCALE
Blast Furnace	large scale coke blast furnace	(world capacity around 600 Mt/an)	
	charcoal blast furnace	(world capacity around 5 Mt/an)	
	low shaft blast furnace	(has operated on small scale plants)	
Electric Pig Iron Furnace		(world capacity around 5 Mt/an)	possible development with: - preheating) of - prereduction) charge - utilization of gas for prereduction
Rotary Kilns	Have been used or tested: - cement/iron kilns (BASSET, SMIDTH) - STÜRZELBERG - DORED (see below)		
Smelting Reactors			new processes being proposed or tested (see Table III)

Table III

VARIOUS NEW SMELTING REDUCTION PROCESSES

PRINCIPLE	STAGE OF DEVELOPMENT
Carbon based without electrical energy	
- EKETORP in static reactor	small pilot plant
- in rotary kilns or reactor:	
- DORED	pilot plant
- ROTORED	pilot plant
- BOUCHET	small commercial plant
Carbon based with electrical energy	
- UD	pilot plant
- plasma	lab and pilot plants
Hydrocarbon based	
- jet smelting	pilot plant

Table IV

CLASSIFICATION OF SOLID STATE REDUCTION PROCESSES

PROCESS	IN COMMERCIAL UNITS	IN PILOT PLANT OR RESEARCH SCALE
GAS REDUCTION		
Shaft Furnace (continuous or batch processes)	H y L (3 Mt/year) MIDREX (3 Mt/year) PUROFER (2 units) ARMCO (1 unit)	1 ROMANIA 2 U.S.S.R. etc.
Fluid Bed Processes	FIOR (1 unit)	NOVALFER
Rotary Kiln Processes	ACCAR (1 unit)	
CARBON REDUCTION		
Saggers in stationary furnaces	HOGANAS (2 units) RIVERTON (1 unit)	U.S.S.R. CHINA
or tunnel kiln	OXELOSUND (1 unit)	
Shaft Furnace	KINGLOR METOP (1 unit)	
Rotary Kiln	SL/RN (several units) KRUPP (1 unit)	

1 - expanding to about 10 Mt/year

2 - expanding to about 10 Mt/year

Table V

POSSIBLE CLASSIFICATION OF DIRECT PROCESSES TO PRODUCE LIQUID OR SOLID IRON

	high temperature processes to produce liquid metal		medium temperature processes to produce solid metal	low temperature processes to produce solid metal		
	reactor with fossil fuels or hydrogen	reactor with electrical energy	application of solid state reduction processes	electrical methods	chemical methods	biological methods
TYPES			practically all so called "direct reduction processes"	electrolysis - in solution (iron salts) - pulps (iron ore slurry)	leaching at low or medium temperature with Cl, S, etc.	reduction with bacterias
REMARKS	it seems there is a need of a second stage as "nuanceur" or grading furnace		need of specially pure iron ores practically iron oxides without gangue -------- iron powders	existing on small scale for solutions (iron sulphates or chlorides)	not yet developed up to metallic stages	not yet developed

Table VI

SCHEMATIC COMPARISON BETWEEN SINTERING AND PELLETIZING REGARDING IMPACT ON THE ENVIRONMENT

	SINTERING	PELLETIZING
Exhaust gases Nm^3 per ton of product process gases cooling gases	 2000 Nm^3 1800 Nm^3	gas from firing 1500 Nm^3 gas from cooling 1300 - 1800 Nm^3
Dust in exhaust: process gases cooling gases	 1000 mg/Nm^3	 500 - 800 mg/Nm^3 <200 mg/Nm^3
Composition of exhaust gases: CO	1% CO	no CO
S	300 - 1500 mg S/Nm^3	from 0 to 1000 mg S/Nm^3 depending of fuel
F Cl	depending of the ore feed	
NO_x	0 - 200/300 ppm	0 - 200/300 ppm

Table VI a

MAIN EXHAUST GASES EFFLUENT WATER AND SOLIDS FROM TWO GAS-BASED "DIRECT REDUCTION" PROCESSES

	MIDREX	ARMCO
exhaust gases	around 3000 Nm^3/t Fe	around 3200 Nm^3/t Fe
temperature	around 400°C	——
composition	12.9% CO_2 4.0% O_2 65.7% N_2 17.4% H_2O no NO_x no S	—— —— —— —— no NO_x no S
dust	around 4 mg/Nm^3 or 12 g/t Fe	around 30 mg/Nm^3 or 100 g/t Fe
particulate emission		
total	3 to 5 t/h for a 400000 t/year module with: 0.5 kg/h from the stock as indicated above 2.5 kg/h from dust collection systems 1.0 kg/h from storage and load out collection system 1.0 kg/h from screening dust collection system —— dedusting systems are designed in order that under normal operating conditions, dust emission in atmosphere will not exceed 0.159/m^3 (NTP)	

TABLE VI b

	MIDREX	ARMCO
effluent water		
depends of cooling arrangement average clarifier water	0.90 m^3/t Fe would be around 40 m^3/t Fe with no water recirculation	1 m^3/t Fe
average suspended solids in effluent water solids from clarifier	50 - 150 mg/l 40 - 70 kg/t Fe	93 mg/l
Noise	location — noise level - inside the compressor area — 95 - 100 dB - immediately outside of the compressor area — 85 dB - miscellaneous stations around the plant — 80 - 88 dB - at plant boundaries — 70 - 80 dB	

Table VII

Addition to Table VIa

	MIDREX	ARMCO	PUROFER
Exhaust gases volume	2,000/2,300 Nm^3/t Fe with heat recovery from exhaust gas	around 3,200 Nm^3/t Fe	4,300 Nm^3/t Fe without heat recovery from exhaust gas
temperature	around 400°C can decrease further with heat recovery	—	around 600°C without heat recovery from exhaust gas
composition	12.9% CO_2 4% O_2 65.7% N_2 17.4% H_2O	—	7 - 10% CO_2 7 - 9% O_2 74 - 78% N_2 10 - 15% H_2O
	NO_x quantity very small S depending on sulphur content of natural gas and iron ores usually very small and close to nil		
dust	4 - 5 mg/Nm^3 or 10 g/t Fe	around 30 mg/Nm^3 100 g/t Fe	less than 5 mg/Nm^3
Particulate emission	3 to 5 kg/h for a 400,000 t/year module — Dedusting systems are designed in order that under normal operating conditions dust emission in atmosphere will not exceed 150 mg/m^3.	—	Dust emission, mainly from iron ore fines depends on the humidity content & will vary with the seasons. At transfer points & screening station dust collection & dedusting equipment is installed & the dust level is controlled within the limits of prevailing standards. At the time being the dust concentration is kept below 150 mg/Nm^3.

Table VII (continued)

	MIDREX	ARMCO	PUROFER
Effluent water depends on cooling arrangement	$0.75\ m^3/t$ Fe ——— would be around $35\ m^3/t$ Fe with no water recirculation	$1\ m^3/t$ Fe	$0.90\ m^3/t$ Fe with clarifier and recirculation ——— $23.5\ m^3/t$ Fe without recirculation
average suspended solids in effluent water	50 mg/l	93 mg/l	———
solids from clarifier	35 - 45 kg/t Fe	———	28 kg/t Fe
Noise	Location / noise level - inside the compressor area 95 dB - immediately outside of the compressor area 85 dB - miscellaneous stations around the plant 80 - 88 dB - at plant boundaries 70 - 80 dB		Location / noise level - inside the compressor area 90 dB (could be decreased at ...... 80 dB by silences) - at plant boundaries 60 - 70 dB

Table VIII

MAIN EXHAUST GASES AND DUST FROM A SOLID COAL BASED "DIRECT REDUCTION" PROCESS

	K R U P P		
	bituminous coal	bituminous coal	Lignite
exhaust gas	from the furnace around 2,750 Nm^3/tFe (dry)	from the furnace 2,450 Nm^3/t of ore (wet)	from the furnace 2,750 Nm^3/t of ore (wet)
temperature	around 850°C	850 - 900°C	850°C
composition	25 - 26 % CO_2 0.5 - 0.8 % CO 0.5 - 0.8 % O_2 <0.4 % CH_4 <0.4 % H_2 <0.07 % SO_2 remainder N_2	24 % CO_2 2 % CO 1 % O_2 <0.5 % CH_4 2 % H2	21 % CO_2 6 % CO <0.5 % O_2 1 % CH_4 5 % H2
dust	around 50 - 60 g/Nm^3 with 24 - 30% fixed carbon 3 - 6% volatiles 65 - 75 % "ash" and 40% Fe ——— 30 % + 100 microns 25 % 100-30 microns 25 % 30-10 " 20 % - 10 "	around 30g/Nm^3 40% Fe	around 25 g/Nm^3 25 % C 40% Fe

Table VIII (Continued)

	after filters (clean gas)	following after combustion chamber	following after burner		
reference		1	1	2	3
	3,250 Nm^3/tFe	5,000 Nm^3/tFe	6,250 Nm^3/ t of ore (wet)	3,850 Nm^3 t of ore (wet)	-
temperature		300°C	300°C	-	80°C
composition	20 - 22% CO_2 0.4 % CO 4 - 5 % O_2 $<$0.4 % H2 $<$0.4 % CH_4 $<$0.06 % SO_2		200 to 340 mg/Nm^3 30 mg/Nm^3 HCl 2 mg/Nm^3 FH 20 mg/Nm^3 NO_x no H_2S no COS no CH_x no aldehyde		
dust	around 150 mg/Nm^3 5% + 50 microns 14% 50 - 30 microns 58% 30 - 10 " 23% 10 "		50 to 100mg /Nm^3	-	50 to 60 mg/ Nm^3

Remarks :

Reference 1 : no heat utilization and electrostatic precipitation: the large volume is due to steam.

Reference 2 : heat utilization

Reference 3 : use of wet scrubbers.

Table IX

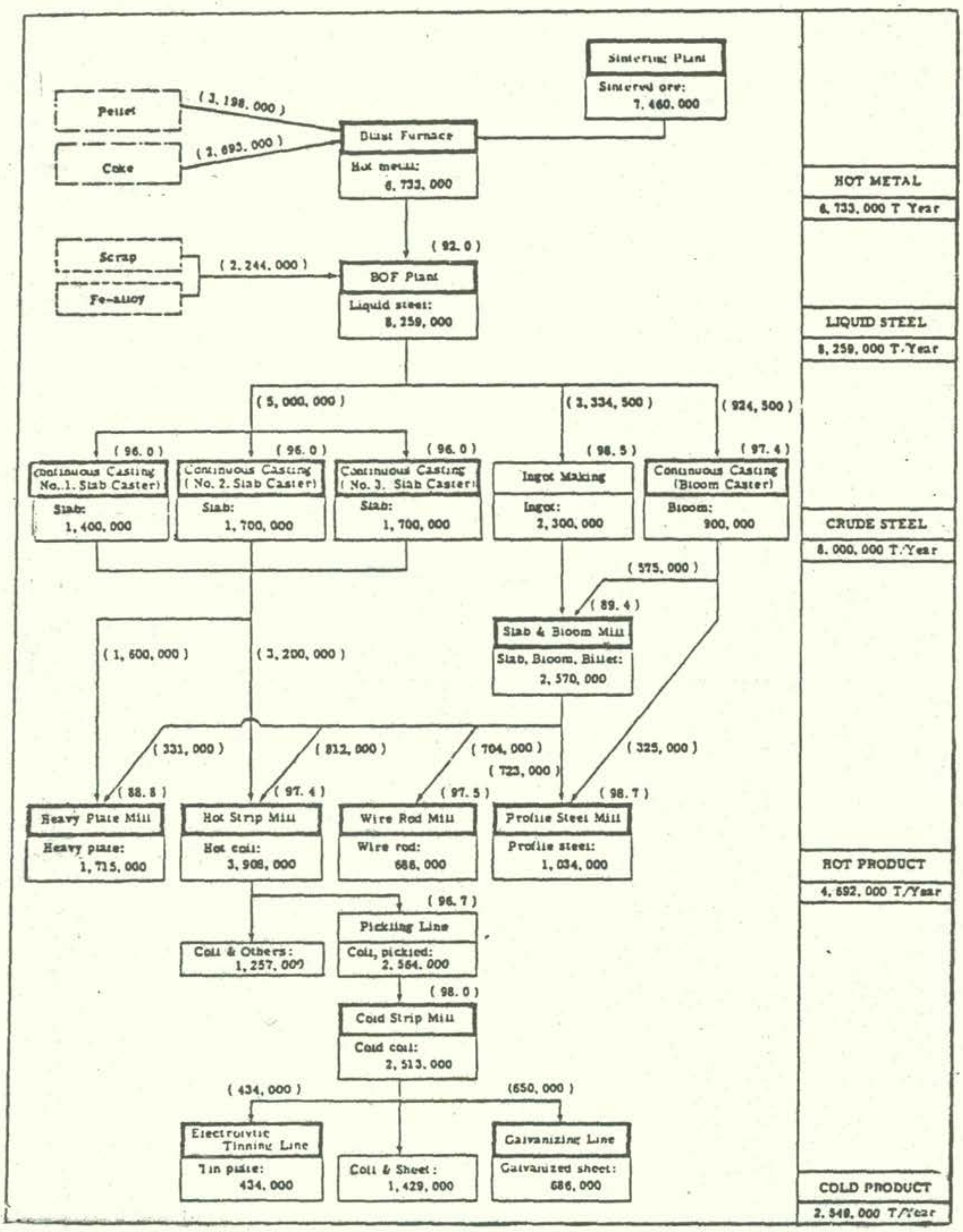
WORLD COAL RESERVES AND PRODUCTION

	Reserves (millions of metric tons)	Annual Production (millions of metric tons)			
		average 1963-67	1971	1973	1977**
Total World	6,641,200	1,969	2,124	2,189	2,465
USA	1,100,000	472	503	547	602
USSR	4,121,603	394	441	499	502
CHINA	1,011,000	283	390	370	490
UK	15,500	188	147	130	120
POLAND	45,741	119	145	157	186
F.R. OF GERMANY	70,000	132	111	97	85
INDIA	106,260	66	70	78	100
SOUTH AFRICA	72,465	47	59	62	85
AUSTRALIA	16,000	29	45	60	72
FRANCE	2,800	50	33	26	21

** Provisional number (June 1978)

Table X

MATERIAL FLOW AND PRODUCT MIX IN MODEL PLANT (A)



TECHCO
MARCH, 1975

Table XI

ENERGY REQUIREMENT TABLE FOR MODEL PLANT (A)

PLANT PRODUCT: Annual Production (T/Year)		CONSUMED ENERGY (I)											RECOVERED ENERGY (II)			ENERGY REQUIREMENT (I - II)	CUMULATIVE TOTAL
		Coke	Oil and Gas					Electric power	Oxygen	Others		SUB - TOTAL	BFG	LDG	SUB - TOTAL		
			Fuel Oil	COG	BFG	LDG	Sub - Total			Energy required to produce pellet	Energy loss in coking process						
		7,200 kcal/kg	10,000 kcal/kg	4,400 kcal/Nm³	800 kcal/Nm³	2,000 kcal/Nm³		2,450 kcal/kWh	1,715 kcal/Nm³	300 x 10³ kcal/T pellet	1,000 kcal/kg coke		800 kcal/Nm³	2,000 kcal/Nm³			
Sintering Plant Sintered ore: 7,460,000	Unit consumption	49.2	0	13	0	0		42.8	0		49.2						
	10³ kcal/T.P.	354		57				105			53	569				569	
	10³ kcal/T.C.S.	330		53			53	98			49	530				530	530
Blast Furnace Hot metal: 8,333,000	Unit consumption	400	65	38.3	430	0		86	18		400		1,570				
	10³ kcal/T.P.	2,880	650	168	344			211	31	142	432	4,858	1,258		1,258	3,602	
	10³ kcal/T.C.S.	2,424	547	141	290		978	178	36	120	363	4,089	1,057		1,057	3,032	3,562
BOF Plant Liquid steel: 8,250,000	Unit consumption	0	0	1.1	0	0		23	53					70			
	10³ kcal/T.P.			5				56	91			152*		140	140	12	
	10³ kcal/T.C.S.			5	(LPG:Kg/T)		5	58	94			157*		145	145	12	3,574
Continuous Casting Slab, Bloom: 5,700,000	Unit consumption	0	0	2.7	1.0	0		40	10.5								Up to crude steel
	10³ kcal/T.P.			12	11			98	18			139				139	
	10³ kcal/T.C.S.			9	8		17	70	13			100				100	3,674
Slab & Bloom Mill Slab, Bloom, Billet: 2,570,000	Unit consumption	0	0			0		34	5								Up to semis
	10³ kcal/T.P.			248				83	9			340				340	
	10³ kcal/T.C.S.			80			80	27	3			110				110	3,784
Heavy Plate Mill Heavy plate: 1,715,000	Unit consumption	0						73									
	10³ kcal/T.P.						509	179				688				688	
	10³ kcal/T.C.S.						109	38				147				147	
Hot Strip Mill Hot coil: 3,900,000	Unit consumption	0						120									
	10³ kcal/T.P.						410	294				704				704	
	10³ kcal/T.C.S.						200	144				344				344	
Wire Rod Mill Wire rod: 586,000	Unit consumption	0						135									
	10³ kcal/T.P.						310	331				641				641	
	10³ kcal/T.C.S.						27	28				55				55	
Profile Steel Mill Profile steel: 1,034,000	Unit consumption	0						122									
	10³ kcal/T.P.						410	299				709				709	
	10³ kcal/T.C.S.						53	39				92				92	
Cold Strip Mill Cold coil: 1,543,000	Unit consumption	0						154									
	10³ kcal/T.P.			272			272	377				649				649	
	10³ kcal/T.C.S.			85			85	118				203				203	
Electrolytic Tinning Line Tin plate: 434,000	Unit consumption	0						156									
	10³ kcal/T.P.						0	382				382				382	
	10³ kcal/T.C.S.						0	21				21				21	
Galvanizing Line Galvanized sheet:	Unit consumption	0						80									
	10³ kcal/T.P.						318	196				514				514	
	10³ kcal/T.C.S.						27	17				44				44	
Others Steam	10³ kcal/T.C.S.						141										
Others Water	10³ kcal/T.C.S.							65									
Others Others	10³ kcal/T.C.S.						27	16				249				249	
TOTAL	(10³ kcal/T.C.S.)	2,754					1,802	917	136	120	412	6,141	1,057	145	1,202	4,939	* 4,939

kcal/T.P. = kcal/Ton of Product
kcal/T.C.S. = kcal/Ton of Crude Steel

(*Energy required for teeming operation to make ingot is included)

TECHCO
September,

Table XII

DUSTS (DRY, WET) SOURCES AND RECOVERIES

Source	Production (t/year)	Recovery (t/year)	Recovery Process
Blast furnace dust (dry)	96,000	96,000	Sintering plant
Coke oven dust	9,600	9,600	Sintering plant
Blast furnace and Sintering plant wet dust	72,000	72,000	Reduction plant
Steelmaking fume	96,000	96,000	Reduction plant
Dust from environmental control facilities	18,000	18,000	Reduction plant

Table XIII

Distribution by Processes of Direct Reduction Annual Capacity
(10^3 t/year)

Year	Various Processes	Special Application	HyL	MIDREX	PUROFER	ARMCO	SL/RN + KRUPP	HIB + FIOR	Total
1954	330								330
1957	330	24	100						454
1960	330	24	370						724
1964	330	34	370						734
1967	330	34	650						1014
1968	330	1034	650						2014
1969	330	1106	965	300					2701
1970	330	1226	965	300	110				2931
1971	330	1274	965	700	110				3379
1972	330	1514	965	1100	110	330			4379
1973	330	1514	965	1500	110	330	210	650	5609
1974	330	1864	1690	1500	110	330	210	650	6684
1975	360	2374	1690	1500	110	330	570	650	7584
1976	640	2524	2050	2190	460	330	570	1050	9814
1977	640	3414	4160	3990	790	330	570	1050	14944
1978	640	3414	5985	5610	790	330	670	1050	18489
1979	640	3414	9810	9310	790	330	670	1050	26014
1980	640	3414	9810	14330	1590	330	670	1050	31834

Table XIV

RESERVES AND PRODUCTION OF NATURAL GAS

	Reserves millards of m^3	Annual Production (millards of m^3)			
		average 1963-67	1971	1973	1977
Total World	49,900	707	1,142	1,260	1,395
USA	7,895	462	637	636	564
USSR	18,010	125	212	232	346
CANADA	1,571	35	71	89	74
NETHERLANDS	2,500	3	44	144 +	97
ALGERIA	4,417	1.5	3	3.4	10
IRAN	3,681	1	16	20	22
SAUDI ARABIA	1,918	- -	- -	- -	- -

+ : Total Western Europe

Table XV

RESERVES AND PRODUCTION OF OIL

	Reserves (millions of metric tons	Annual Production millions of metric tons				
		average 1963-67	1971	1972	1973	1977
Total World	76,200	1,525	2,400	2,600	2,800	3,000
USA	5,144	395	467	528	513	463
USSR	8,203	245	377	394	421	546
SAUDI ARABIA	18,727	103	223	286	365	453
IRAN	8,265	98	223	252	294	276
VENEZUELA	1,966	178	186	168	176	116
KUWAIT	10,370	108	147	151	138	94
LIBYA	3,695	56	132	106	105	100
CANADA	1,126	40	64	87	100	71
IRAK	4,420	62	84	70	95	111

Table XVI

ENERGY REQUIREMENT TABLE FOR MODEL PLANT (B2)

PLANT PRODUCT: Annual Production (T/Year)		CONSUMED ENERGY							TOTAL	CUMULATIVE TOTAL
		Added Carbon	Natural gas	LPG & Others	Electric Power	Oxygen	Electrode	Energy required to produce pellet		
		8,080 kcal/kg	9,000 kcal/Nm³	10,900 kcal/kg	2,450 kcal/KWh	1,715 kcal/Nm³	8,000 kcal/kg	300 x 10³ kcal/T pellet		
Direct Reduction Plant	Unit consumption	0	344.5	0	80	0	0			
Sponge iron : 903,000	10³ kcal/T. P.		3,100		196			432	3,728	
	10³ kcal/T. C. S.		2,722		172			390	3,284	3,284
Electric Arc Furnace		0	0	0	550	7	5			
Liquid steel : 1,027,000					1,348	12	40		1,400	
					1,384	12	41		1,437	4,721
Continuous Casting		0	0		14	10.5	0			
Bloom, Billet : 1,000,000				23	34	18			75	
				23	34	18			75	4,796
Profile Steel Mill		0	0		122	0	0			
Profile steel : 568,000				410	299				709	
				233	170				403	
Wire Rod Mill		0	0		135	0	0			
Wire rod : 414,000				245	331				576	
				101	137				238	
Others										
									(50)	
TOTAL	(10³ kcal/T.C.S.)	0	2,722	357	1,897	30	41	390	5,487	5,487

Table XVII

MATERIAL FLOW AND PRODUCT MIX IN MODEL PLANT (B2)

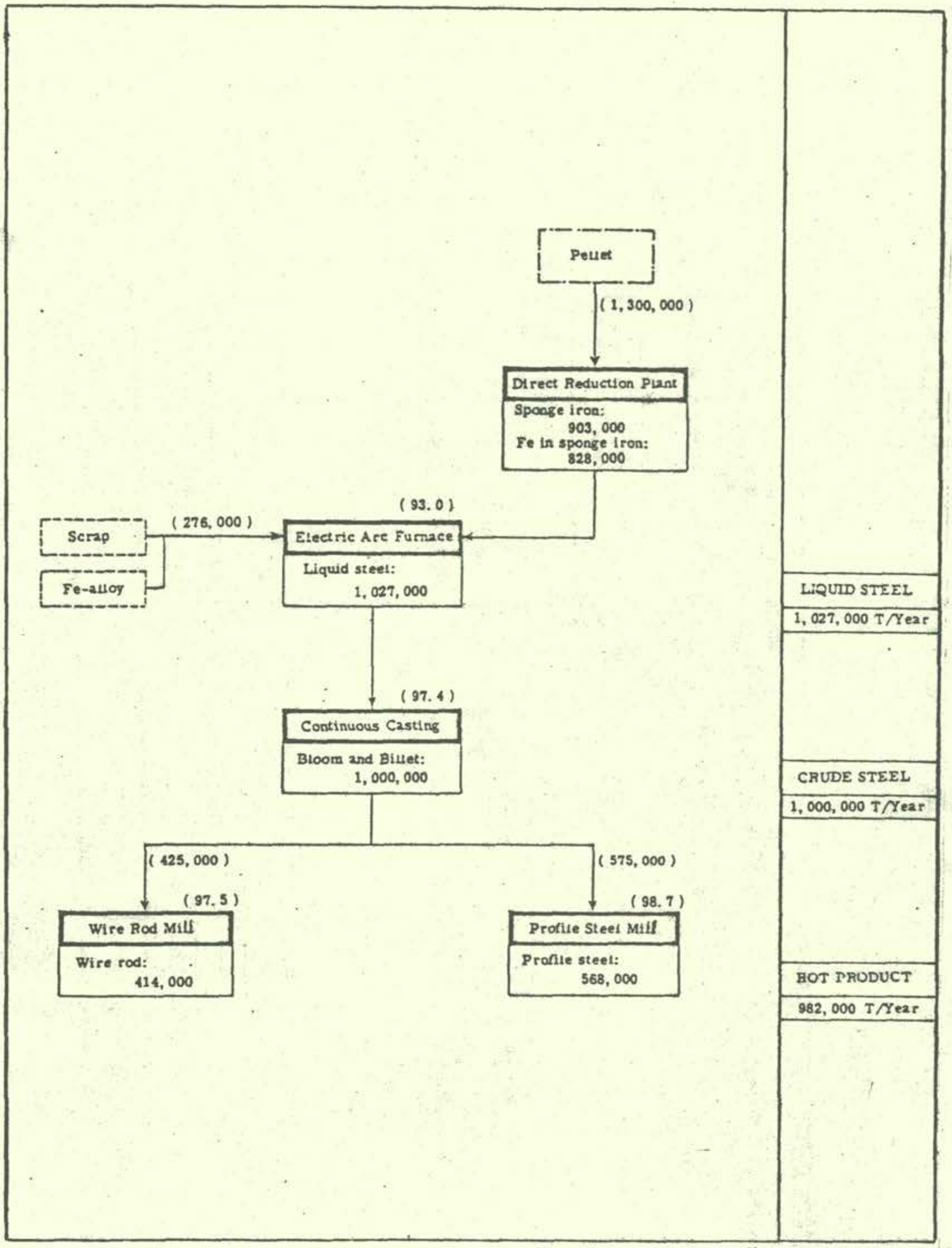


TABLE XVIII

MATERIAL FLOW AND PRODUCT MIX IN MODEL PLANT (B1)

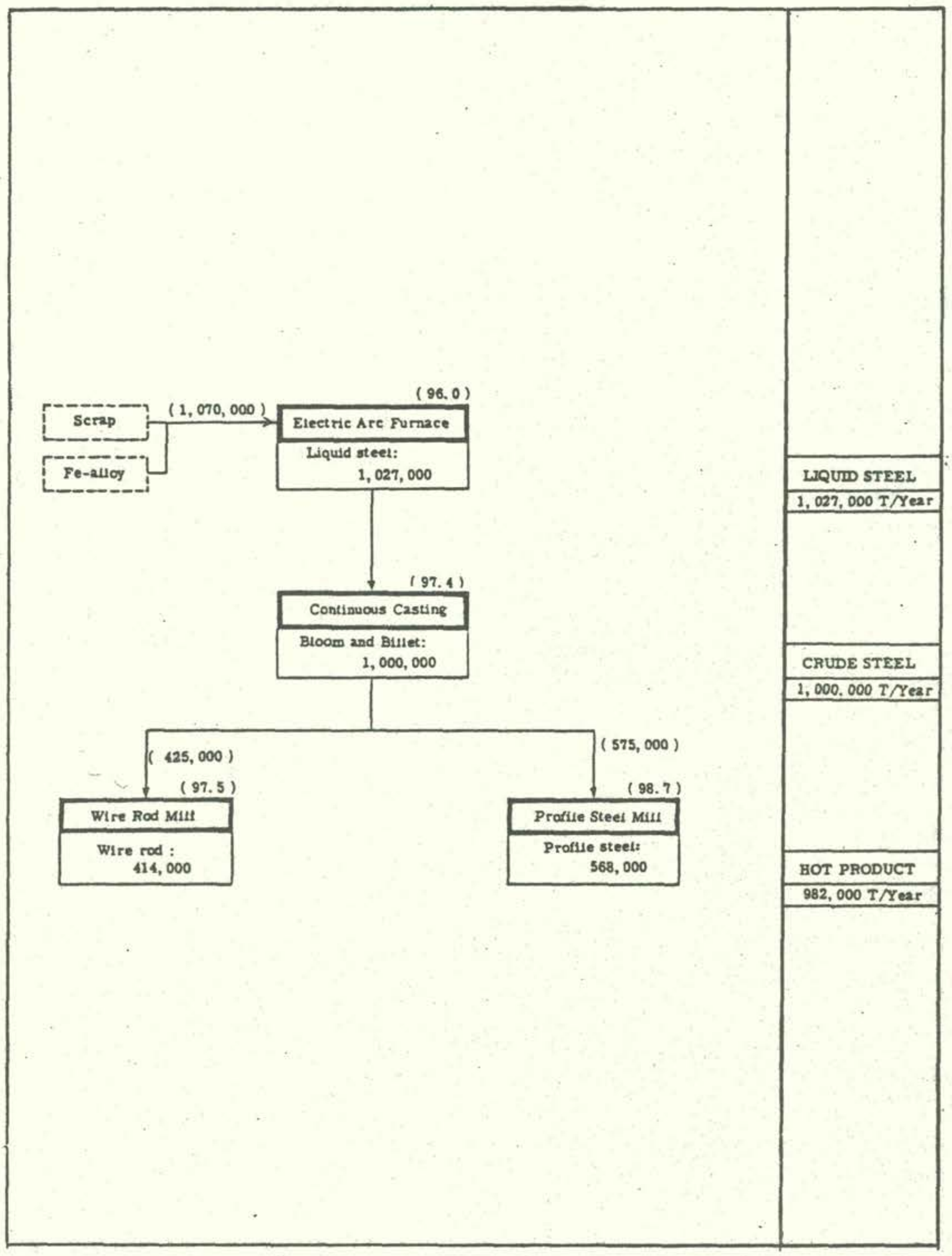


Table XIX

ENERGY REQUIREMENT TABLE FOR MODEL PLANT (B1)

PLANT PRODUCT: Annual Production (T/Year)		CONSUMED ENERGY					TOTAL	CUMULATIVE TOTAL
		Added Carbon	LPG & Others	Electric Power	Oxygen	Electrode		
		8,080 kcal/kg	10,900 kcal/kg	2,450 kcal/KWh	1,715 kcal/Nm³	8,000 kcal/kg		
Electric Arc Furnace	Unit consumption	8	0	460	17	5		
Liquid steel :	10^3 kcal/T.P.	65		1,127	29	40	1,261	
1,027,000	10^3 kcal/T.C.S.	67		1,157	30	41	1,295	1,295
Continuous Casting		0	2.1	14	10.5	0		
Bloom, Billet :			23	34	18		75	
1,000,000			23	34	18		75	1,370
Profile Steel Mill		0	37.6	122	0	0		
Profile steel :			410	299			709	
568,000			233	170			403	
Wire Rod Mill		0	22.5	135	0	0		
Wire rod :			245	331			576	
414,000			101	137			238	
Others								
							(50)	
TOTAL	(10^3 kcal/T.C.S.)	67	357	1,498	48	41	2,061	2,061

Table XX

MAIN WORLD CHARCOAL - BASED

IRON AND STEEL PLANTS

Country	Companies	number of blast furnaces	annual production of pig-iron, t
AUSTRALIA	WUNDOWIC	2	70,000
UNITED KINGDOM	BACKBARROW	1	------
MALAYSIA	MALAYAWATA STEEL BHD	2	130,000
USSR	NEDISHDRUSK	1	65,000
USSR	VERKNYAYA SALDA	1	------
THAILAND	SISCO	3	60,000
ARGENTINA	ALTOS HORNOS GUENES S.A.I.C.	1	12,000
ARGENTINA	ALTOS HORNOS ZAPLA	3	122,000
BRAZIL	detail in table XIII	136	3,777,400

Table XXI

BRAZIL CHARCOAL BASED IRON AND STEEL PLANTS

Empresas	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Cia Siderurgica Barra Mansa	59.5	58.5	60.3	49.6	86.3	113.0	117.6	124.5	149.7	146.1
Cia Siderurgica Barbara	50.4	57.0	66.1	66.1	83.5	90.6	90.7	92.9	94.2	96.4
Siderurgica S.A.	26.4	16.6	23.4	60.9	41.4	82.5	80.0	78.3	71.2	.
Cia Sider. Belgo Mineira	438.2	470.3	478.1	473.4	483.9	478.4	518.3	533.9	578.5	585.3
Cia Sider. Mannesmann	62.6	94.8	116.5	121.6	117.3	97.8	97.4	135.6	145.2	129.8
Cia açus esp Itabira Acesita	85.0	99.6	104.8	103.0	138.0	120.0	128.0	131.0	154.0	163.0
Cia Siderurgica Pains	33.6	33.7	36.0	34.6	29.9	57.6	77.7	78.5	98.5	123.5
Lam. de Ferro S.A. Lafersa	16.4	21.9	20.1	25.0	23.1	29.5	25.4	25.0	38.4	29.2
Cia Industrial Itaunense	.	.	.	.	.	.	.	.	.	0.1
Cimetal Siderurgica S.A.	.	.	.	.	.	.	.	.	.	71.0
Siderurgica Aliperti S.A.	47.4	51.0	63.1	86.6	93.3	118.4	123.9	127.8	139.4	149.0
Cia Sider. Mogi das Cruzes -Cosim	.	.	46.2	49.3	79.8	85.1	74.0	71.9	79.2	53.2
Usinas nao integradas	378.0	393.3	641.1	826.7	960.7	1 036.2	1 128.1	1 136.2	1 798.6	2 230.8
Total de gusa de carvao vegetal	1 196.5	1 296.1	1 655.7	1 896.8	2 177.6	2 310.1	2 461.1	2 535.6	3 345.9	3 777.4
Total geral de gusa	3 078.1	3 228.7	3 766.8	4 235.1	4 743.1	5 287.3	5 533.8	5 858.3	7·016.5	8 174.7
Part. % do gusa de c. vegetal	38.9	40.1	44.0	44.8	45.9	43.7	44.5	43.3	47.7	46.2

Fonte : CSN - Vice-Presidencia de Planejamento. Dados Estatisticos
IBS - Anuario Estatistico da Industria Siderurgica Brasileira. 1977

Table XXII

Some Different Furnaces Used to Produce Charcoal

Characteristics	Types				
	1	2	3	4	5
Type	C.S. Belgo Mineira (Brésil) Altos Hornos Zapla (Argentine)	ACESITA (Brésil)	ACESITA and Belgo Mineira (Brésil)	Schwartz Altos Hornos Zapla (Argentine)	Selama Malayawata Steel Bhd (Malaysia)
Implantation on Site	flat	flat	side of hill	flat	flat
Main Dimensions					
Hearth	5.10 m	5.0 m	4.0 m	8 x 3 m	5.0 m
Height maxi. (top)	4.0 m	3.0 m	2.2 m	2.4 m	3.7 m
Height mini. (wall)	2.4 m	1.8 m	1.3 m	1.7 m	1.1 m
Operation			batch		
Feed	Eucalyptus	Eucalyptus	Eucalyptus	Eucalyptus	Rubber tree
Capacity	55.0 m^3	37.3 m^3	17.8 m^3	43.0 m^3	34.0 m^3
Wood for Heating	-	-	-	7 m^3	3 m^3
Charcoal Produced by Operation	6.9 t	17.8 m^3	8.9 m^3	28 m^3	7.5 t
Cycle Time	240 h	192 h	120 h	240 h	338 h

Table XXIII

A COMPARISON OF DIFFERENT HEATING COMBINATIONS FOR SLAB REHEATING FURNACES

(per ton of slab)

Basis : 300 metric tons/hour

Case a

1 MJ fossil fuel = 1.66 S

1000 kWh = 14 S

Case b

1 MJ fossil fuel = 1.91 S

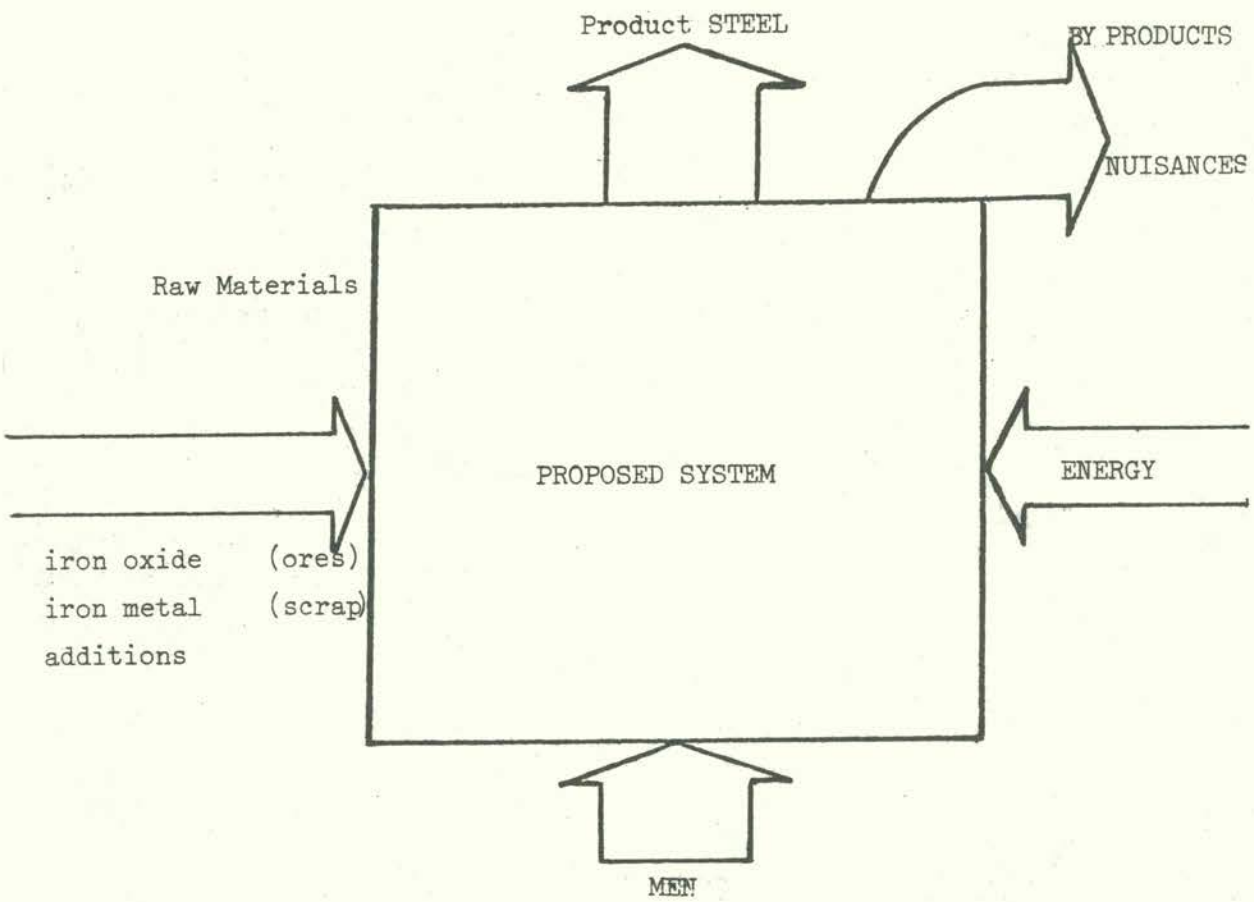
1001 kWh = 12 S

	Classical "flame" furnace	Induction reheating furnace
heat consumption	350 th 1890 MJ	350 kWh equivalent to 300 th 1250 MJ
heat efficiency	45 %	67 %
cost of energy S/t case a case b	 3.16 3.60	 4.90 4.20
total cost S/t (with maintenance refractories amortization) case a case b	 4.36 4.80	 6.10 5.40
losses by oxidation S/t	2.40	0.80
total cost S/t including metal yield (losses by oxidation) case a case b	 6.76 7.20	 6.90 6.20

LIST OF FIGURES

Figure 1

PROPOSED REPRESENTATION OF IRON AND STEEL INDUSTRY



- operation
- maintenance
- supervision
- design for new technology
- creativity for future processes and machines built by men from other sectorial activities

Figure 2

THE VARIOUS DIFFERENT ROUTES TO PRODUCE LIQUID STEEL

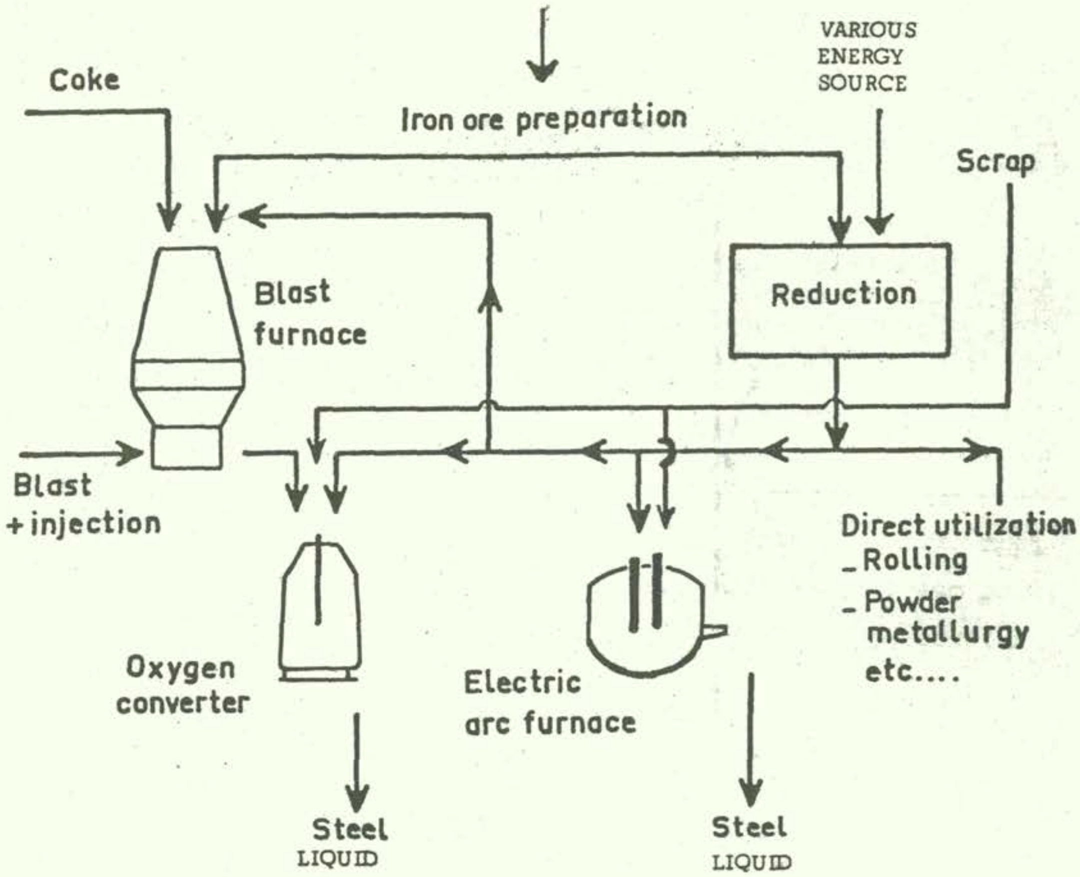


Figure 3

THEORETICAL "DIRECT" STEEL PRODUCING SCHEME

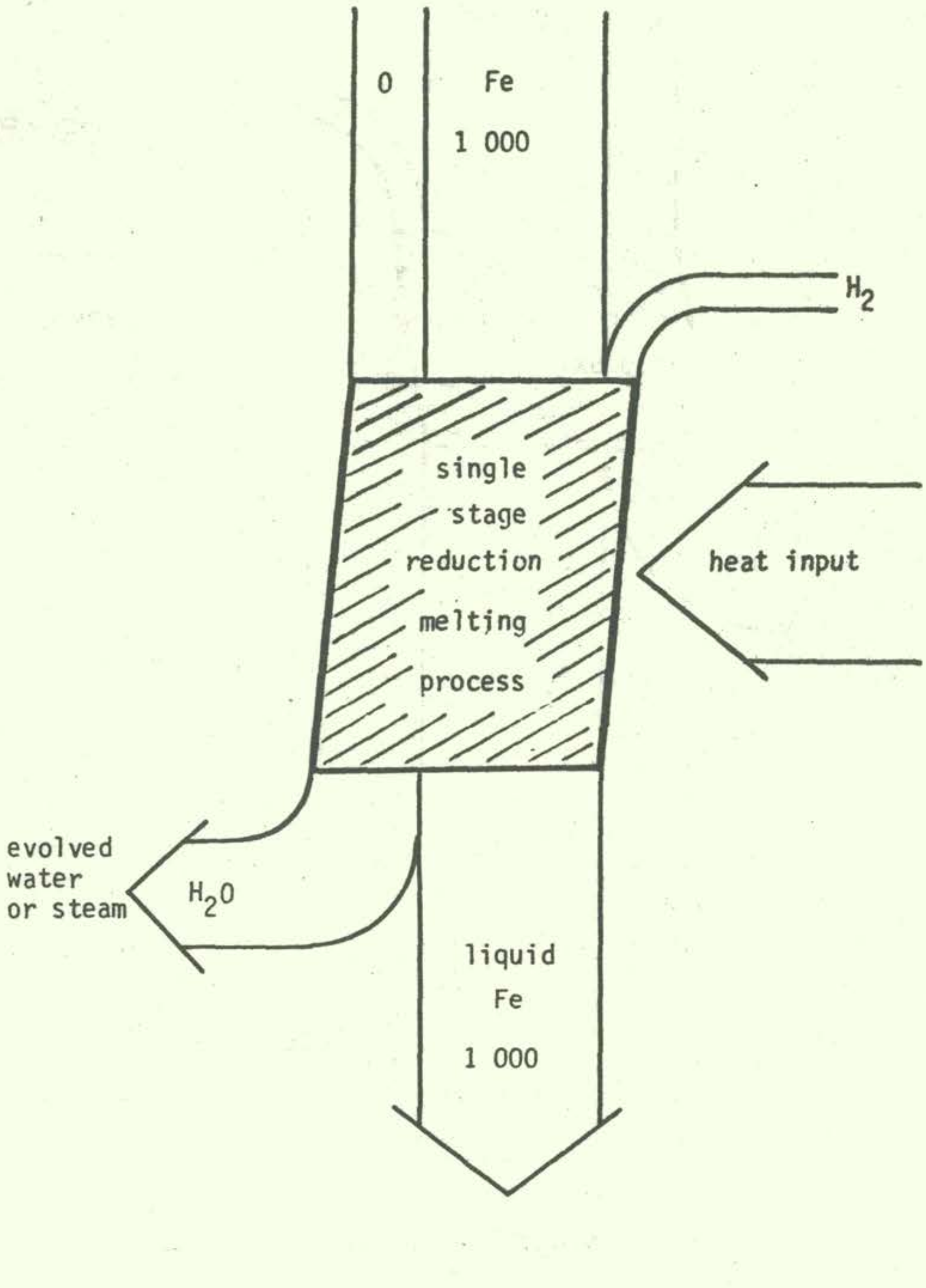


Figure 4

THEORETICAL SIMPLE "TWO STAGE" IRON AND STEELMAKING SYSTEM

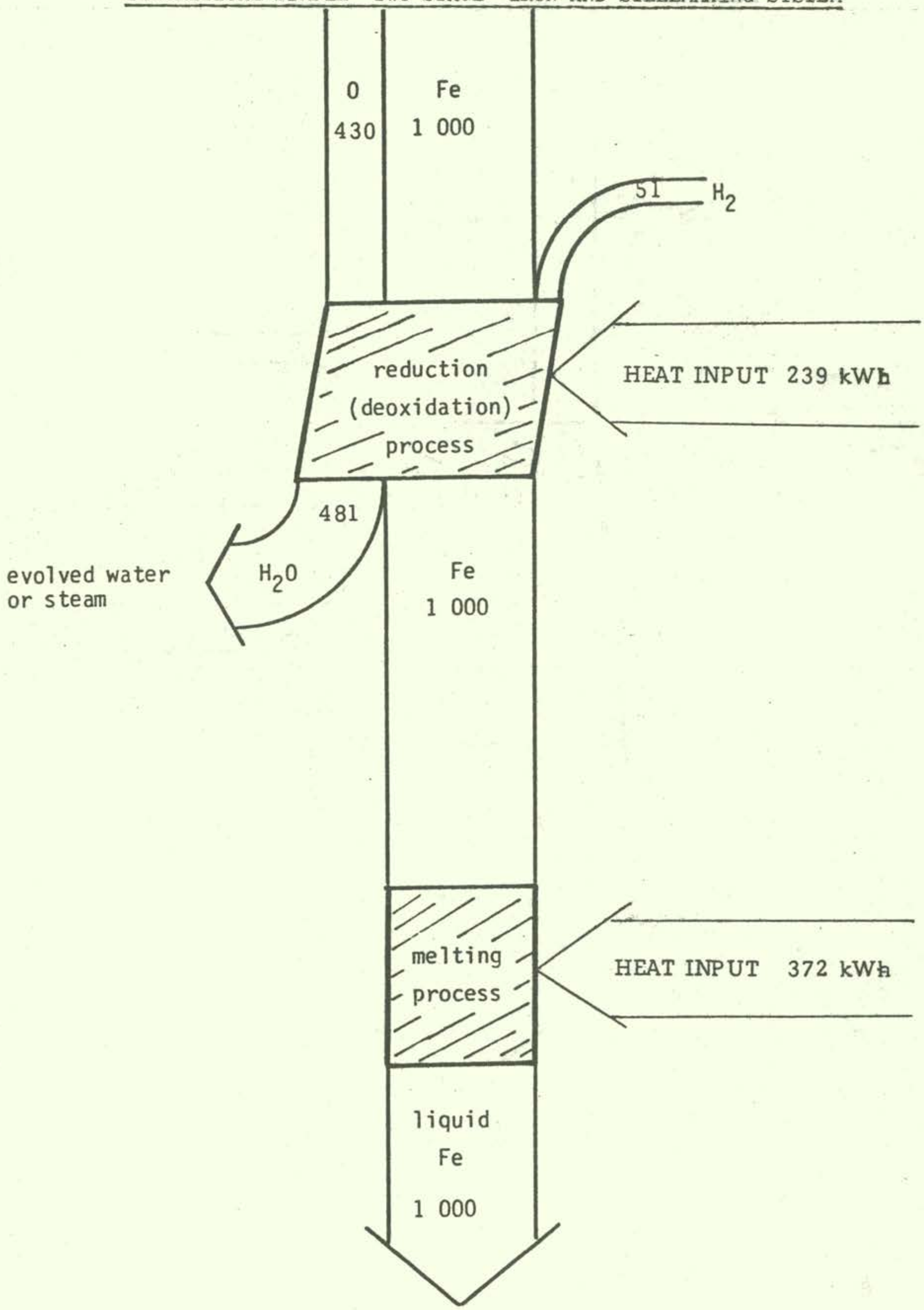


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Figure 5

SYSTEMS BASED ON SMELTING REDUCTION

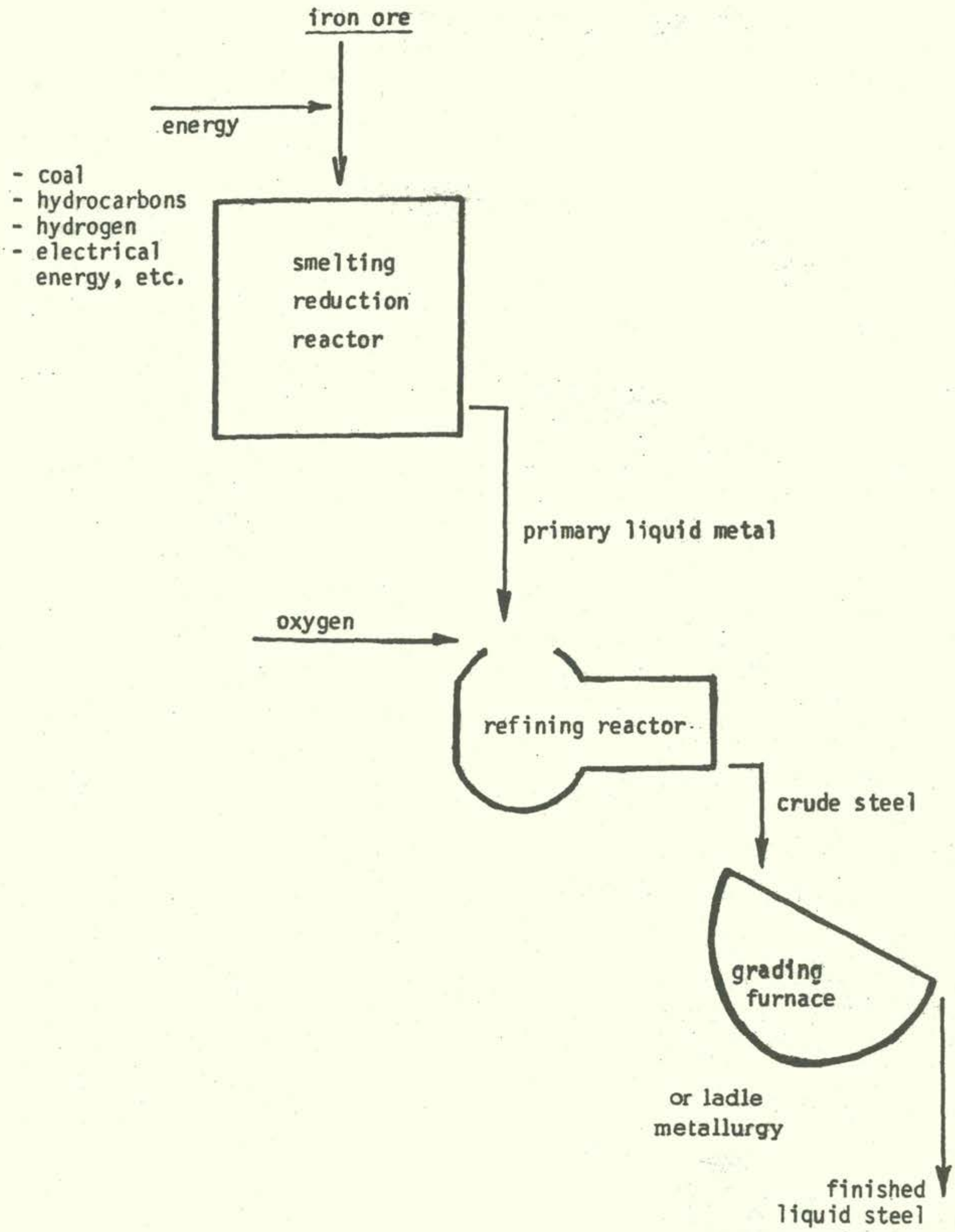

Figure 6

SCHEMATIC MATERIAL BALANCE FOR A TWO STAGE STEEL PRODUCING SYSTEM

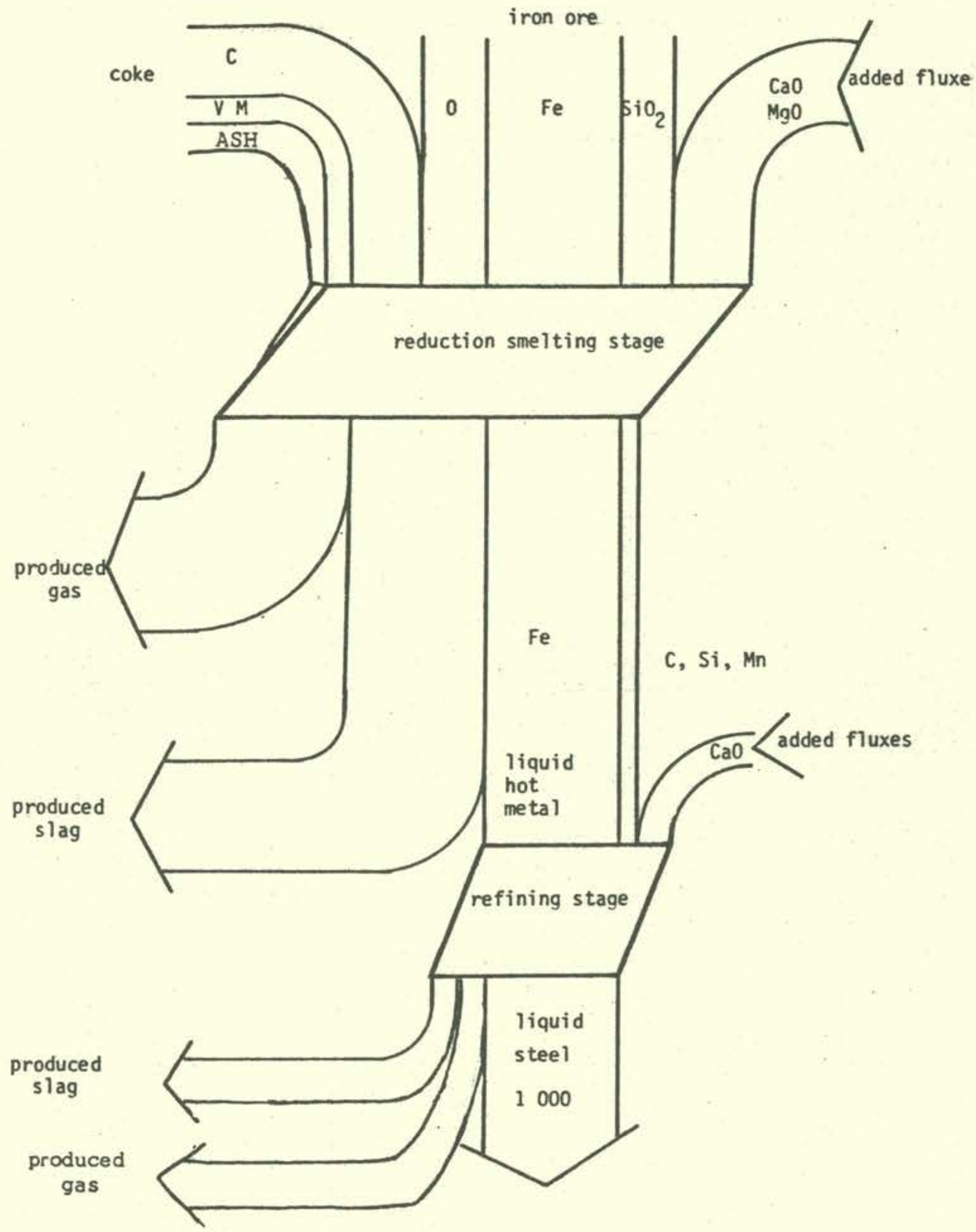

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Figure 7

VARIOUS OXYGEN STEELMAKING PROCESSES

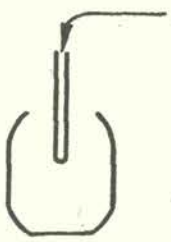
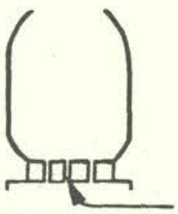
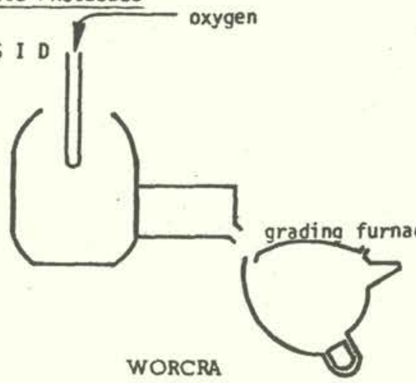
Principle	stage of development
BATCH PROCESSES top blowing oxygen 	largest existing process capacity around 600 Mt/year
bottom blowing  QBM QBOP LWS	newest developing commercial process capacity around 30 Mt/year
CONTINUOUS PROCESSES I R S I D oxygen  grading furnace WORCRA spray refining, etc.	still at pilot plant stage (up to 500 t/day)

Figure 8

MATERIAL BALANCE FOR A CONVENTIONAL TWO-STAGE STEEL PRODUCING SYSTEM

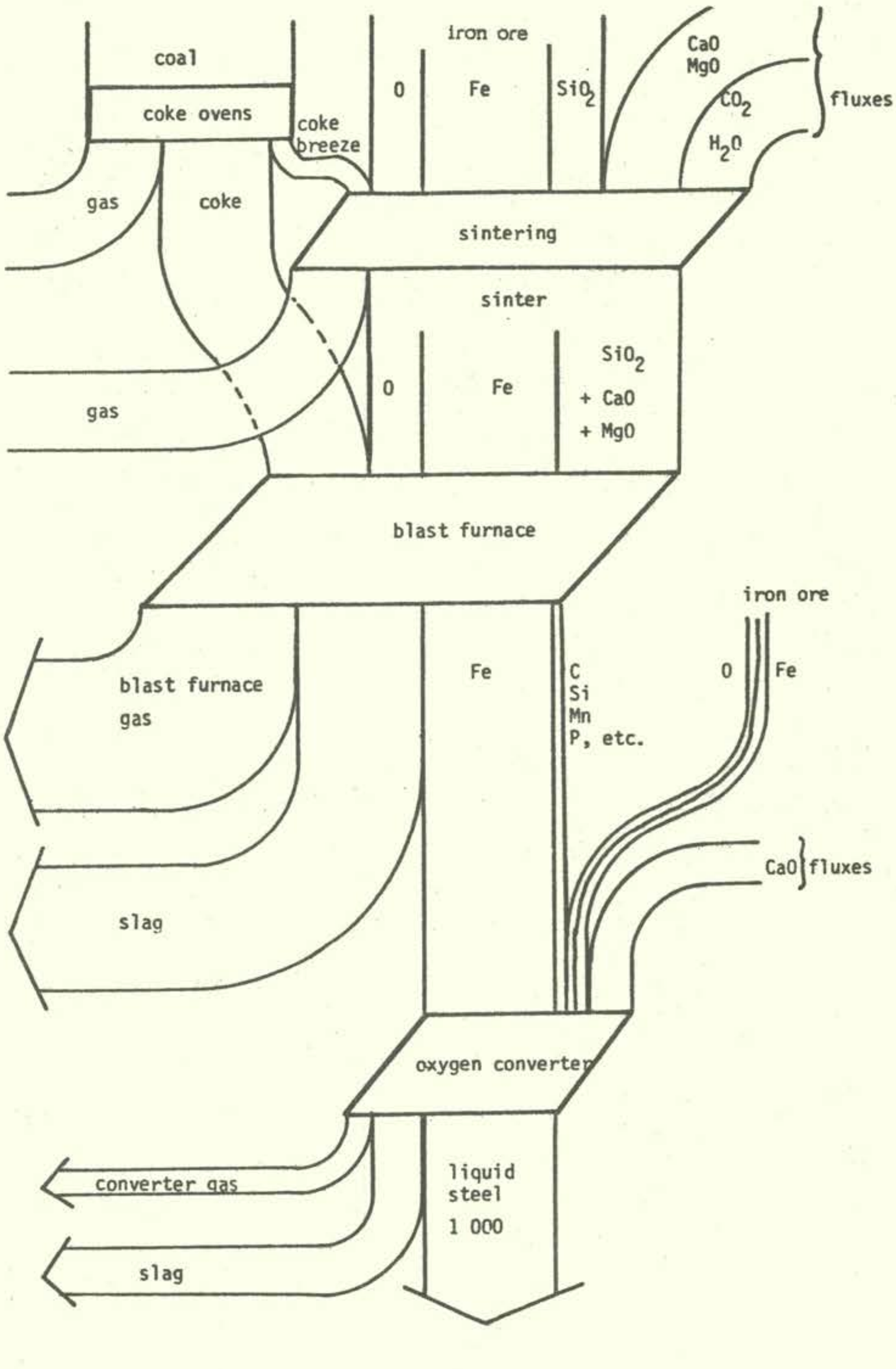


Figure 9

SYSTEMS BASED ON SOLID STATE REDUCTION

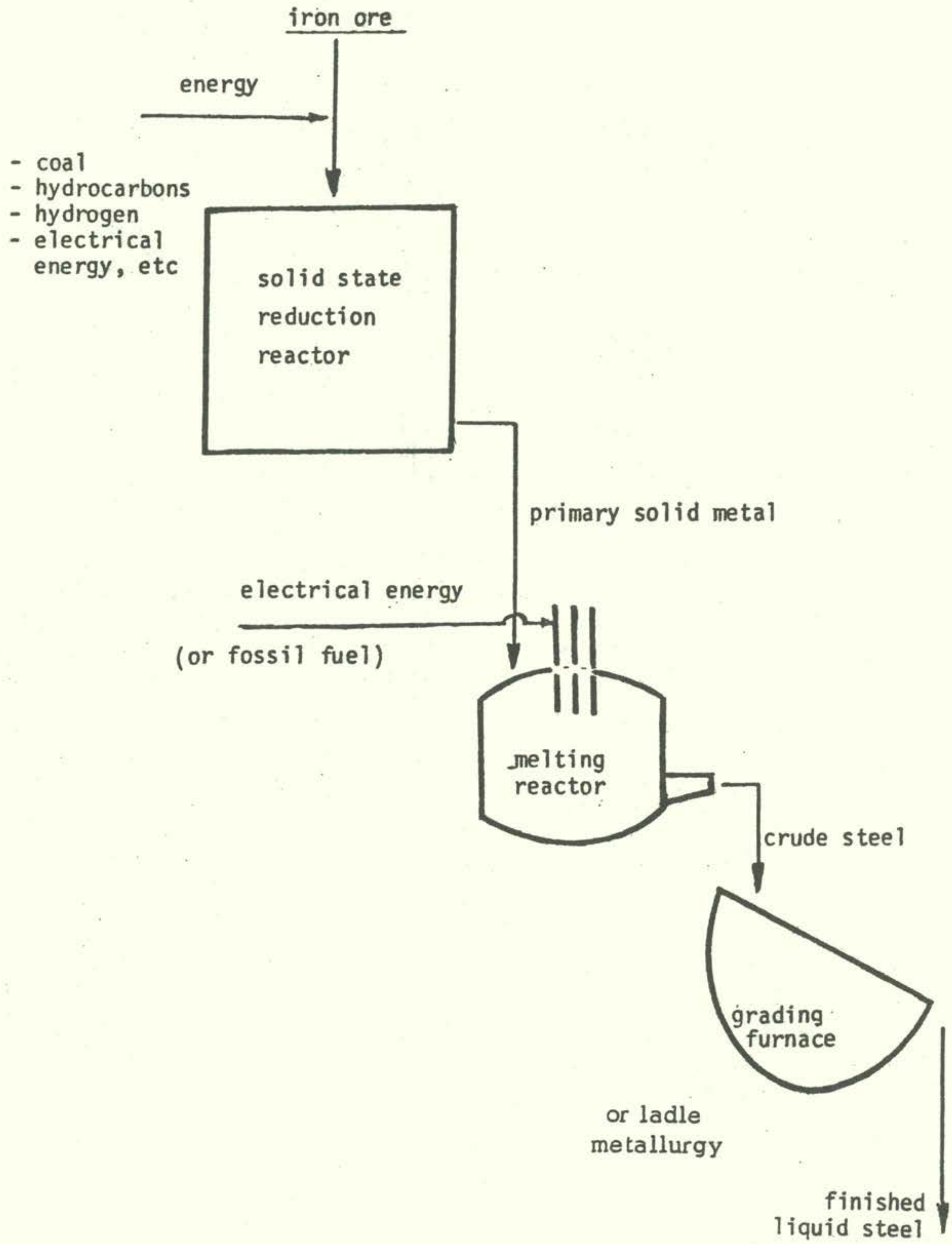


Figure 10

PRACTICAL TWO-STAGE SYSTEM BASED ON SOLID STATE REDUCTION

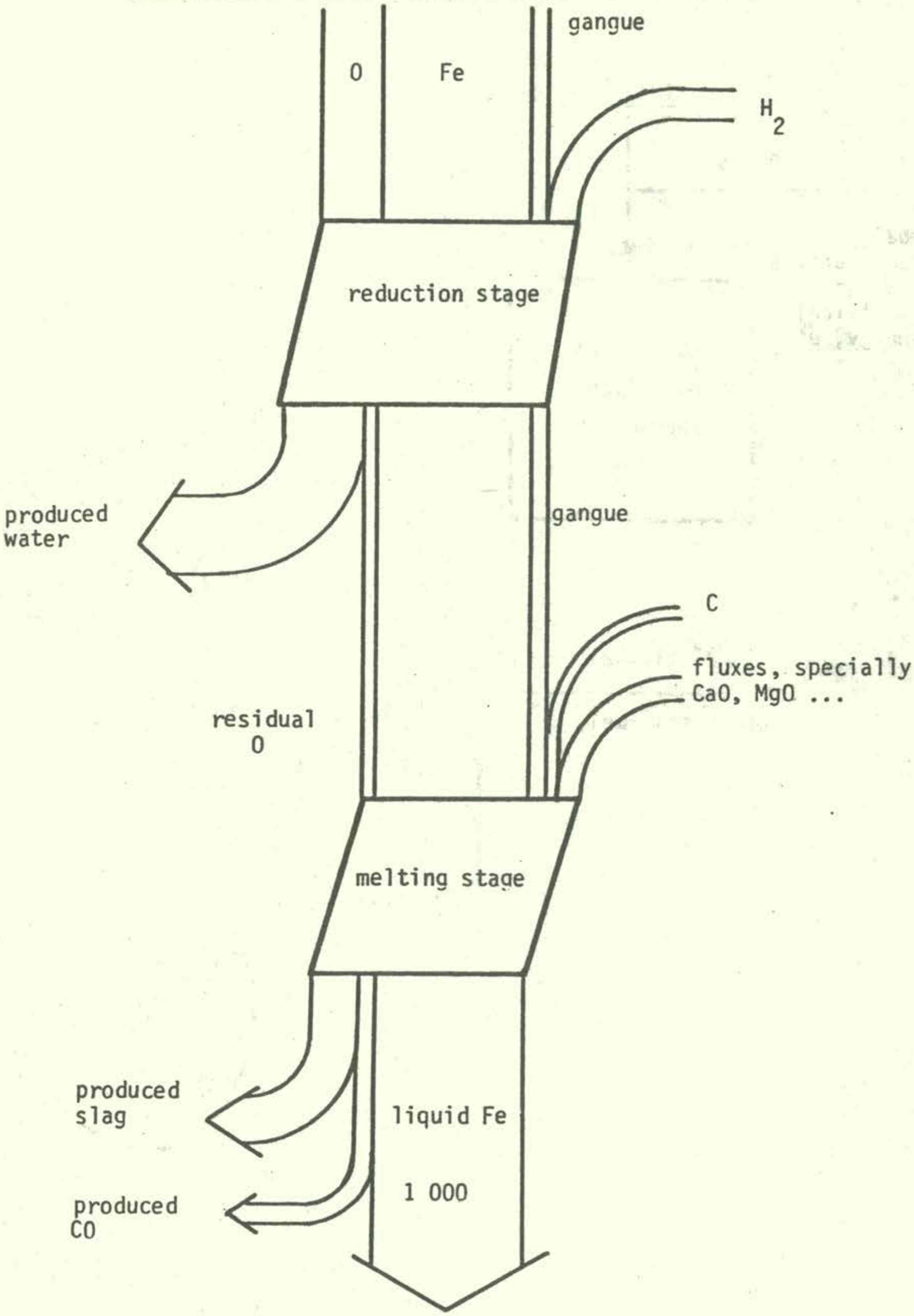


Figure 11

VARIOUS MELTING PROCESSES TO PRODUCE STEEL

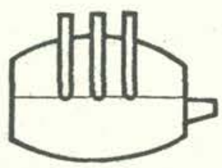
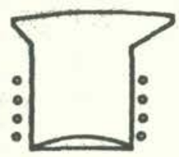
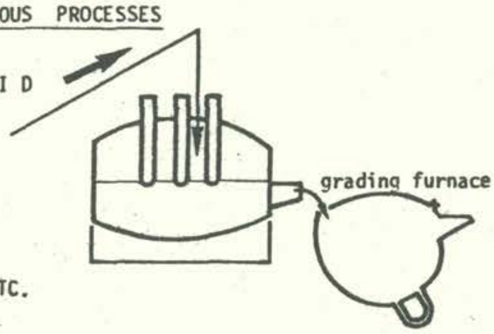
P r i n c i p l e	Stage of development
BATCH PROCESSES	
arc furnace 	largest existing process capacity around 150 Mt/year
induction furnace 	
CONTINUOUS PROCESSES	
I R S I D  WORNER ETC.	still at pilot plant stage (up to 100 t/day)

Figure 12

MAJOR POLLUTION SOURCES and TYPES IN IRON and STEEL INDUSTRY

Type iron and steel plant	coke plant coke plant		direct ore reduction		blast furnace			steel making	HOT forming incl. acid pickling		COLD rolling incl. galvanizing and tin plating	
								open hearth furnace basic oxygen furnace electric furnace	ingot casting continuous casting			
Plant No.	1				2			3	4		5	
Wastes produced	Air	Water	Air	Water	Air	Water	Solids	Air Water Solids	Water	Solids	Water	Solids
	Ammonia Steam Hydrogen Sulfide	Ammonia	?	?	Ammonia	Amm. Cyanide Phenol	Suspended solids	Suspended solids	Oil+grease Chloride Sulfate Iron Acidity	Suspended solids	BOD Cyanide Oil+grease Susp.sol. Chronium Iron Tin Cyanide	Suspended solids

Other sources of relatively minor contamination include the yards (ore, coal and scrap), sintering, steam, generation, lime kiln, and cooling towers.

Figure 13

SCHEMATIC IMPACT ON THE ENVIRONMENT OF A GAS-DIRECT REDUCTION PLANT

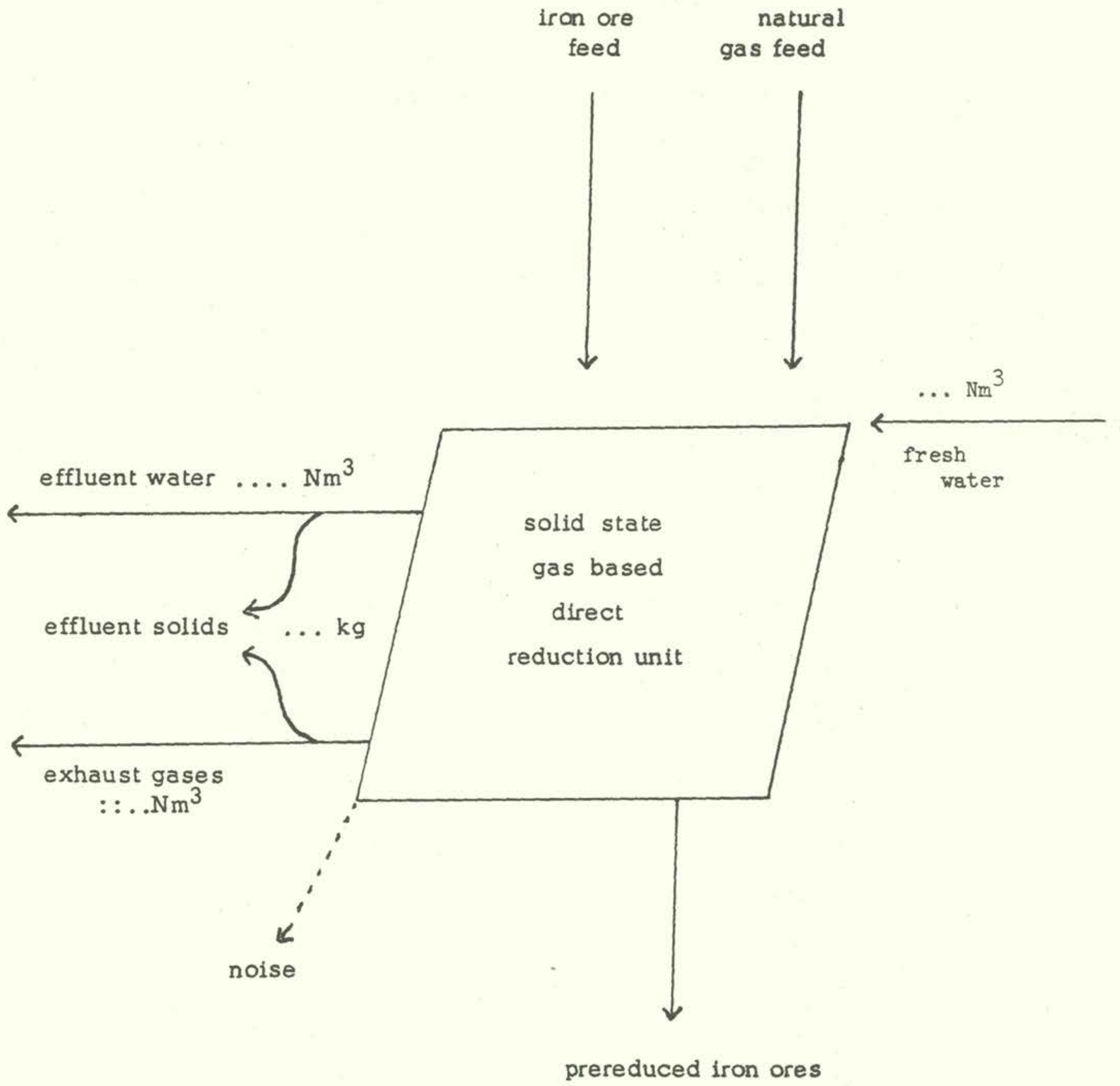


Figure 14

SCHEMATIC IMPACT ON THE ENVIRONMENT OF A SOLID-COAL-DIRECT REDUCTION PLANT

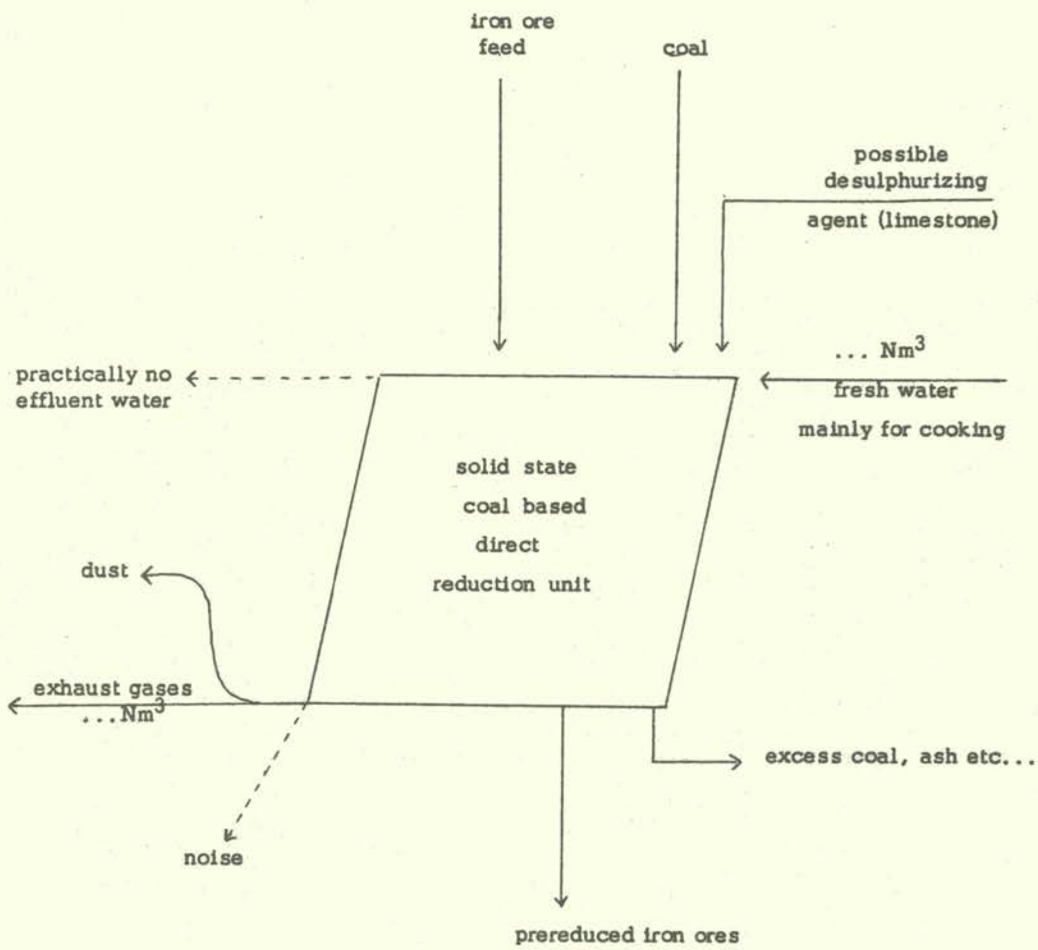


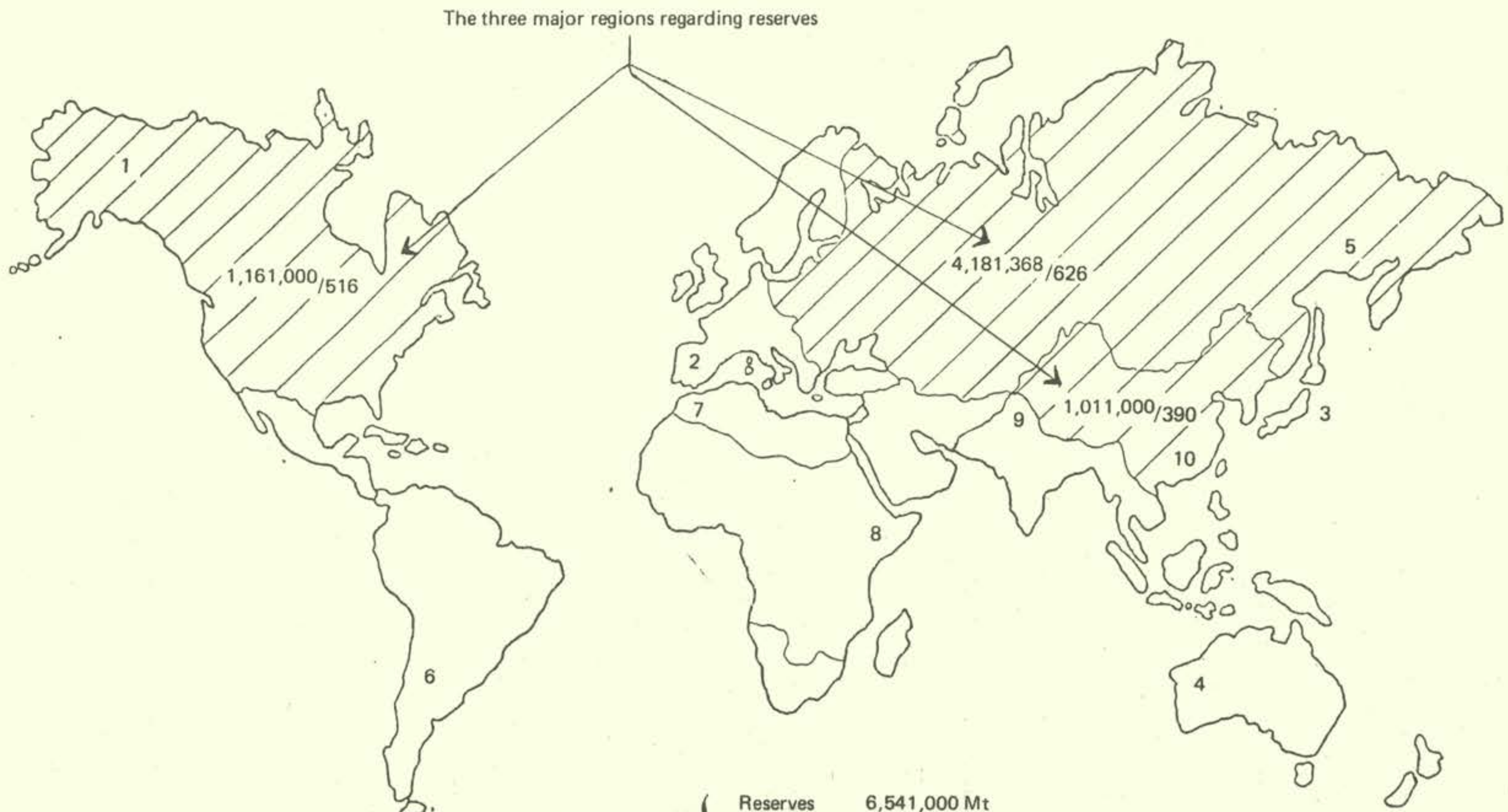
Figure 15

EVOLUTION OF THE SO CALLED "CLASSICAL FLOW SHEET" OF THE IRON AND STEEL INDUSTRY

	——— Evolution ———→
Raw material preparation	Better and larger iron ore preparation, including sintering and pelletizing. Beehive → modern large coke ovens by product recovery → formed coke ?
First stage SMELTING REDUCTION	Better charged, equipped and controlled Blast Furnaces
Second stage STEELMAKING	Open hearth acid and basic converters → oxygen converters
Grading and casting of liquid steel	Trends to ladle metallurgy and grading furnaces - - - - - - - - - - definite trends to continuous casting

Figure 16

RESERVES AND PRODUCTION OF COAL



World Coal	Reserves	6,541,000 Mt
	Production (1971)	2,124 Mt

Figure 17

Fe BALANCE INTEGRATED STEEL WORKS

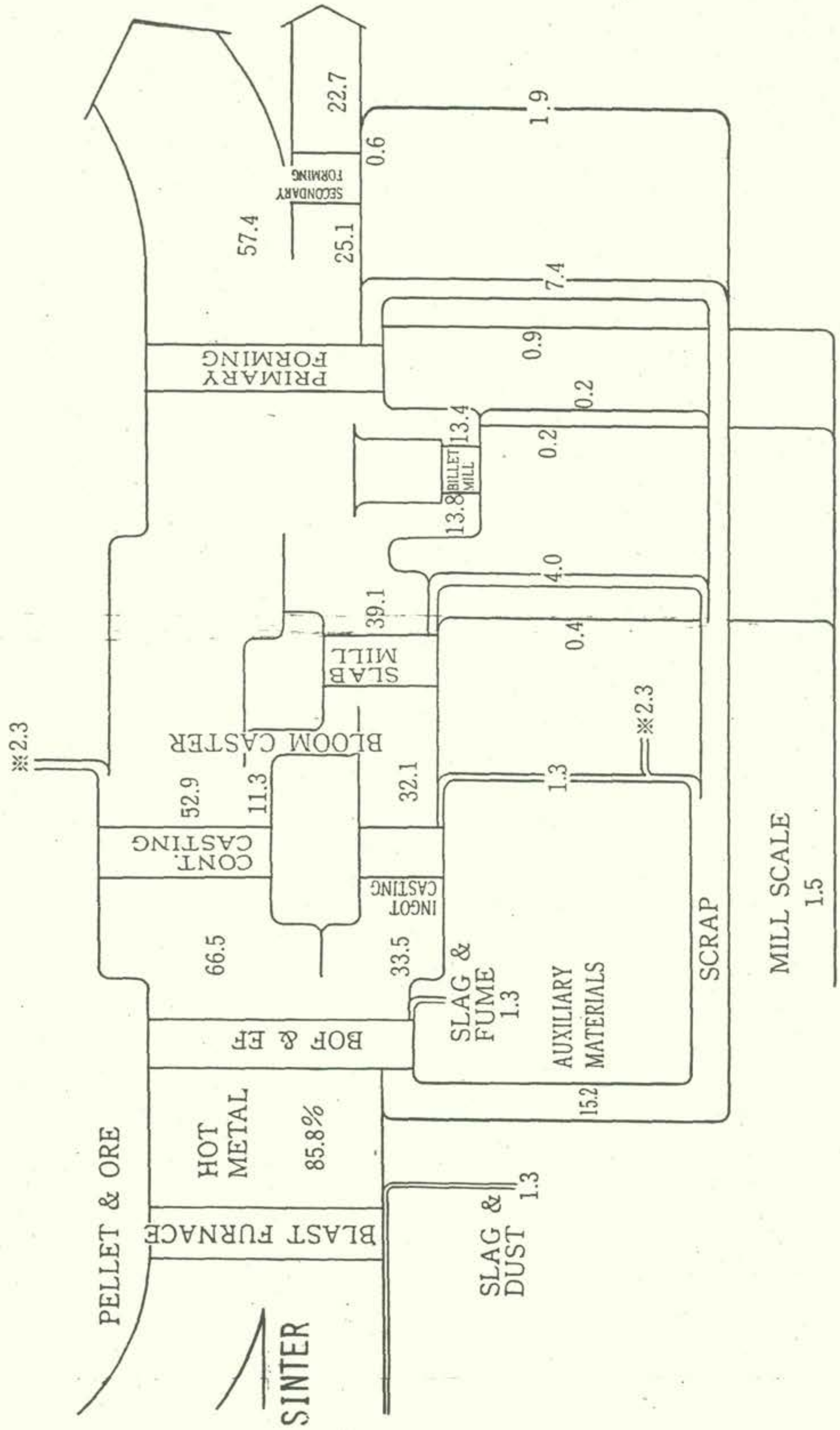
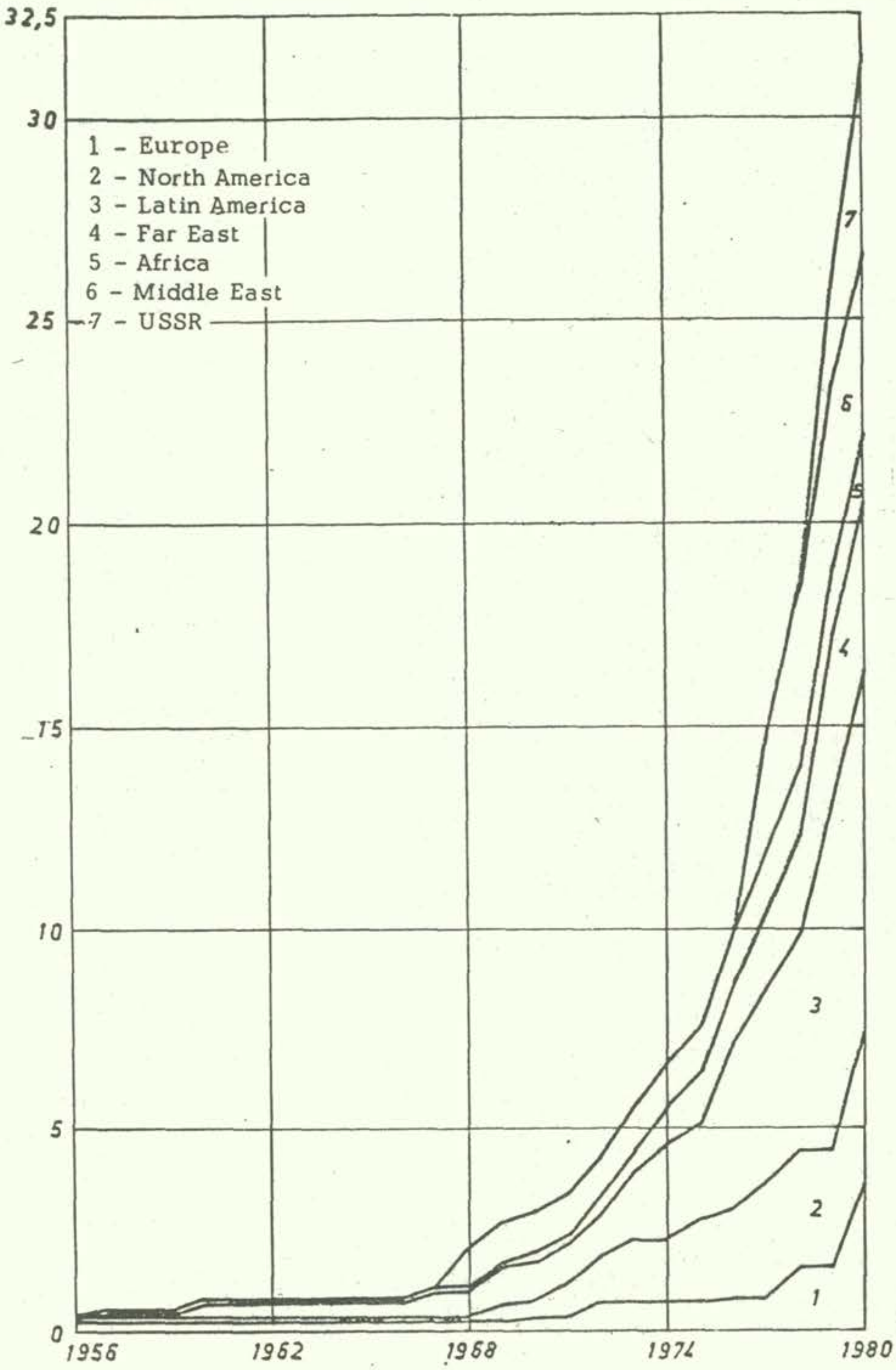


Figure 18

GEOGRAPHICAL DISTRIBUTION OF DIRECT PRODUCTION ANNUAL CAPACITY
(Mt or 10^6 t/year)



Production capacity

Figure 19

RESERVES AND PRODUCTION OF NATURAL GAS

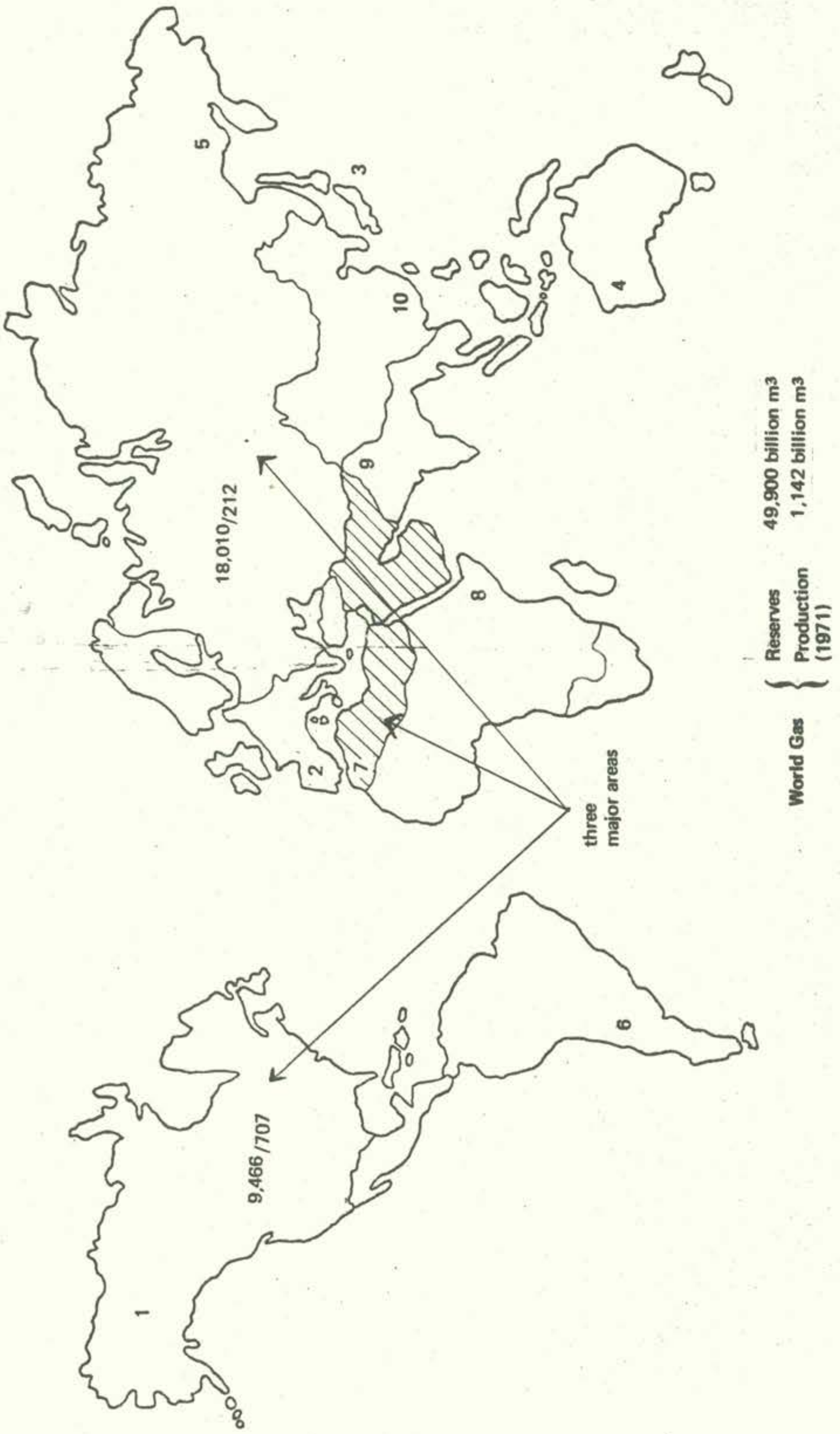


FIGURE 20

RESERVES AND PRODUCTION OF OIL

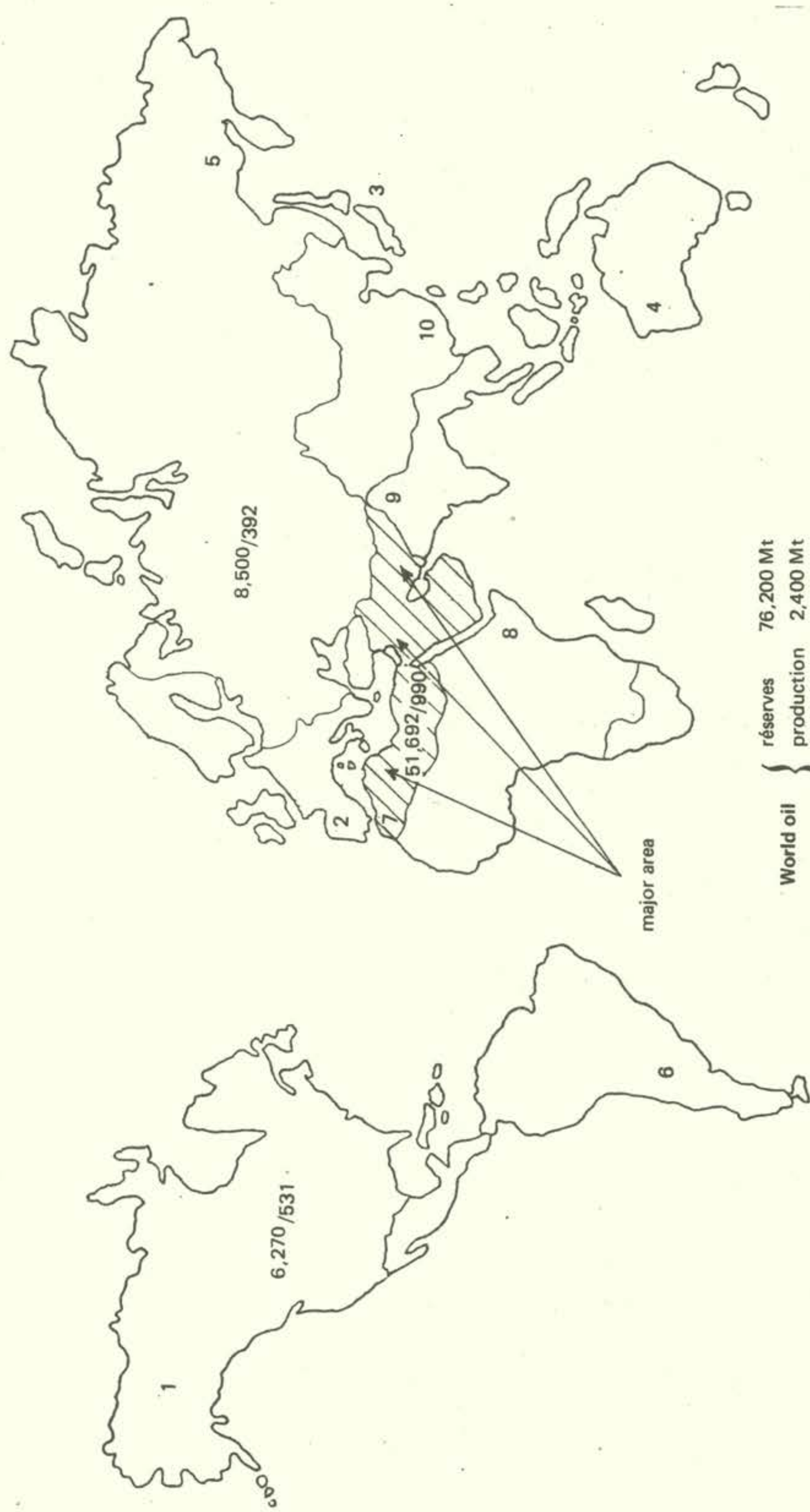


Figure 21

COMPARISON OF THE ENERGY CONSUMPTION OF MODEL PLANTS A, B1 & B2 BY PROCESS

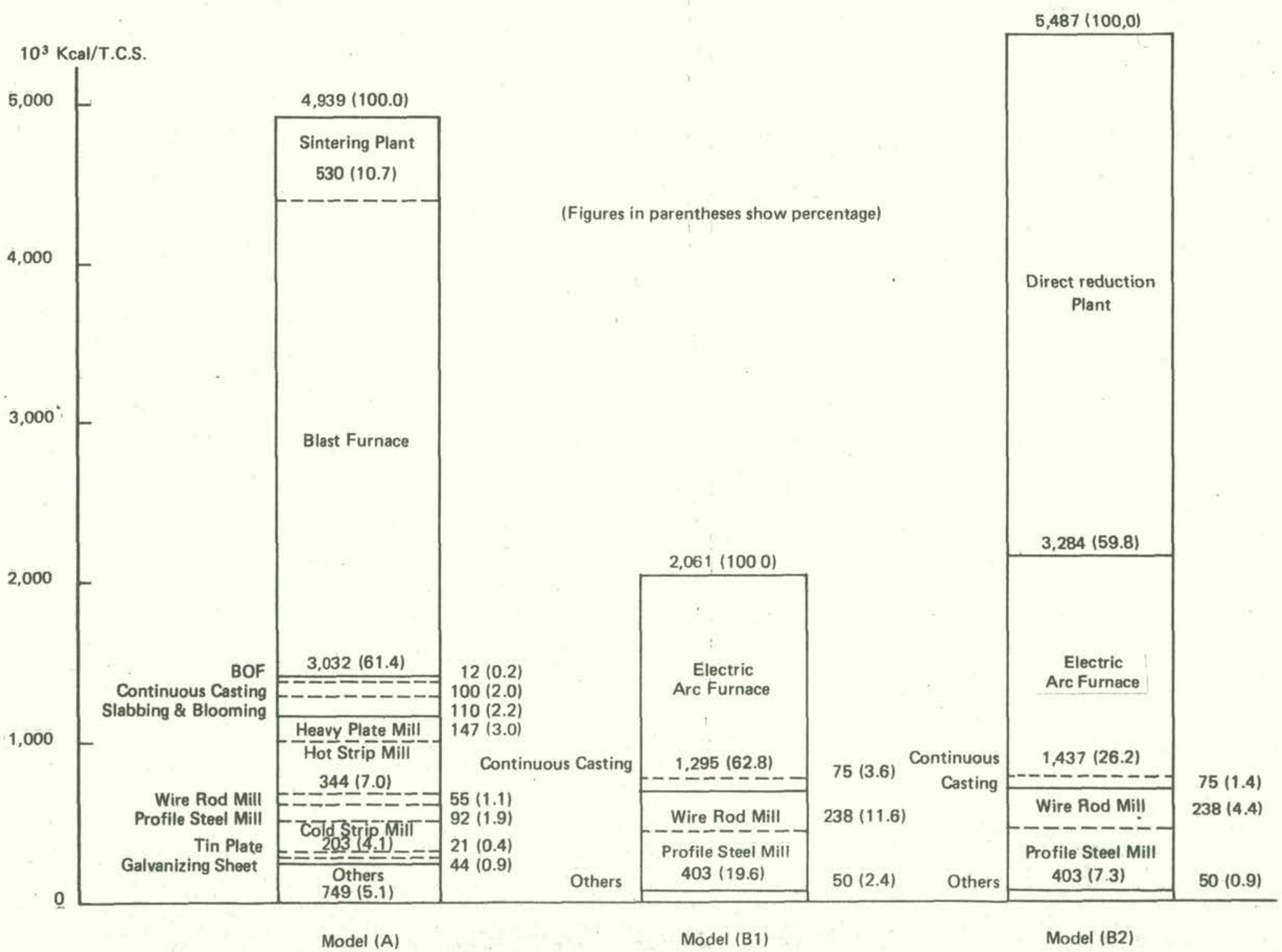


Figure 22

COMPARISON OF THE ENERGY CONSUMPTION OF MODEL PLANTS A, B1 & B2 BASED ON FUELS USED

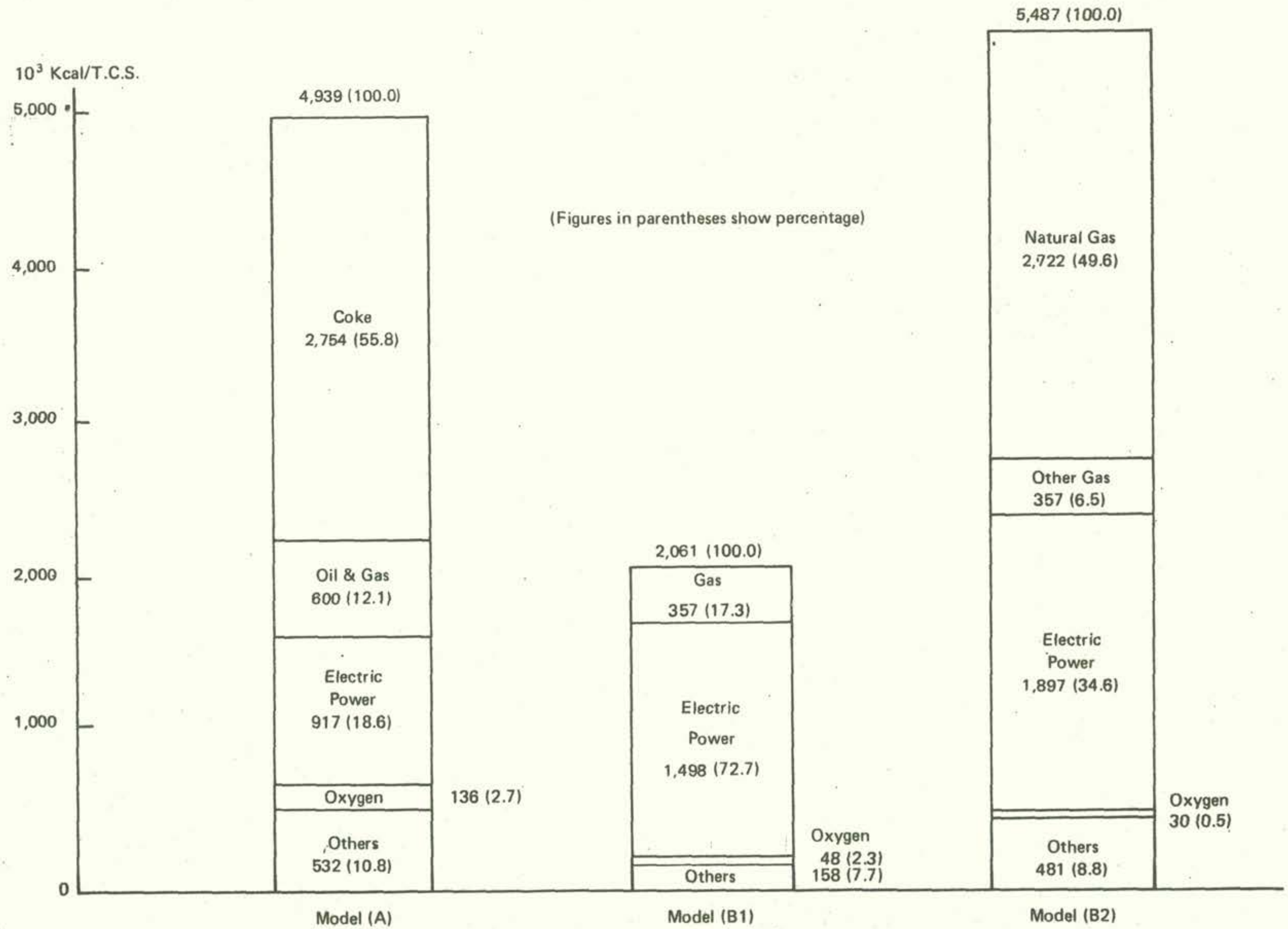


Figure 23

VARIOUS SCHEMES BASED ON SOLAR ENERGY

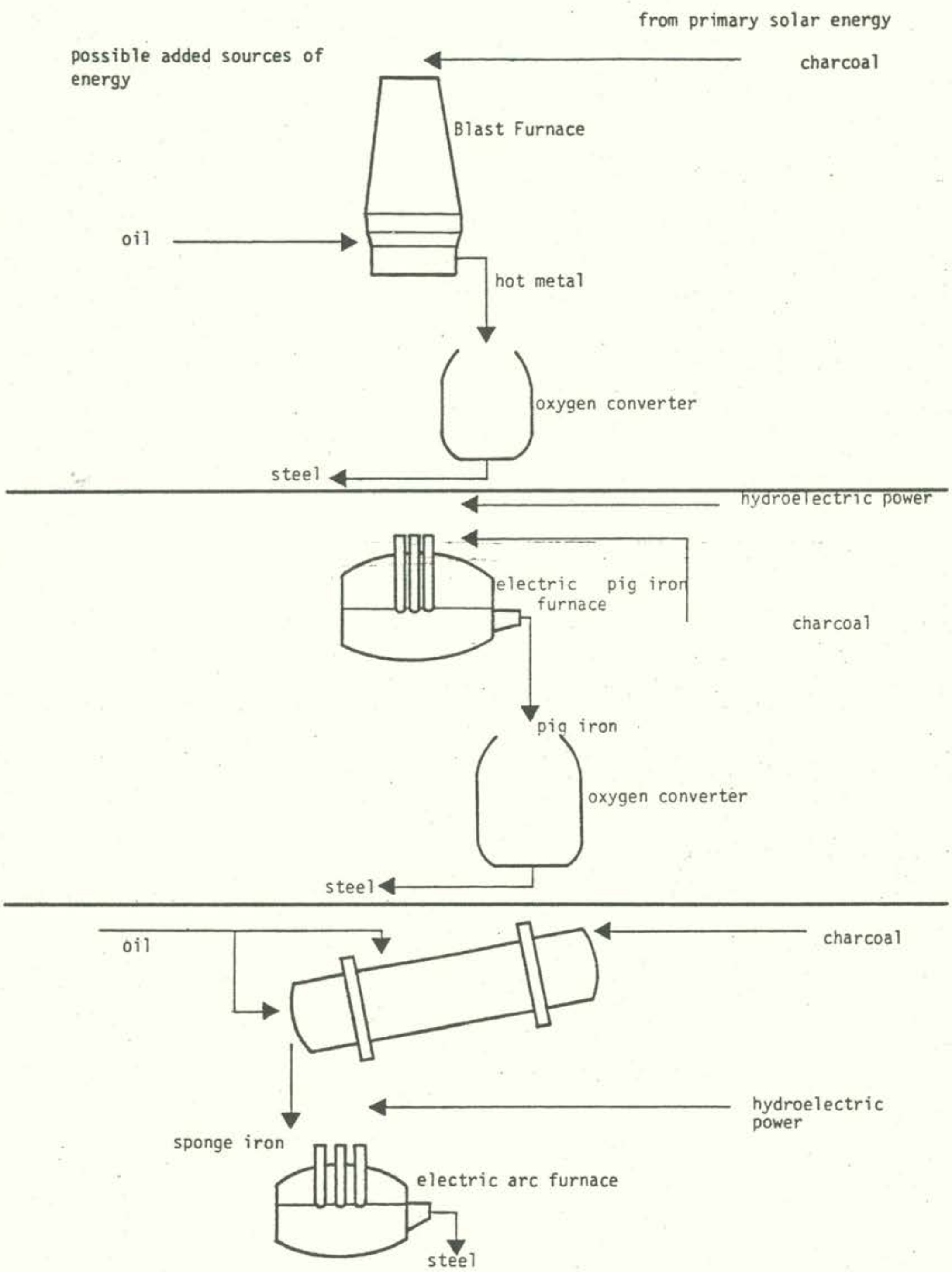
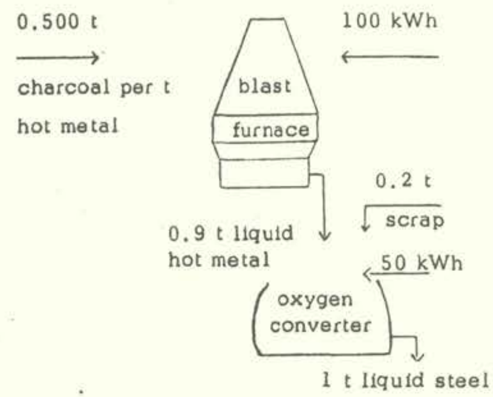
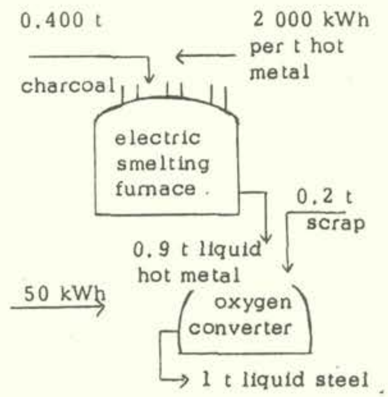
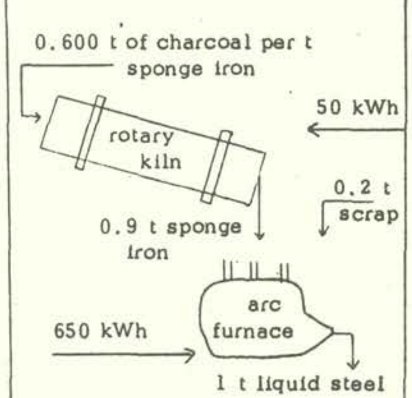


Figure 24

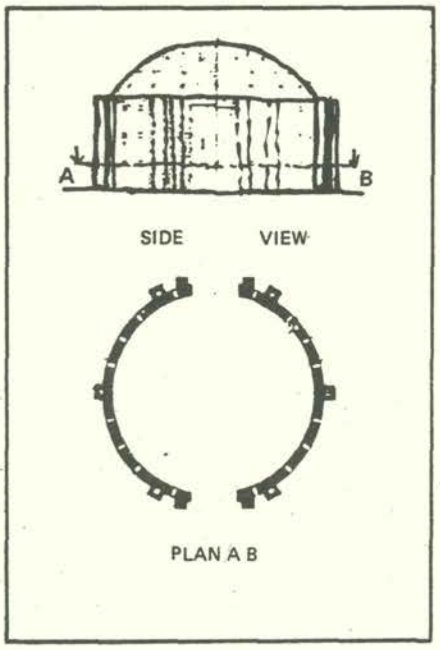
SCHEMATIC COMPARISON OF THE THREE FLOW SHEETS

simplified flowsheet			
energy charcoal t/t of steel	0.450 (13 200 MJ)	0.360 (10 500 MJ)	0.540 (15 800 MJ)
kWh/t of steel	140 1 344 MJ ° or 504 MJ °°	1 850 17 760 MJ ° or 6 660 MJ °°	695 6 672 MJ ° or 2 502 MJ °°
recovery of	405 Nm3 blast furnace gas at 3.7MJ/Nm3 i.e. 1 507 MJ	540 Nm3 smelting furnace gas at 8.4 MJ/Nm3 i.e. 4 520 MJ	———

° : with conventional power and efficiency of 9.6 MJ/kWh °° : with the equivalent of 3 600 MJ/kWh

Figure 25

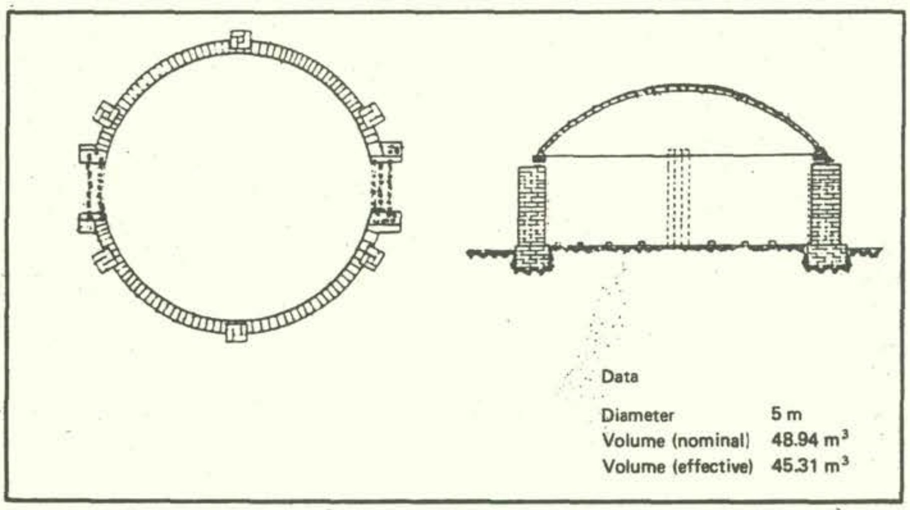
BELGO-MINEIRA and ZAPLA FURNACE



Source : Methods of producing charcoal without recovery of biproducts, Bartolomé Piza, Presentation at ILAFA Conference on Charcoal, Mexico 25-30 July 1976

Figure 26

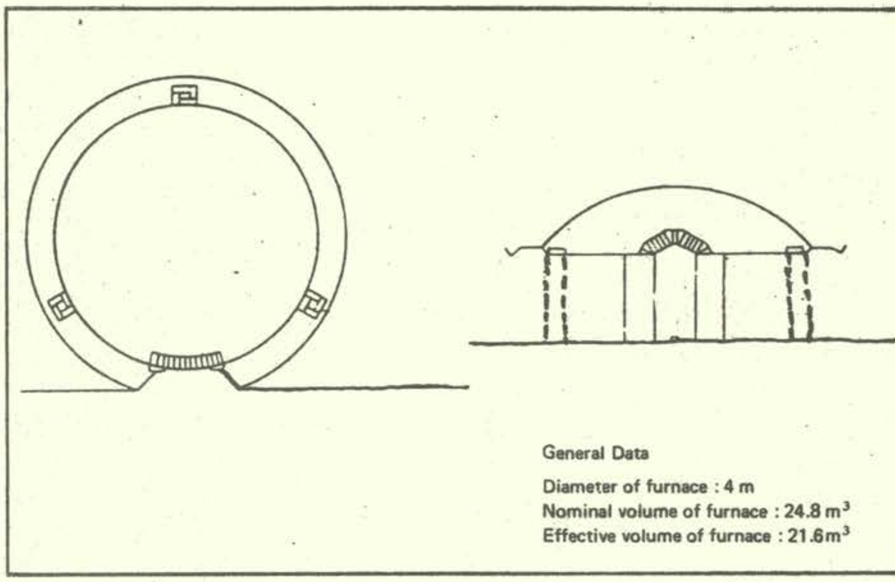
ACESITA FURNACE



Source : Siderurgia Brasileira a Carvao Vegetal. Work undertaken by ABM for UNIDO, December 1975

Figure 27

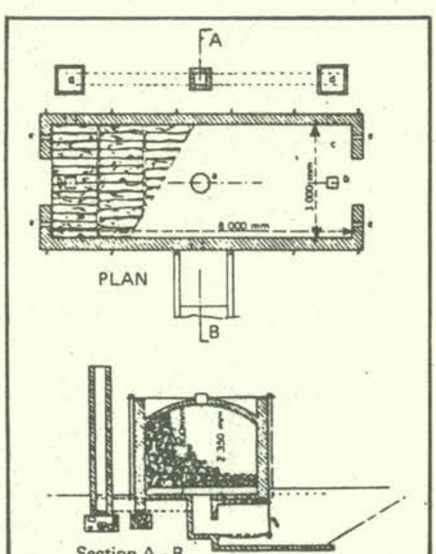
ACESITA & BELGO-MINEIRA FURNACE



Source : Siderurgia Brasileira a Carvao Vegetal. Work undertaken by ABM for UNIDO, December 1975.

Figure 28

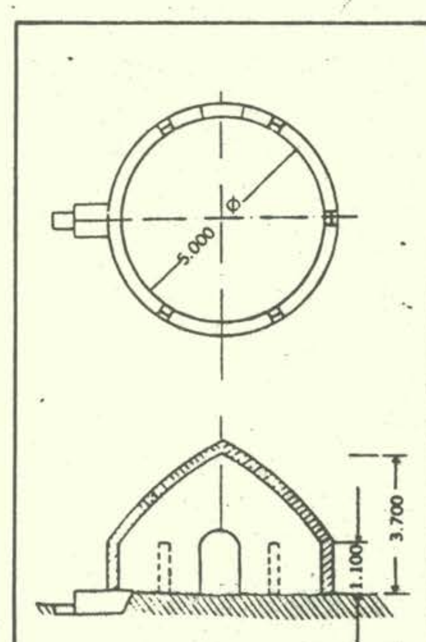
SCHWARTZ (ZAPLA) FURNACE



Source : Methods of producing charcoal without recovery of biproducts. Bartolomé Piza. Presentation at I LAFA Conference on Charcoal, Mexico, 25-30 July 1976.

Figure 29

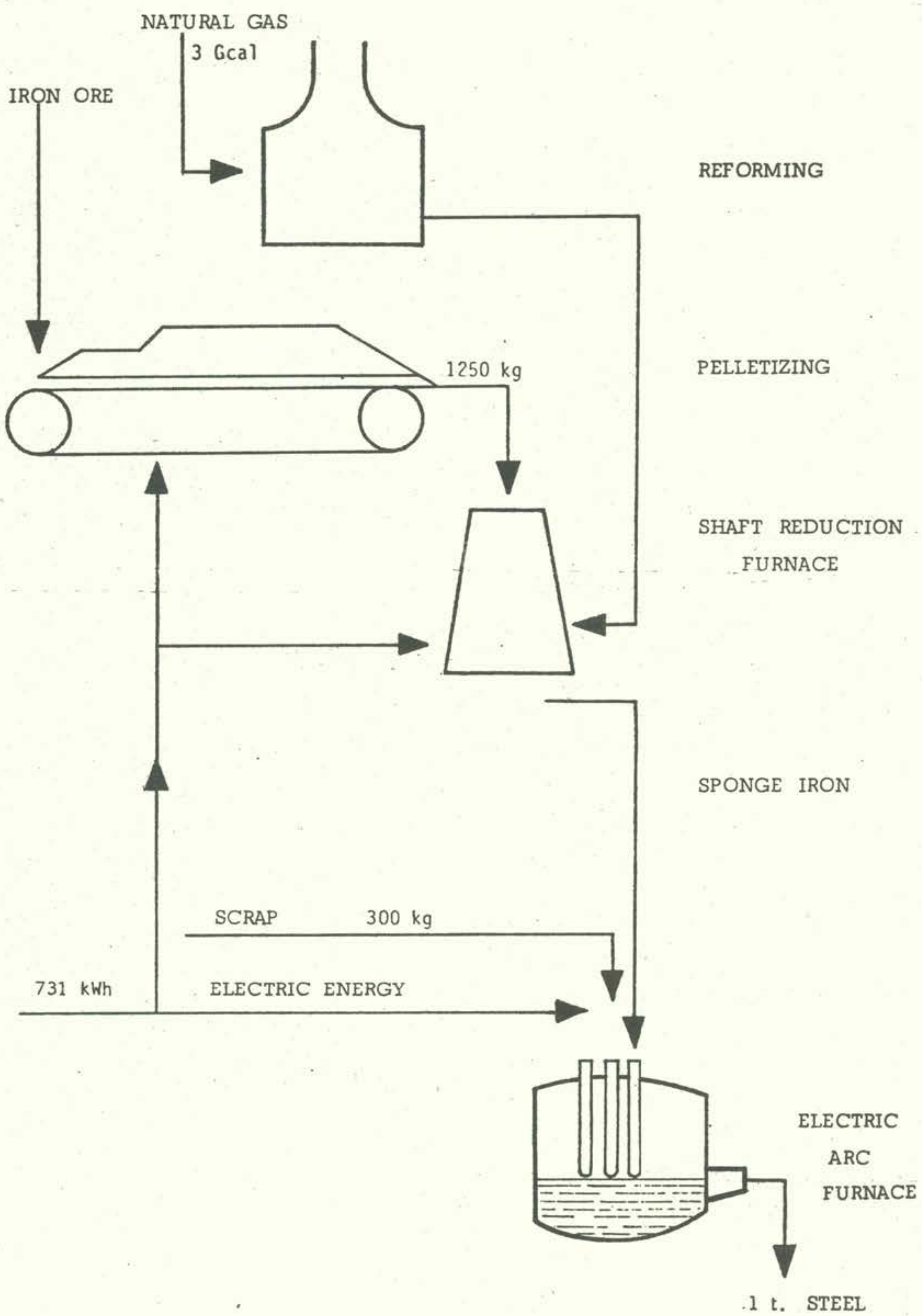
SELAMA (Malayawata Steel Bhd) FURNACE



Source : S.E.A.I.S.I. Quarterly, p. 36, April 1975

Figure 30

CLASSICAL SCHEME OF A DIRECT REDUCTION-ELECTRIC STEELMAKING PLANT



ALTERNATIVE FLOW DIAGRAMS FOR DIRECT REDUCTION WITH HIGH TEMPERATURE NUCLEAR REACTOR AND ELECTRIC STEELMAKING :

Figure 31

Case a : nuclear reactor separated from Ironmaking facilities.

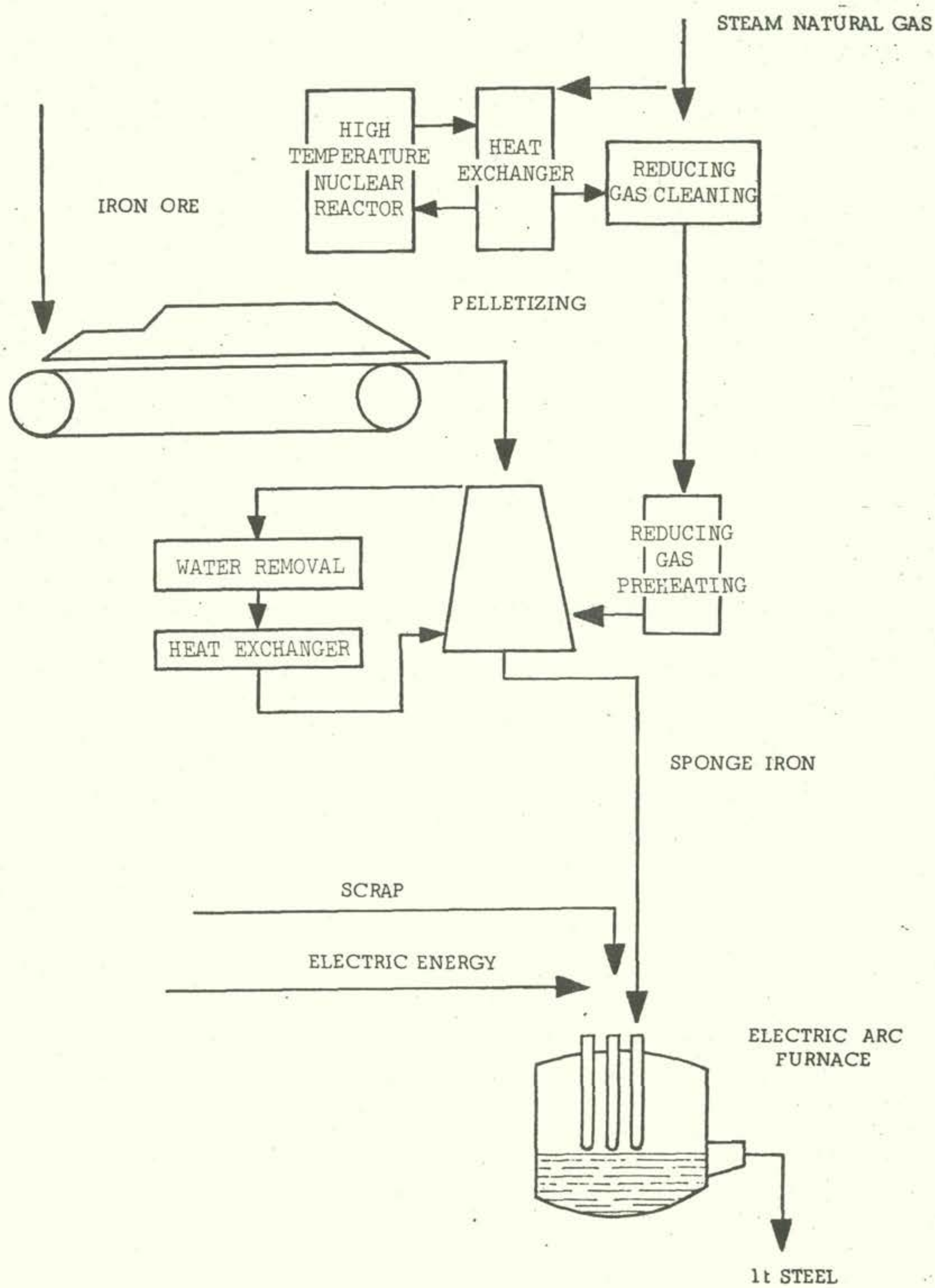
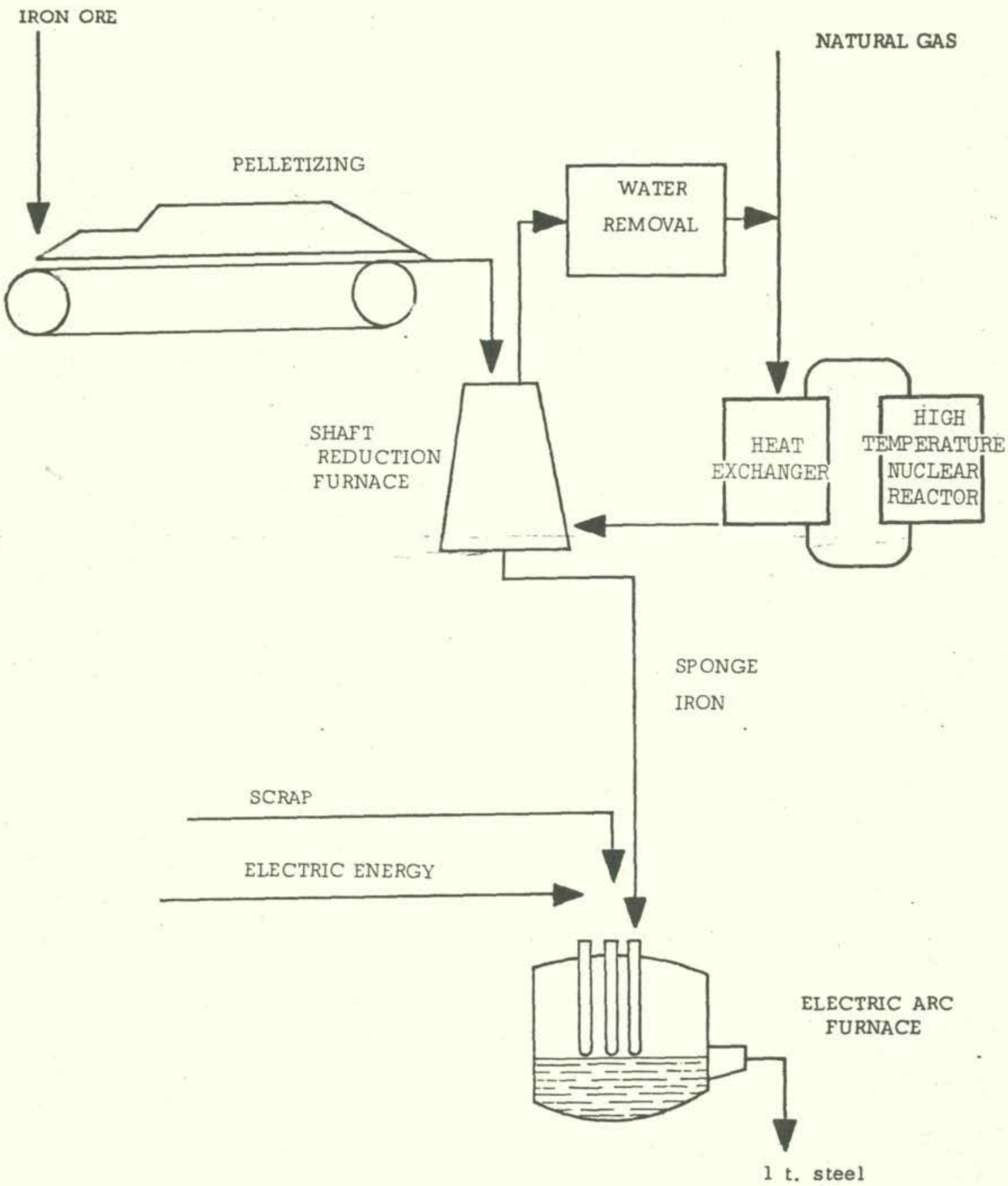


Figure 32

Case b : direct association of nuclear reactor with Ironmaking.



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