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ENVIRONMENTAL ASPECTS OF IRON AND STEEL PRODUCTION

An Overview

UNITED NATIONS ENVIRONMENT PROGRAMME

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Industry & Environment Office
UNITED NATIONS ENVIRONMENT PROGRAMME

First edition 1984

ISBN 92 807 1078 8

FOREWORD

Within the context of UNEP's on-going review of the environmental aspects of specific industries, a workshop of experts was held in Geneva in October 1978 on the environmental aspects of the iron and steel industry. A UNEP Secretariat report was prepared as the basic document for examination at the workshop. The proceedings have been published in the UNEP Industry and Environment Workshop Proceedings Series, Volume I.

With a view to making more widely known the environmentally related issues associated with steel making and to providing guidance to environmental policy makers in Governments and industry, the UNEP Secretariat has prepared this overview on the iron and steel industry, drawing on material gathered in association with UNEP's on-going consultation in this industrial sector and on the basis of the UNEP Secretariat report agreed at the workshop. A first draft of this overview was circulated for comment to those experts who participated in the original workshop, as well as to other partners in UNEP's consultation in this sector. Amendments and additions received by the beginning of September 1983 were incorporated.

In support of the overview, a technical review is also being prepared which deals with the technical aspects of environmental management in steel making, particularly covering air and water pollution, solid waste and noise problems associated with new integrated steel works based on the classical production route. Environmental management guidance in relation to the direct reduction route to steel making is the subject of a special review entitled Environmental Guidelines for the Direct Reduction Route to Steel Making.

It should be borne in mind that environmental protection technology in relation to the steel industry is continually changing and no overview can be comprehensive and completely up to date. Whilst it is considered that the information given in this overview is very representative of the current state of the art, this document is not meant to be used directly in design specification for specific pollution abatement technology and equipment for a particular plant. This requires the advice of reliable engineering consultants and equipment manufacturers. The purpose of the overview is rather to provide basic knowledge and an understanding of environmental protection in relation to the steel industry. Attention is drawn to certain conclusions made by the experts at the time of the UNEP workshop, namely : that adequate environmental protection should be an essential requirement in the planning, designing, siting and construction of a steel plant, the responsibility for its cost-efficient application resting with the management and technical experts of the industry ; that, in the overall economic context, it is more cost-efficient to foresee and incorporate adequate environmental protection measures from the inception of the plant rather than to add on later ; that a prerequisite of environmental protection is the proper operation and management of plant and processes as well as the regular maintenance and repair of pollution control equipment ; that all plant personnel should receive the environmental education and training appropriate to their functions in the industry and that application of appropriate measures enables the operation of a steel industry under environmentally sound and acceptable conditions.

ACKNOWLEDGEMENTS

The Secretariat gratefully acknowledges the advice of Mr. Christopher Davis (British Steel Corporation), the International Iron and Steel Institute (IISI), Brussels, and all participants in the UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry in the preparation of the initial Secretariat report ; and of Mr. Jean Raguin (President of the Laboratoire d'Etude et de Contrôle de l'Environnement Sidérurgique - LECES) in the preparation of this document, as well as the help of UNEP consultant Mr. C. A. Cochrane in its editing. The Secretariat further acknowledges the valuable suggestions and comments on the text provided by :

- Mr. A. Abate, International Labour Office
- Mr. S. Das Gupta, M. N. Dastur & Company (P) Ltd., India
- Mr. Hans Eberling, Ministry for Ore Mining, Metallurgy and Potash, German Democratic Republic
- Dr. Y. Hasegawa, World Health Organization, Switzerland
- Mr. D. Larré, UNEP Industry & Environment Office, France
- Mr. T. Matsuda, International Iron and Steel Institute, Belgium
- Mr. H. Obata, Brazil
- Mr. Jesus M. Peña, HYL Technology, Mexico
- Mr. Dhira Phantumvanit, UNEP Industry & Environment Office, France
- Mr. Jacques Pivont, Belgium
- Mr. W. Tso-Ting, Chinese Society of Metals, People's Republic of China
- Mr. E. F. Young, American Iron and Steel Institute, USA

The UNEP Officers responsible for this activity were Mr. John A. Haines, Senior Programme Officer, on inception, and Mr. Takao Hamada, Senior Industry Liaison Officer, on conclusion.

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CHAPTER I

THE IRON AND STEEL INDUSTRY AND ITS CURRENT DEVELOPMENT

(i) Iron and Steel Processes

1. The raw materials for iron and steel making are iron ore, coal or wood charcoal, limestone, natural gas and a variety of other materials such as fluxes, oil, etc., as well as air and water. A considerable amount of steel (approximately 40%) is also made from scrap. The main processes which transform these materials into iron and steel products are described below in this section. Figure 1 gives a flow-line on steel making (1).

a) Iron ore mining

2. Iron ore is naturally occurring and is mined from geological deposits, both at open cast sites and underground. Mining is frequently undertaken by the industry itself or by enterprises closely associated with the industry. The ores are treated according to type, quality and process requirements. Operations may include crushing, screening, beneficiation, and in some cases calcining and drying. Specific quality of ore is required for direct reduction, depending on the design of the process employed. Advanced magnetic, chemical, and physical processing may be needed to treat ores in certain circumstances.

b) Scrap

3. Scrap consists of ferrous wastes collected from three different sources within the steel industry itself ; from engineering and other industries using iron and steel ; and from manufactured goods containing iron and steel which are rejected at the end of their useful life. Its collection from sources outside the industry is usually an operation separate from the steel industry. Depending on its origin, scrap often contains other materials which may interfere with the steel making process or the quality of the product. For further details reference should be made to chapter III (e).

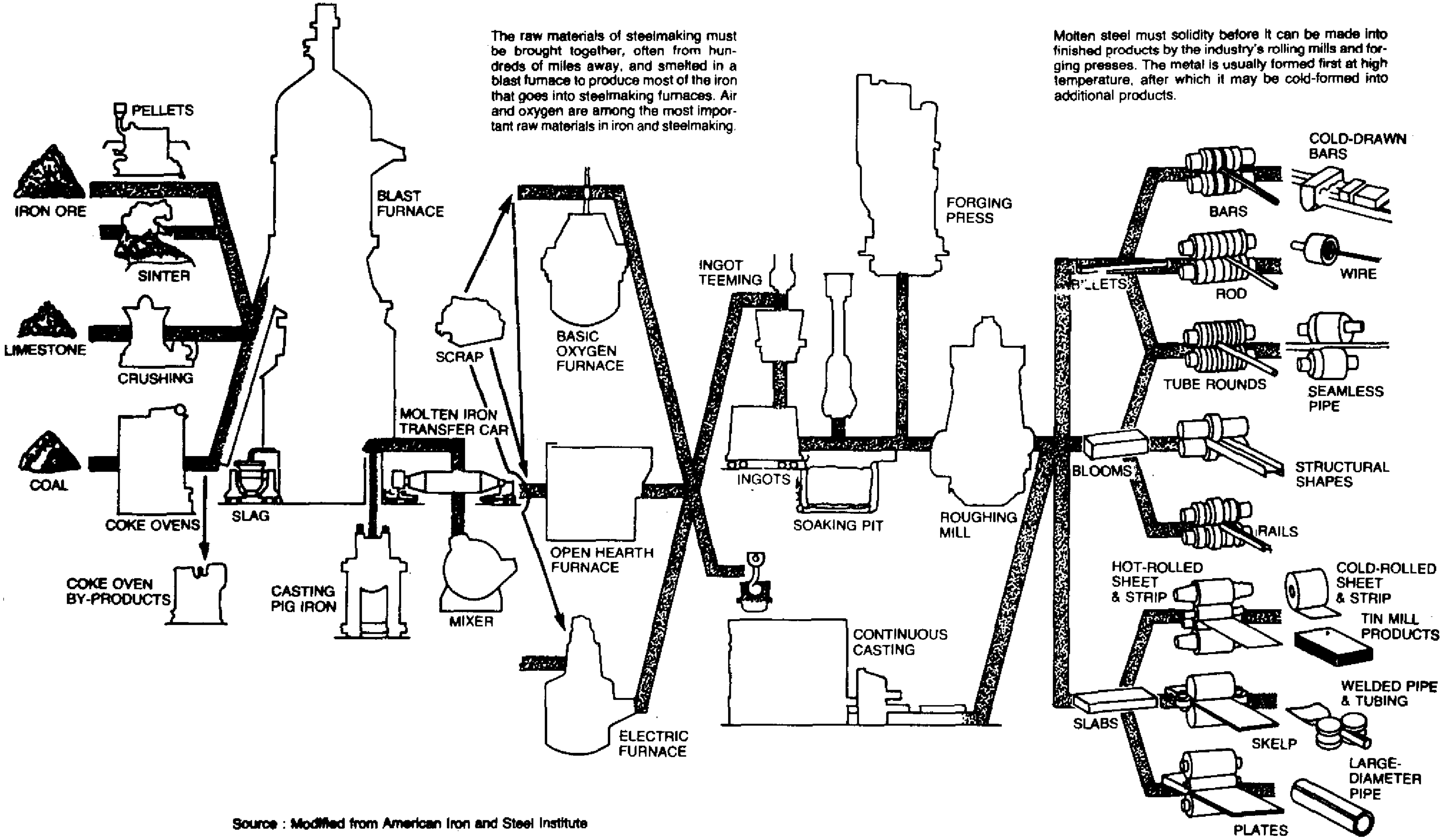
c) Fluxes

4. The main fluxing materials used in the industry are limestone/lime, dolomite and fluorspar. Limestone is quarried and crushed to suitable size. Some limestone is converted to lime by heating in kilns.

d) Coke-making

5. The other major raw material, coking coal, is also mined from natural deposits, but this is normally done by the coal industry and is not considered further in this overview. Coking is traditionally associated with iron and steel and foundry operations but not universally so. The special type of coking coal is washed, crushed and screened in preparation for blending prior to charging to the coke-making process. By far the majority of coke is produced in the traditional vertical slot oven from which the by-products of coal distillation can be recovered. In the area of new technology, improvements to conventional coking operations are being developed in the form of improved charging techniques, e.g. pipeline charging of coal, slot ovens and in a new concept of producing coke directly from briquetted

FIGURE 1 - A FLOWLINE ON STEELMAKING



Source : Modified from American Iron and Steel Institute coal (i.e. formed coke). This last continuous process of coking is used with recirculation of the gas, after washing and by-product removal, for heating purposes. Attempts are also being made to develop techniques for stretching resources of coking coal by addition of other coals. Dry quenching with an inert gas, such as nitrogen or carbon dioxide, with recuperation of energy in the form of steam is also practised at some integrated works.

6. The metallurgical coke is cut and screened, and the smaller sized material, coke breeze, is used as a fuel in the iron ore agglomeration processes with the larger sized coke being used as a fuel in the blast furnaces.

7. Wood charcoal can also be used as a fuel in a similar fashion to coke, although its lower mechanical strength and generally lower availability make it much less important in world-wide terms. It may become more significant in certain regions such as South America and South East Asia, with abundant wood resources, but no coking coal.

e) Preparation of iron ore

8. Prior to charging the iron ore to the direct reduction or blast furnace processes, it is generally agglomerated to give suitable size and strength of material. Sintering or pelletizing are normally used in this process. In the sintering process the finely crushed iron ore is mixed with coke breeze or, in some cases coal, and the appropriate fluxing materials. At the sinter plant the mixture is spread on a continuous grate (sinter strand), ignited from the tip of the surface by a gas or oil fired ignition hood, and air is drawn through the bed of material so that in burning of the coke breeze the mix is fused into a porous but strong material (sinter). The sinter is broken up and screened in readiness for charging to the blast furnace, the fines being recycled within the process.

9. In pelletizing the iron ore fines have a suitable binding agent added so that pellets can be formed which are then dried and heated in a kiln to between 1200 and 1370°C to achieve agglomeration of the iron ore particles. The control of moisture content is important to ensure the strength of the pellets. The direct reduction process requires predominantly pellets as feed material.

10. Nodulizing and briquetting are also ore preparation treatments for certain processes. In nodulizing, ore fines are heated in an oil or gas fired rotary kiln. The ore agglomerates into lumps near the fusion point of 1260 to 1370°C. Nodules are not used in the blast furnace. For the briquetting process ore fines are mixed with a binder and compacted between rotating rollers. In hot briquetting the ore is heated to between 870°C and 1040°C and then briquetted in a press at loads of 45 to 55 tons.

f) Reduction of iron ore

11. The main process used for reducing iron ore to metallic iron is the blast furnace which is in essence a large vertical shaft which is charged from the top with iron ore, sinter or pellets, together with coke and fluxing material such as limestone. To achieve the necessary temperatures and reducing conditions, heated air is injected at the base of the furnace. Molten iron is tapped from the bottom of the furnace, as is the liquid slag formed by the fluxes and gangue in the iron ore. Iron can also be produced in electric reduction furnaces. Molten

iron is passed on for refining in the steel making process or cast and solidified into pig iron. The gas given off from the furnace contains carbon monoxide and can be collected and cleaned for use as a fuel.

12. A recent industrial innovation is direct reduction of iron ore in the solid state, which is achieved either with gaseous (e.g. natural gas) or solid reductants (e.g. coke or coal). Various processes are in existence. In some, the direct reduction is carried out on naturally sized ore. In others, the iron ore is formed into pellets prior to being heated in a kiln in the presence of the reducing agent. The product, sponge iron or pre-reduced pellets, is used as a substitute for steel scrap, for example in electric arc furnaces. Direct reduction is very much a developing technology which has not yet seen its full potential. It is clearly an attractive alternative to conventional iron making, where adequate supplies of low cost hydrocarbon fuels are available as reductants (2).

13. The steel making processes commonly in use today which utilize molten iron as a charge material are the open hearth furnace and the basic oxygen furnace. The acid and Bessemer processes, which were bottom-blown with air or oxygen enriched air, have declined and almost disappeared. The open hearth and tandem processes, although still of importance, are being progressively replaced by the basic oxygen furnace, either top or bottom blown. For example, 56% of the world's steel production is now by the basic oxygen furnace (BOF), 22% by electric arc furnace and 22% by open hearth furnace and other processes (3).

14. The open hearth process can either be based on 100% scrap, which is melted by oil fired burners or on a hot metal/scrap mixture. In the latter case oil fired burners are still required to maintain the necessary temperatures. Refining of the steel is by the formation of an appropriate slag and by the addition of oxidizing agents such as ore or oxygen to oxidize the carbon and other impurities in the iron. Oxygen shortens the process time considerably.

15. In the BOF process, scrap and hot metal are charged to the converter and oxygen is blown onto the surface of the melt via a lance to achieve rapid refining. No additional heat is required in the process. The reasons for the rapid growth in the adoption of the BOF process can be seen from the fact that whereas an open hearth furnace not using oxygen would produce 200 tons of steel in 12 hours, the BOF can achieve this in 1/20th of the time.

16. Present day developments in bulk steel making include a new generation of bottom blown processes (e.g. Q-BOP, OBM, LWS) similar in concept to the Bessemer process, but using high purity oxygen with hydrocarbon gases to provide protection of the tuyeres in the base of the vessel. The AOD (Argon Oxygen Decarburisation) process is similar in concept, but is used on a relatively modest scale for the refining of high alloy steels with argon as the protective gas for metallurgical reasons.

17. Another commonly used steel making process employs the electric arc furnace. It is essentially a cold metal scrap based process using electrical power as a source of heat for melting. Direct reduced iron may also be added (see paragraph 11 above). Refining may be with ore addition or oxygen lancing and oxy-fuel burners may also be used to assist melt down. The electric arc process is suitable both for conventional steel production and the manufacture of special alloy steels.

g) Ladle metallurgy

18. Whilst steel making furnaces are highly versatile, accepting a wide range of raw materials for producing a variety of steels, it may also be necessary to employ secondary metallurgical processes in the ladle immediately after tapping. A further range of chemical composition adjustments may be made such as : decarburization ; refining and deoxidation products. Furthermore, homogenization and temperature adjustment before casting can be made in the ladle.

h) Casting

19. Molten steel from the ladle may be cast into ingots from which products are later manufactured or cast directly into specific products. There is a growing practice of continuous casting whereby molten steel is cast directly into semi-finished products such as slabs, bloons or billets, which are immediately rolled or further treated to produce bars, shapes or flat products.

i) Hot forming of steel

20. Shaping of steel into a wide range of products is carried out in rolling mills with soaking furnaces or reheating furnaces, as required, to maintain appropriate temperatures in the material for rolling. Although the products are varied, the basic principles of rolling are generally similar, with the rolls suitably designed to produce the final product shape required. Certain products are formed by forging.

j) Cold rolling and finishing

21. In the steel strip industry, the hot rolled strip is pickled with acid to provide a clean surface and the product may then be cold rolled and annealed to achieve the desired properties and surface finish. There are a variety of finishing processes including galvanizing, tinning, organic coating and painting. Pickling, annealing, heat treatment, etc., may also be applied to other products than strip. Hydro-shot blast may also be used for surface cleaning.

k) Foundry iron

22. The production of molten iron for iron foundries is generally by the cupola process or by straightforward electric melting processes. The cupola is a vertical shaft furnace charged with iron and steel scrap and coke, and injected with either a cold or hot air blast to burn the coke and achieve melting. Foundry iron contains high levels of carbon and silicon and is cast direct into products after suitable treatments depending on metallurgical requirements.

l) Ferro-alloys

23. Ferro-alloys are essential additive materials in steel making and they are produced in a variety of processes, including blast furnace (for ferro-manganese), electric arc furnaces and thermic fusion processes.

(ii) Size, Distribution and Future Prospects of Industry

24. World steel production has grown rapidly over the last 30 years from 114 million tons in 1945 to a peak of 708 million tons in 1974, decreasing to 673 million tons in 1977, then increasing to 717.1 million tons in 1980. There was a small drop in production to 707.6 million in 1981. Within that growth pattern, significant changes are occurring in the geographical distribution of production and consumption, as will be seen in Table 1 (3). During the last ten years there has been a steady expansion of steel production in a number of developing countries (see Table 2). The geographical distribution of apparent steel consumption is shown in Table 3 (3).

25. Broadly speaking, the western industrialized countries are net exporters of steel, and the developing countries are net importers. There are certain notable exceptions, as may be seen by comparing Tables 2 and 3. In the future the geographical pattern of steel production is expected to change even more significantly. Whilst estimates of total steel production by the year 2000 are very uncertain, it is clear that the developing countries will increase their share of steel production substantially. Various scenarios for steel production in 1990 were examined at the UNIDO Third Consultation on the Iron and Steel Industry and on the basis of projects under way, an increase in annual production capacity of 63 million tons was estimated for the end of this decade (4). If projects under consideration and subject to pre-feasibility studies were also included, the added new capacity could be 117 million tons.

26. Note must, however, be taken of the present situation in relation to the industry, where currently there is overcapacity globally and many installations are producing well under capacity. There is a lack of investment capital, particularly in some developed countries, for either new installations or modifications to existing plant. Furthermore some serious pollution problems remain in relation to most of the steel making steps. This situation will influence not only the type of measures required to achieve clean up of pollution problems, but also the time frame in which effective action is feasible.

(iii) Resource Utilization in the Iron and Steel Industry

a) Energy

27. The steel industry is a major consumer of energy in different forms : coal, natural gas, oil and electricity. The production from iron ore of 1 ton of finished steel requires about 37 GJ. The energy consumption in different forms varies with the type of installation. Figures 2 and 3 are the result of a comparative study of energy consumption (5) for different types of installation : type A is an integrated steel works with an annual production capacity of 8 million tons ; type B_1 is a scrap based mini-steel mill with continuous casting, having an annual production capacity of 1 million tons ; type B_2 is a direct reduction electric arc furnace plant with continuous casting and having a production capacity of 1 million tons per annum.

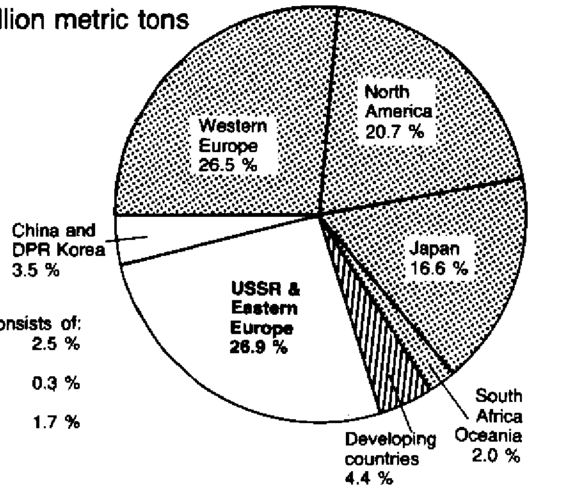
TABLE 1

Steel Production and Consumption: Geographical Distribution, 1974

World Total: 704 million metric tons

Production

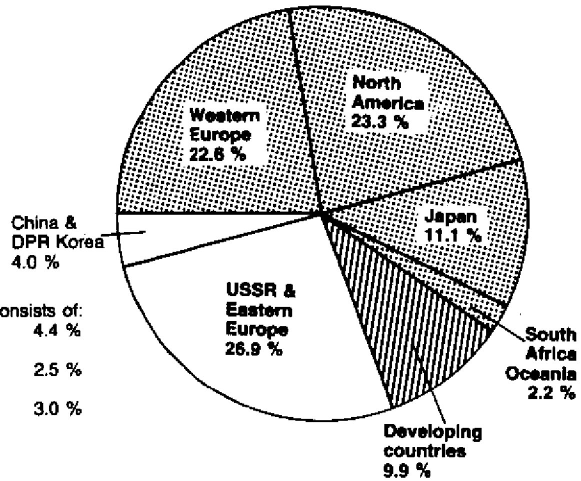
Industrialised countries	65.8 %
Developing countries	4.4 %
Centrally planned economies	29.8 %



Developing countries total consists of:	
Latin America	2.5 %
Africa, except South Africa, and Middle East	0.3 %
Asia except Japan, China, DPR Korea	1.7 %

Consumption

Industrialised countries	59.2 %
Developing countries	9.9 %
Centrally planned economies	30.9 %



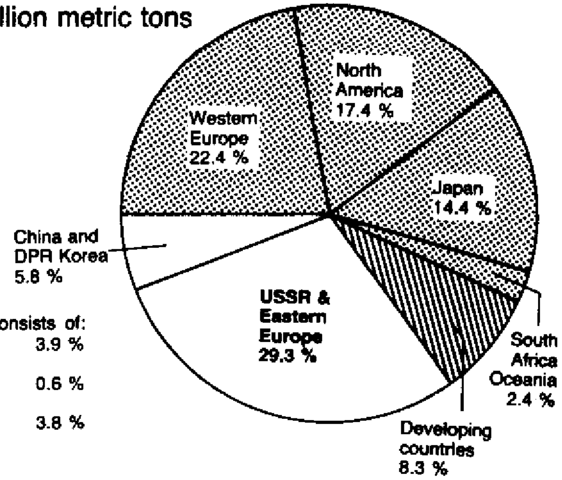
Developping countries total consists of:	
Latin America	4.4 %
Africa, except South Africa, and Middle East	2.5 %
Asia except Japan, China, DPR Korea	3.0 %

Steel Production and Consumption: Geographical Distribution, 1981

World Total: 708 million metric tons

Production

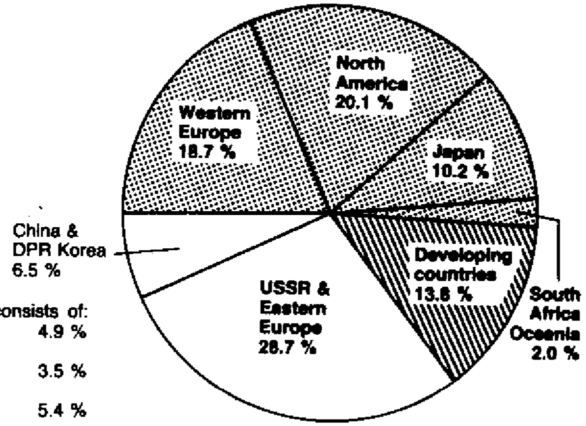
Industrialised countries	56.6 %
Developing countries	8.3 %
Centrally planned economies	35.1 %



Developing countries total consists of:	
Latin America	3.9 %
Africa, except South Africa, and Middle East	0.6 %
Asia except Japan, China, DPR Korea	3.8 %

Consumption

Industrialised countries	51.0 %
Developing countries	13.8 %
Centrally planned economies	35.2 %



Developing countries total consists of:	
Latin America	4.9 %
Africa, except South Africa, and Middle East	3.5 %
Asia except Japan, China, DPR Korea	5.4 %

SOURCE: World Steel in Figures 1982, International Iron and Steel Institute

TABLE 2

THE MAJOR STEEL-PRODUCING COUNTRIES (3)

1981 rank		Crude Steel Production (million tons) 1967	1974	1977	1981
1	USSR	102.2	136.2	147.0	149.0
2	USA	115.1	132.0	113.1	108.8
3	Japan	62.2	117.1	102.4	101.7
4	Fed. Rep. of Germany	36.7	53.2	39.0	41.6
5	China	E14.0	E26.0	E23.4	35.6
6	Italy	15.9	23.8	23.3	24.8
7	France	19.7	27.0	23.1	21.3
8	Poland	10.4	14.6	18.0	15.6
9	UK	24.3	22.4	20.5	15.6
10	Czechoslovakia	10.0	13.6	15.0	15.2
11	Canada	8.8	13.6	13.5	14.8
12	Romania	4.1	8.8	12.2	13.5
13	Brazil	3.7	7.5	11.3	13.2
14	Spain	4.5	11.5	11.1	12.9
15	Belgium	9.7	16.2	11.3	12.3
16	India	6.3	7.1	10.0	10.8
17	Republic of Korea	0.3	1.9	4.2	10.8
18	South Africa	3.7	5.8	7.3	8.9
19	Australia	6.4	7.8	7.3	7.6
20	Mexico	3.0	5.1	5.6	5.6
21	German Dem. Rep.	4.6	6.2	6.8	7.5
22	Dem. Rep. of Korea	E1.5	E3.2	E3.2	5.5
23	Netherlands	3.4	5.8	4.9	5.5
24	Austria	3.0	4.7	4.1	4.7
25	Yugoslavia	1.8	2.8	3.2	4.0
26	Luxembourg	4.5	6.4	4.3	3.8
27	Sweden	4.8	6.0	4.0	3.8
28	Hungary	2.7	3.5	3.7	3.6
29	Taïwan	-	-	-	3.1
30	Bulgaria	1.2	2.2	2.6	2.6
31	Argentina	1.3	2.4	2.7	2.6

TABLE 3

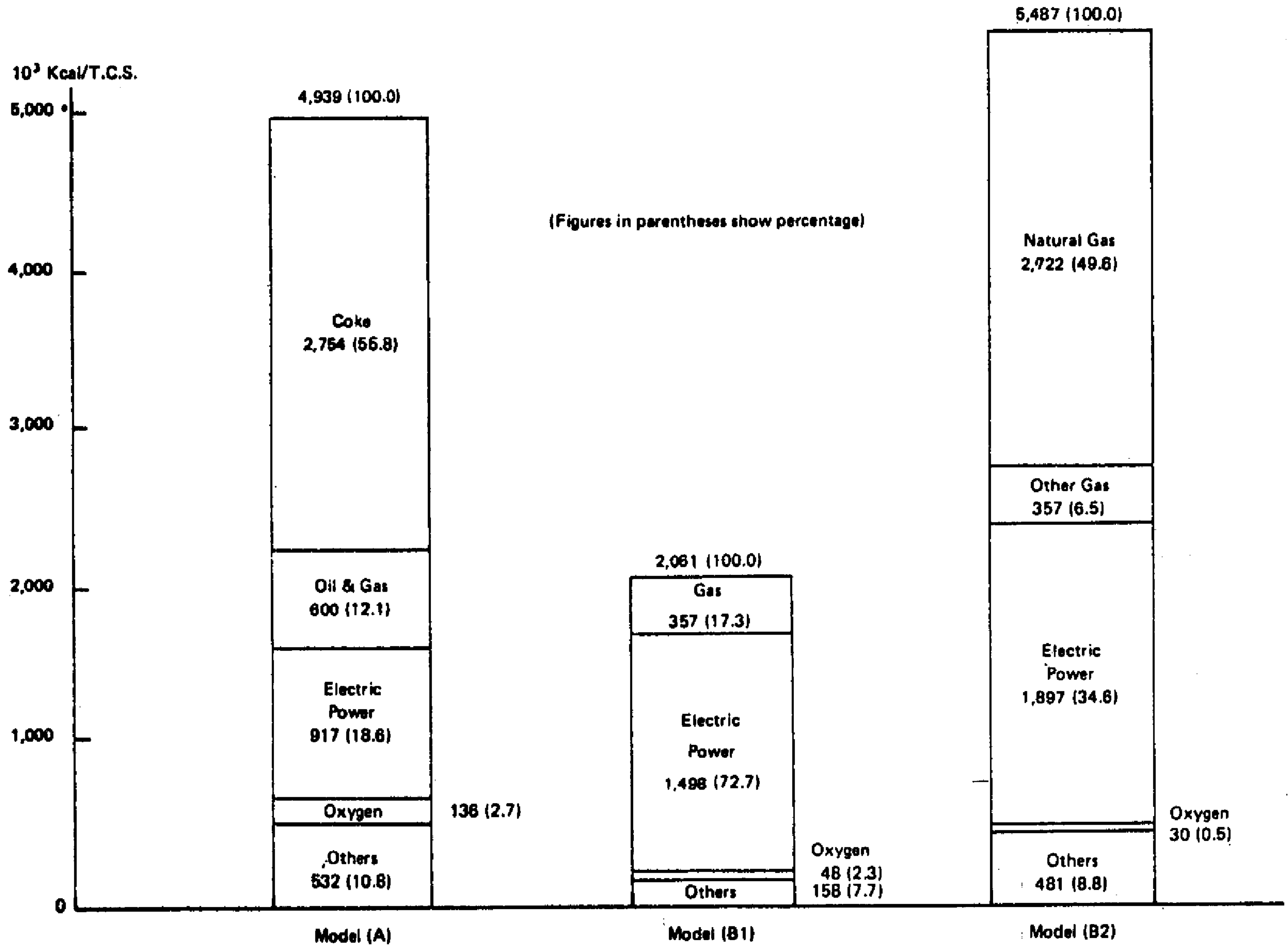
APPARENT STEEL CONSUMPTION, 1976 to 1981 (3)

	1976	1977	1978	1979	1980	1981
Japan	65.2	65.1	67.9	78.5	78.8	72.2
EEC	114.7	107.2	105.4	114.8	108.7	100.9
Other Western Europe	33.3	33.7	31.9	31.6	32.8	32.0
United States	127.1	137.4	145.2	142.6	118.4	128.2
Canada	12.6	12.8	13.6	14.9	13.8	14.4
South Africa	5.4	4.5	5.1	6.0	6.9	6.9
Oceania	6.4	5.8	5.7	7.2	7.1	7.4
Total industrialized countries	364.7	366.5	374.8	395.6	366.5	362.0
Latin America	27.0	30.6	33.0	34.8	37.4	34.7
Africa except South Africa	7.2	8.5	8.1	7.3	8.6	8.6
Middle East	15.1	14.3	16.2	16.7	16.0	16.0
Asia except Japan, China DPR Korea	24.0	29.8	33.7	36.5	36.5	38.9
Total developing countries	73.3	83.2	91.0	95.3	98.5	98.2
Total Western World	438.0	449.7	465.8	490.9	465.0	460.2
USSR and Eastern Europe	200.9	203.4	212.8	211.6	207.0	204.0
China and DPR Korea	29.5	35.7	47.0	48.7	49.2	46.0
Total Centrally planned economies	230.4	239.1	259.8	260.3	256.2	250.0
Total World	668.4	688.8	725.6	751.2	721.2	710.2
Unallocated	7.6	-13.1	-8.4	-3.7	-4.2	-2.6
World crude steel production	676.0	675.7	717.2	747.5	717.0	707.6

(3) SOURCE: World Steel in Figures 1982, International Iron and Steel Institute

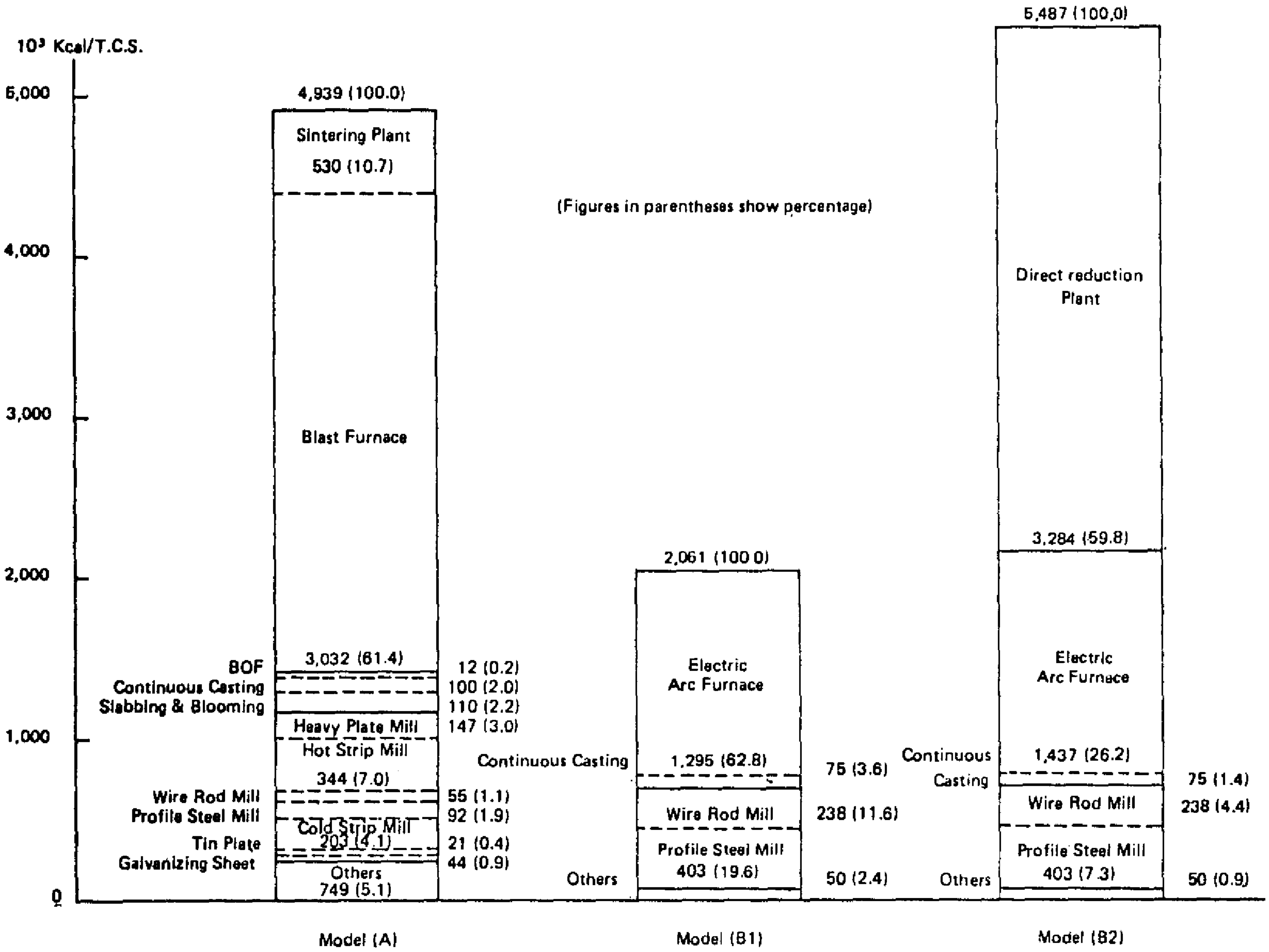
FIGURE 2

COMPARISON OF THE ENERGY CONSUMPTION OF MODEL PLANTS A, B1 & B2 BASED ON FUELS USED



SOURCE: A Technological Study on Energy in the Steel Industry, International Iron and Steel Institute, Brussels, 1976

FIGURE 3 **COMPARISON OF THE ENERGY CONSUMPTION OF MODEL PLANTS A, B1 & B2 BY PROCESS**



SOURCE: A Technological Study on Energy in the Steel Industry, International Iron and Steel Institute, Brussels, 1976

28. Much has already been done in the industry to conserve energy, for example coke oven gas and blast furnace gas have been used as fuels for many years and the carbon monoxide-rich gas collected from suppressed combustion waste systems at BOF plants is being used increasingly as a fuel source. Similarly, waste heat recovery has also been practised for many years, for example in coke ovens, blast furnaces and steel making furnaces. Recent years have seen significant reductions in coke consumption in blast furnaces and savings in energy consumption in soaking pits and reheating furnaces and wider adoption of energy recovery using evaporative cooling systems in which the steam generated is utilized. Process changes, for example the replacement of the open hearth process by the BOF process and the introduction of continous casting in place of ingot casting and primary mills, have also had substantial effects in saving energy.

29. There are still areas where more saving should be possible, for example in the recovery of low temperature waste heat, the economics of which have hindered doing so in the past. Further process changes to reduce energy consumption might also be possible. Process changes and R & D work should be aimed at achieving reductions in energy consumption by increasing process efficiency (e.g. computer control of the blast furnace and continuous casting), direct energy savings (e. g. dry coke quenching, use of turbines to recover energy from blast furnace gas in high top pressure systems, utilization of BOF gas), and fuel substitution to make use of lower grade or cheaper fuels (e.g. formed coke, coal briquetting, coal preheating, fuel injection at blast furnaces, external desulphurization of blast furnace hot metal, thus permitting use of high sulphur coke and coal). It should be noted that in relation to external desulphurization the energy/material savings might be offset by the resources required to produce calcium carbide and magnesium coke. It is clear, therefore, that numerous opportunities for saving energy need to be further evaluated and research work undertaken on longer term issues.

30. Environmental control measures in themselves consume energy, especially where high rates of extraction are necessary to collect fugitive emissions. Integrated steel works approximately ten years old consume about 45 kWh/t crude steel in their anti-pollution equipment. Electricity consumption for this purpose at the latest integrated plants may exceed 120 kWh/t crude steel (6). However, overall energy usage for pollution control does not usually exceed 3 - 4 % of total energy requirements at an integrated works. The generation of electrical power used in environmental control installations can also create, in itself, additional burdens of environmental pollution. The impact will depend on where the power is generated (frequently on-site) and how (usually by the use of fossil fuels).

b) Raw materials

31. The iron and steel industry is an important user of raw materials such as iron ore, coal, limestone and refractory materials. It is important that such resources are used efficiently with as little waste as possible.

32. Iron ore in itself is effectively used in the reduction processes with little waste of the iron units. Windborne dust control during handling and stocking is available to prevent losses. Limestone and other fluxes are necessary in the smelting and refining processes for iron and steel as a means of removing gangue and other impurities : the slag that results from this may readily be used and is discussed later. Coal is used for coke manufacture in coke ovens where by-products are normally collected for re-use and sale. At the blast furnace, much of the carbon from the coke which is not required for reducing the iron ore is collected and re-used as carbon monoxide in blast furnace gas. The efficient use of these materials is encouraged in the industry because they represent a significant part of the cost of producing steel.

c) Water

33. Water is an essential raw material in iron and steel manufacture, the requirement for water at an integrated works being of the order of 70 to 90 m^3/t crude steel. The industry can therefore potentially represent a major demand on water resources. However, only about 3 t of water/t crude steel is permanently lost, mostly by evaporation, and it is possible through good water management to reduce the demand on resources down to a figure far below the total direct flow requirement. Water recycling in excess of 96 % can be achieved in some processes. There would be difficulties in achieving this level of recycling in cold rolling or coating processes. There is a wide degree of choice of water management practice which can be adopted according to local circumstances such as available resources or constraints on the liquid effluents that can be discharged. Plant located on the coast may use sea-water for cooling purposes e.g. in blast furnaces. The water engineering approach adopted and the control of liquid effluents discharged are closely inter-related and both should be considered as integral parts of water management. For convenience, however, effluents have been dealt with in chapter II (c) and this section concentrates on water engineering practice.

34. The main reasons for using water in iron and steel making are to remove unwanted heat from plant and equipment or from solid, liquid or gaseous products and by-products, to arrest dust and fumes from certain processes, to transport certain waste products to treatment facilities within the plant, and to provide various miscellaneous services such as steam raising, product rinsing, etc. Precisely how the water system is designed to perform these functions depends on a number of factors.

35. To some extent a major industry such as iron and steel will usually conflict with the local natural environment and the main objective in good water management in the industry is to achieve a workable compromise between the existence of an essential industry and its effects on the environment in the terms of water demand and water pollution. What is acceptable environmentally will differ from place to place, depending on local factors concerning overall water resource availability, the natural assimilative capacity and the downstream uses of the water which receive the effluents. These are important factors in the choice of siting for new iron and steel work developments or indeed in the decision as to whether a particular environment can accept a major industry of this kind.

d) Manpower (4)

36. The manpower requirements in the iron and steel industry vary with the type of installation. Typical figures vary between a productivity of 0.0200 man/t and 0.0050 man/t for large integated installations, and between 0.0050 man/t and 0.0033 man/t for mini steel mills (100,000 to 500,000 t/year capacity) at which the process involves only melting of scrap. Manpower requirements tend to be higher in developing countries, not necessarily resulting from a deliberate choice of maximizing employment, but rather due to management difficulties and the inability to achieve the steel industry full production capacity. Furthermore, manpower productivity has been rising during the last decade as can be seen from the example of the French industry given in Figure 4. A typical example of the cost of training manpower in developing countries is an average \$ 17,000 (1980 U.S. dollars) per worker, which represents about 5 % of the total investment cost at a new plant. The cost can be much higher, particularly when training is carried out abroad and can reach levels of more than US \$ 40,000 per worker.

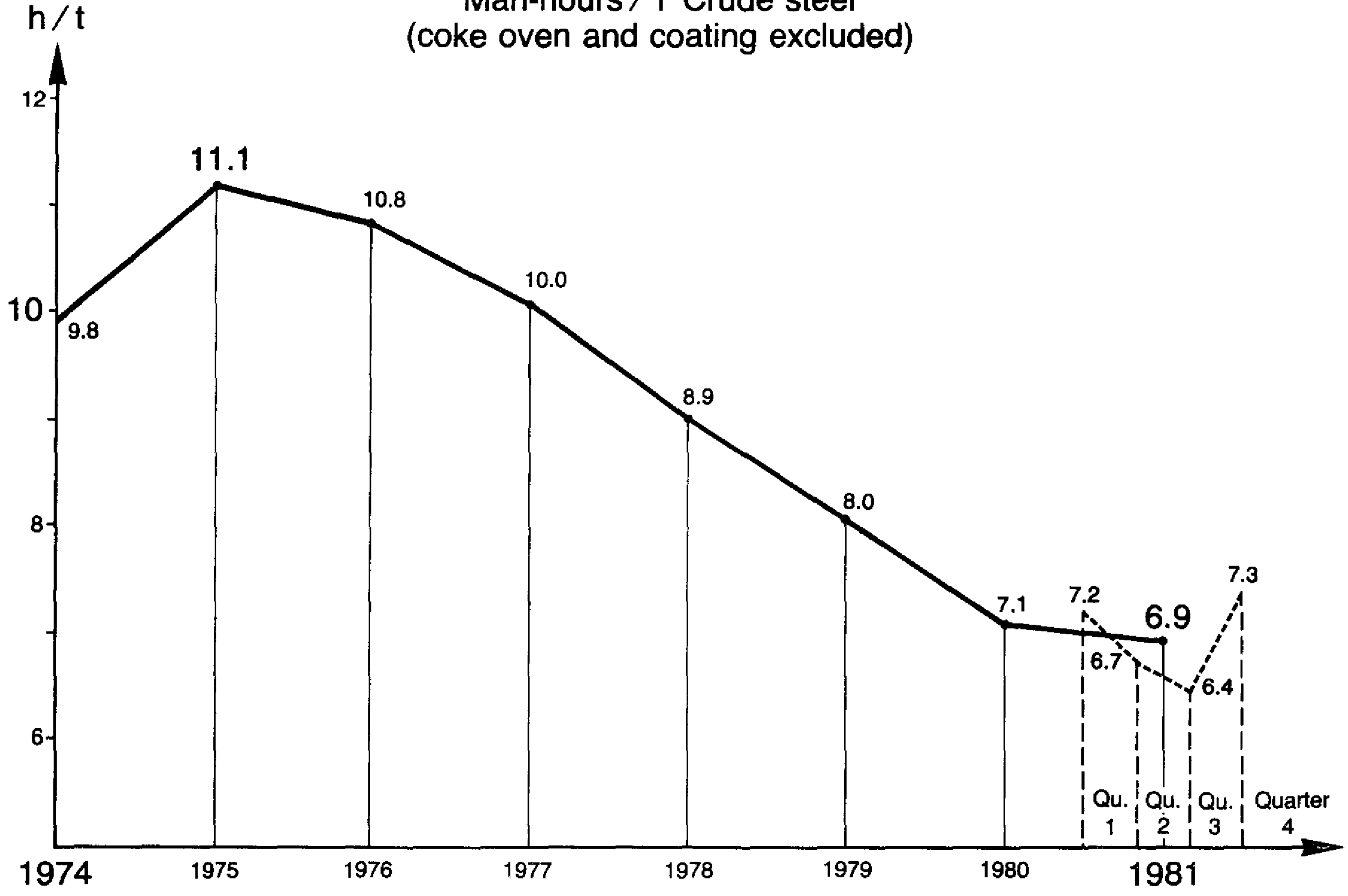
e) Capital

37. Capital requirements for the steel industry vary with type of installation and location and have been escalating rapidly during the last decade. In 1980 installation costs of an integrated plant were estimated as \$ US 1200/tonne in industrialized countries and \$ US 1500/tonne in developing countries. Costs, however, now exceed \$ US 2000/tonne and in some developing countries have reached \$ US 3000 to 4000/tonne. The additional investment costs for plants in developing countries are associated mainly with the infrastructure requirements and additional transportation costs. Installation costs of integrated plants based on the direct reduction route are now approximately \$ US 2000/tonne. Capital costs for mini-steel mills vary from \$ US 300 to 400/tonne installed capacity for the classical type with electric arc furnace and continuous casting into simple products to \$ US 400 - 500/tonne where more sophisticated products are made. The additional investment factor for infrastructure in developing countries is up to approximately 25% of the basic capital costs. The proportion of capital costs allocated to environmental control at new integrated works averages 10 to 15 % but may be as high as 20 %. The figures quoted in 1978 for additional operating and maintenance costs of pollution control equipment in western industrialized countries ranges from \$ US 7 to 17/t crude steel and could conceivably now be as high as \$ US 20/t.

FIGURE 4

Manpower Productivity in French Iron and Steel Industry

Man-hours / T Crude steel
(coke oven and coating excluded)



Source : B. TRENTINI : Journées sidérurgiques ATS 1982

CHAPTER II

ENVIRONMENTAL IMPACT OF IRON AND STEEL MAKING OPERATIONS

38. The flow diagram given in Figure 5 indicates the main discharges to the environment from an integrated iron and steel works. This chapter will consider environmental impacts under the headings of (a) siting (b) air pollution (c) water pollution (d) noise and (e) solid wastes. Careful consideration of the environmental factors in relation to the choice of site for an iron and steel works, its ancillary facilities and the inevitable community developments can greatly reduce the potential for generation of unacceptable environmental impact. To be effective this evaluation has to enter into the calculations of investment value from the earliest stages of planning and therefore at a time when other considerations appear predominant. It must be borne in mind that environmental impact becomes apparent after plant comes into operation when any necessary technological clean-up procedures not incorporated in the original plant may well be excessively expensive. Other key areas for attention are the water management plan, which if properly prepared can greatly simplify pollution control, and the potential air pollution problems arising from coke ovens sinter strands and steel making. The coke ovens in particular are a potential source of pollution where the technological solutions available still call for very high degrees of operating skill and where improved technology is very desirable.

a) Siting

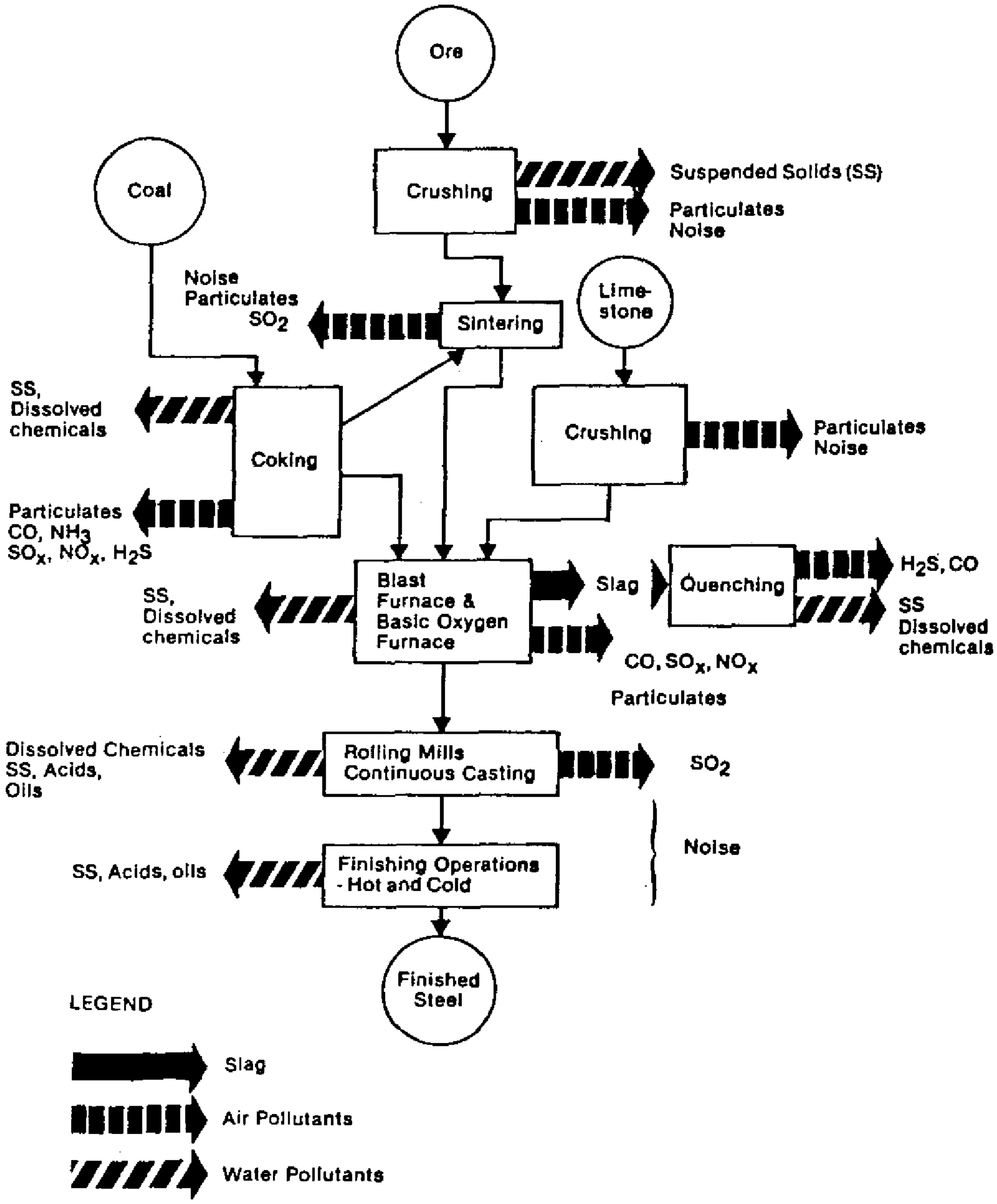
Introduction

39. The mitigation of the environmental impact of iron and steel operations is highly dependent on siting. Whilst the physical environment is only one of the aspects which must be considered in selection of sites, it is essential that this aspect be properly incorporated in the initial planning and subsequent construction stages of operations. The environment must also be considered when extending existing facilities. There should be an integration of the environmental factors into each aspect of the siting decision in such a way that the environmental parameters are incorporated into the decision weighing process (7). Although the final overall decisions on siting may be strongly influenced by considerations not related to the environment, these decisions must be taken in the full light of the likely environmental consequences of the decisions, including the investment costs, in environmental control which will depend on the requirements for the chosen site.

40. A forward looking approach of environmentally sound development, which involves both a pre-siting assessment of the potential environmental impact of a proposed iron and steel activity, and integrates at each step and for each aspect of siting decision the environmental parameter, will help to ensure a wise and rational use of resources. In the first place it will help plan the overall effective use of raw materials and energy. Secondly, it will ensure that water resources are seen in the context not only of the isolated needs of the industry but also of the current and future overall requirements of the local community and region. Thirdly, it helps plan effective use of economic resources, minimizing both unnecessary, excessive expenditure and the need for expensive and capital intensive retrofitting pollution control in the future. Finally, it helps the company in planning its manpower needs in terms of maintenance and running of abatement equipment as well as training of personnel in good operating practices and measures which have a view to protecting the internal and external environment.

FIGURE 5

MATERIALS FLOW DIAGRAM FOR AN INTEGRATED IRON AND STEEL WORKS INDICATING MAIN BY-PRODUCTS AND WASTES



Sources : Reproduced from Steel Times, December 1979, with acknowledgement

41. This type of approach requires the close co-operation of industry, national and local authorities and calls for clear policies and guidance on the part of Governments in relation to industrial siting. The form of such co-operation will vary with the socio-historical and legal structure pertaining in each country. In some cases there may be quite informal arrangements and in others contractual agreements between authorities and industry. It will be for each country to establish the mechanism most effective under the local circumstances. However, it is vital in any greenfield project that a proper social infrastructure is developed along with the works. Policy guidance on the part of Governments is also important in relation to international aspects, such as transfrontier pollution arising from long range transport of pollutants. Attention is called to the current studies of the problem in relation to auditing of precipitation in Europe and North America.

Mining Sites (2)

42. As a general policy, land at mining sites should be restored to an equal or more useful state than before mining operations were undertaken. One of the decisions in planning mining sites should be the use to which the land is to be put after mining and a clear recognition of the requirements for reclamation. This enables the costs of reclamation to be assessed before mining begins, information which could affect decisions as to the viability of the whole operation. There are examples of land reclamation in FRG and the UK at open cast coal mining sites where the restored land has been sold at a profit, e.g. for agricultural purposes, well recovering the costs of reclamation. In Katowice, Poland, mine derelict land has been restored for recreational purposes with great social benefit. There are sites, however, where due to the nature of the soil, the steep terrain or the climatic conditions (e.g. low rainfall), land reclamation is very costly or not practicable, e.g. due to lack of water, and research may be required to find satisfactory feasible restoration techniques. Such research should be initiated before commencing mining operations, so that results may be available when reclamation begins.

43. The water runoff control at mining sites which, depending on local conditions, may be expensive and present certain technical difficulties, must again be integrated into the mining site planning. Where ore is to be concentrated, on the site, besides provision for adequate removal of tailing and dissolved impurities from waste water, regular monitoring of surface and underground waters should be started before operations begin, to be able to evaluate possible subsequent degradation of water resources due to the mining operation. It is essential to foresee effects on water quality of mining operations in terms of other uses in the area, e.g. irrigation for agriculture, drinking water (if nitrites, ammonia or toxic substances are present) and recreational purposes.

44. The necessary infrastructure associated with mining operations may also have significant impacts. Some of the activities and facilities may be somewhat removed from the site itself, but should also be taken into consideration. These include access roads and/or railways as well as harbours and bulk loading facilities. Increased employment at mining sites may require the provision of housing and community services, which should be located so as to mitigate any potential effects from the mining operation, e.g. wind blow dust, noise and visual disamenity.

Siting of Iron and Steel Production Facilities

45. Iron and steel works are to be counted among the larger industrial complexes. Consequently their impact on environment is not restricted to the immediate site but, by virtue of the necessary transportation network, power supply demand, service community and ancillary industry, the works may generate extensive environmental modification. On a green field site zoning and advance planning for future development can go far towards mitigating the potential interference of the works on other essential external developments. Wise use of local topographical features can mitigate the effects of noise on residential areas. Siting sensitive industrial developments upwind from the works will mitigate possible effects from an increase in fine dust in the air. A green belt buffer zone should be created around the works ensuring visual amenity and eliminating possible mutual conflict of interest between other activities and effective operation of the works. Where possible, sufficient space should also be available for subsequent expansion as well as environmentally sound on-site disposal of unusable wastes. This calls for firm long-term planning commitment by national and local authorities. The green field site is probably the most cost-effective solution in terms of specific pollution control measures. On the other hand, because of the capital cost of the extensive new infrastructure required it is only really justifiable as part of an overall area development.

46. In respect of a new works, or major extension of an existing works, in an already developed area, the environmental controls applied may well need to be abnormally stringent. The conditions to be met may well be those necessary for sensitive land occupation more or less on the factory fence ; e.g. very low levels of noise and air pollutants for residential occupation, of vibration and fine dust as regards nearby sensitive industrial operations, trace fluoride or other pollutants in respect of sensitive horticultural activity. Much will depend on the extent and nature of the existing development but it can be anticipated that even if the initial public demand for special protection is limited, eventually the pollution abatement measures will have to meet, in respect of specific conditions, standards which are far more stringent than are needed for acceptable in-works environment or maintenance of the general quality of the natural environment of the region around the works.

47. Whether the chosen site is green field or in an existing development special attention needs to be given to maintenance of water quality and air quality. Water use can be minimized and discharge more readily controlled by proper design of the water cleaning/cooling system. In respect of achievement of air quality objectives for the region, it is important to study the prevailing meteorological conditions and topography before deciding on the location of raw material stock yards and the location and heights of chimneys. Flare stacks and exhaust blower systems should be located with care, especially where explosive and toxic gases may be vented. Ambient temperature and relative humidity are other climatic factors in the choice of site. Technologically these affect cooling systems and air-fuel combustion ratios but more important is their effect on working conditions of the personnel.

48. The power requirements of an iron and steel works are considerable ; 350-400 kWh/ton of finished steel at an integrated classical plant, 900-1000 kWh/ton by the direct reduction route, and 700-800 kWh/ton from scrap. Whether generated on site or not, this operation is another major potential source of air pollution whose location needs to be studied also in relation to the supply of energy to the residential and commercial community necessary in the vicinity of the works.

49. Once a location for iron and steel industry operations has been chosen, careful arrangement of different activities within the site must be made. Whilst clearly many of the major decisions of geometry will be made in relation to given physical and organizational aspects of the process itself, environmental and resource conservation aspects should also be considered.

50. Finally, consideration should be given to the necessary ancillary and other facilities and their environmental impact. These include transportation facilities, which are required not only for the operation of the plant, but also its construction ; power requirements, communications facilities and social infrastructure. Electrical power is frequently generated on site in conjunction with steam raising. Depending on the fuel used (coal, oil or gas), this operation can be polluting. Some sites have the advantage of nearby hydroelectrical power. A good social infrastructure and recreational facilities is important. Education facilities are also very important for training of skilled manpower, as well as education of employees' children. It is not always the responsibility of industry to provide the social infrastructure and facilities, but these aspects should be foreseen by the responsible authorities.

b) Air Pollution and Emission Control

(i) Mining and Quarrying

51. Many companies own and operate large underground or open-pit mines. Surface operations such as rock breaking, transport, crushing, grinding and sizing, demand strict attention to well known methods of dust containment, but more specifically care has to be exercised in limiting exposure to dust containing small proportions of cristalline silica.

52. Adjustment of moisture at the point of origin, although a very useful pre-requisite of dust control, is a somewhat contentious issue due to the reluctance of users to purchase "adulterated" raw materials and therefore incur a cost penalty. The very slight decrease in value per ton transported has to be equated with the additional cost of dust control at the destination when handling dry raw material.

(ii) Raw Materials Handling

53. Raw materials, whether imported or available near at hand, are delivered by ship, rail or road and generally require handling and transport within the works and eventual stocking and blending. Depending on the state of the material, its moisture content, and also weather conditions, and how materials are manipulated, the materials to be handled give off dust to a greater or lesser degree. Experience from country to country would be expected to differ widely here.

54. Reduction of emissions in the process of unloading with grabs is possible by extensive enclosure of the receiving hopper, if necessary by spray devices, including water curtains. By using automatic or semi-automatic unloading equipment, the height from which raw materials fall can be limited, thus reducing wind entrainment losses. Bucket conveyor type unloaders, although more expensive, do offer advantages over conventional grab unloaders.

55. Raw materials such as ore, coal, coke and fluxes are predominantly transported within the works area by belt conveyors. The various belt transfer and delivery points can, where necessary, be enclosed and evacuated, cleaning of the extracted

gases in fabric filters being usual in such cases. Spray installations are, however, often sufficient at these points.

56. In the supply and temporary storage of raw materials and the preparation of fine ores on blending beds, care must be taken to maintain sufficiently high stock surface moisture content to avoid windborne loss of fine material. For this reason, stocks of this type are kept moist in many iron and steel works by water spraying. Although investigations carried out in 1976 - 1977 showed specific material losses by windborne drift of fine ore as low as 0.35 g/t of material stores where no spray plant is installed ; this is considerably less than is often quoted in the literature. In a European steel works on the coast, it was shown that a spray of approximately 1mm/hr compensated for natural evaporation by wind and sun. Where material is stockpiled for some time, certain inexpensive binding agents applied by spray have been found successful.

57. It should be noted that the use of water sprays in cold climates may not be practicable due to freezing and subsequent difficulties in handling the materials.

(iii) Coking

58. Air pollution arising from coking operations, one of the seemingly intractable problems of the industry, presents a serious challenge. Unlike most other processes involved in the manufacture of iron and steel, effective control or elimination of environmental problems require strict attention to operational characteristics and working practices as well as appropriate design of engineering equipment. While most attention is paid to the environmental aspects of the carbonization process itself, it is necessary to take account also of the associated by-products plant designed to remove volatile yet condensable distillates from the pyrolisis of coal and to finally clean the valuable coke oven gas fuel. The crucial issue today is centred on the occupational environment and associated health risks of long term exposure (see chapter III), but regardless of whether the main objective is to achieve satisfactory working conditions or an acceptable environment in the surrounding neighbourhood, similar actions are required to limit or arrest emissions. Capital and operating costs to meet environmental control demands on new coke oven batteries have now risen so high (e.g. 20 % of capital cost) that there is some incentive to justify alternative approaches to steel making or to seek alternative yet commercially attractive routes to producing coke.

Fume and Dust

Charging

59. Coal can be charged into the coke oven by gravity feed, by conveyor or pneumatically. Pipeline charging is of necessity linked with coal preheating, the package providing certain process and economic advantages, with a certain added benefit of environmental improvements.

60. Gravity charging, though three or more charging ports can give rise to emissions of toxic and flammable gases and also fume and dust, dependent on two factors. In the first place to avoid gross emissions whilst gravity charging, it is necessary to create sufficient suction on the battery itself whilst avoiding entrainment of excess air into the gas. It is also necessary to allow pathways through the charged coal for the dust and fume-laden gas to escape, either through the collecting main or alternatively by way of the charging machine. Double

collecting mains assist collection with additional suction being applied to each oven by steam ejectors strategically located in the ascension pipes. Sequential (stage or stepwise) charging of coal from different sized hoppers offers a major advantage of allowing the charging gases to escape throughout the charging cycle and avoids blockage and consequent emissions through charge hole lids. Charging time is longer but in spite of this many coking operations have adopted the technique.

61. By linking an additional access port of one oven to another by means of a jumper or breeches pipe, single collecting main batteries not only may improve suction during charging generally but also may permit the adoption of the technique of sequential charging.

62. In another approach to smokeless charging a proportion of the gases evolved during charging are removed by suction on the charging car ; the gas is then burnt and cleaned by wet washers. Although this approach is very effective, severe problems have arisen with availability and maintenance due to the excessive corrosion. These limitations are overcome somewhat by linking the extraction equipment on the charge car by means of a travelling connection to a fixed duct along the battery top and thus to a separate gas cleaning system.

63. While pipeline charging eliminates charging emissions, there are additional cleaning requirements for the waste gases produced in the preheater, together with a need for stringent safety precautions to avoid dust and gas explosions. Preheating and pipeline charging cannot be justified on environmental grounds alone ; the key considerations are the opportunity to utilize lower grade coals and the increase in production capacity of the coke making plant.

Leakage control

64. In order to cut down the level of emissions to atmosphere, particularly in the workplace, it is particularly important to introduce effective designs of seals efficiently on a routine basis. Comprehensive work force training programmes are necessary to achieve a basis for effective operation. Although coke oven batteries are operated under slight suction, this cannot be increased to compensate for poor maintenance as the result would be an unacceptable in-leakage of air. The seal between door and frame continues to be the centre of attention, particularly on tall ovens where the potential for distortion is great and cleaning is difficult. Investigations are in progress in various countries to seek improvements in door and seal design. Various developments of mechanical door scrapers and high pressure water jet cleaning have also proved beneficial.

65. Extraction of fume from above the doors, whilst perhaps creating a disincentive in terms of prevention, is considered to have an advantageous impact on reducing work force exposure.

Coke pushing/discharging

66. Under normal operating conditions up to 20 tons of incandescent coke is discharged from each oven after 12 - 24 hours carbonization time, the shorter time being applicable to a preheated coal charge. During pushing, surface abrasion, fracture and crushing of the product result in emission of coarse grit to atmosphere. Such operating factors as a balanced level of production, even firing and strict adherence to adequate carbonization times are important. Without this discipline the product may still contain some volatile matter when pushed, resulting in

combustion on exposure to atmosphere and unacceptable black smoke emission. While in the Netherlands, for example, a preventive approach to this problem has been adopted involving computer controlled heating and also interlocking of doors to prevent discharging ovens out of sequence, certain other countries have adopted the environmental engineering approach. Choices for control as distinct from prevention are centred on such developments as :

- Hooded quench car with dust arrestment,
- Separate mobile hood over quench car with dust arrestment,
- Mobile hood linked to fixed duct and dust arrestment,
- Coke side enclosure

Most of these engineering solutions are adequately described in the literature and will therefore not be reviewed here.

Coke cooling/quenching

67. Batch quenching of incandescent coke with water is a common practice in most countries. It is now accepted that efficient grit arrestment in the quench tower is required ; also the previous practice of using contaminated waters, including coke oven effluent, for quenching is avoided. A new development as yet untested, of continous quenching allows for emission at higher level through a chimney with an overall reduction in volume of condensed vapour emitted.

68. World-wide interest is focused on dry coke cooling which, like many other developments in technology, offers a major attraction in energy conservation, but also reduces pollution. Replacement of existing quenching plant is limited by high capital cost of dry coke cooling equipment itself and, more importantly, the need to have use for the additional steam generated. Dry coke cooling has been practised for some 40 years now and although not accepted as standard operating practice world-wide offers the potential for energy conservation and improves air quality.

Heater emissions

69. Providing combustion waste gases are passed to a chimney of appropriate height and refractory walls between heating chamber and coke oven are sound, there should normally be no need for dust arrestment.

Gases and vapours from coking

70. The by-products plant can be considered as a series of gas cleaning processes prior to distribution of coke oven gas as a valuable fuel. The extent of fractionation and separation and final recovery on the considerable range of constituents such as polycyclic hydrocarbons and aromatic oils and tars, together with hydrophilic substances including ammonia and phenols, depends on the relative merits of minimizing cost either by marketing refined by-products outside the industry or by solely recovering energy content or destroying "waste" within the works boundary. Specific requirements for air pollution control are associated with the elimination of odours and the removal of sulphur from coke oven gas.

71. The odour problem is minimized by restricting loss of noxious vapours to atmosphere from vent pipes, storage vessels and liquor seals, together with the provision for safe disposal by flaring of raw gas and other volatile products in the event of plant or equipment failure.

72. Desulphurization on the other hand can be considered as a necessary integral process in by-product plant. Techniques for desulphurization, particularly the historical use of iron oxide fines, arose from the need to avoid the formation of sulphur dioxide in domestic use.

73. Other good reasons for desulphurizing gas include a reduction in potential for corrosion, possible sulphur pick up by the product being heated and finally the consequent sulphur mass emission. Up to 60 % of the total sulphur gases emitted from a steel works can arise from combustion of sulphur-laden coke oven gas. Total sulphur content of coals for coking generally does not exceed about 2 %. Approximately half of this remains in the coke whilst the rest, mainly in the form of hydrogen sulphide but containing small amounts of organic sulphur compounds, enter the gas phase. Modern desulphurization processes largely fall into two categories - absorption/desorption and absorption/oxidation, the former approach producing a separate sulphide gas stream requiring further treatment to yield a solid or liquid sulphur product. Removal efficiency for hydrogen sulphide ranges from 80 - 99 % with certain processes also claiming to eliminate organic sulphur compounds, predominantly carbon disulphide.

74. Disposal of stripped gases from ammonia liquor also poses an important question with regard to the potential for sulphur emissions due to the affinity of hydrogen sulphide for ammonia. This represents up to 15 % of the total sulphur content of raw coke oven gas and, in most cases, it is removed prior to incineration or ammonia recovery and returned to the mainstream coke oven gas prior to desulphurization.

75. Cyanide or cyanogen content of coke oven gas (2 g/m^3) apart from its very corrosive action on steel vessels and pipework, tends to complicate the chemistry of most desulphurization processes. In certain of these there is the very distinct danger of passing an environmental problem from one medium to another, namely from air to water.

(iv) Charcoal

76. Where charcoal is used as a primary energy source in iron and steel making, there are several potential environmental impacts. Firstly, there are those related with forestry industry operations including impacts on soil, forest conservation, etc., which will not be dealt will in this overview, but could be very significant with large scale charcoal production. Secondly, there are those related to charcoal manufacture. Where charcoal is made on a small scale directly in the forest, smoke is the main impact. Provided workers are adequately protected, the scale of operation rarely causes important problems. Where charcoal is manufactured on an industrial scale by destructive distillation of wood, the distillate is collected and used as chemical by-products, which include a whole range of organic materials. Adequate dust and smoke arrestment equipment are available for these types of installations. It must be borne in mind that large scale production of charcoal could possibly involve environmental problems similar to those of coke manufacture, including similar working environmental hazards.

(v) Sintering

77. The fine ores used predominantly today must be agglomerated prior to smelting in blast furnaces. The process generally employed is sintering. A suitable

blend of various fine ores with the necessary fluxes added to act as slag-forming agents for the blast furnace process, is fed on to a sinter strand. The mixture containing coke breeze or coal as fuel is ignited by means of a burner and combustion maintained by air drawn through the sinter bed. The surfaces of the fine materials melt and fuse together. The waste gases and excess air, having been drawn through the sinter bed, contain both dust and gaseous pollutants, presenting a number of special problems for pollution control.

78. In the strand sintering method usually employed today, waste gases of the order of 1.5 to 2 m^3/m^2/sec. suction area are produced. Following deposition of coarse dust, the waste gases are passed to dust arrestment plants. Dry electrostatic filters are frequently employed although difficulties with resistivity of dust at sinter basicity exceeding 2 (ratio CaO/SiO_2) have led to experimental use of alternative gas cleaning devices. Oily materials, such as mill scale, fed to the strand can in some cases give rise to hydrocarbon emissions and may cause problems of fires in precipitators. Dust content of the raw gas is between 1-5 g/m^3. The dust extracted before release into the atmosphere contains most of the lead and zinc released in the sintering process. This ferruginous waste is normally recycled directly within the sinter plant but, because of its high content of non-ferrous metals and alkali chorides, may be dumped or passed to a waste recovery operation. The dust content in cleaned gas is generally less than 150 mg/m^3.

79. Recent developments in the handling of ores of high alkali content involving addition of calcium chloride to the sinter mix, will require greater attention to gas cleaning requirements.

80. Dust emissions may also arise in crushing and screening processes, sinter cooling, and all associated handling and transport activities. Modern sintering plants therefore have additional dedusting equipment available in which the secondary dust sources are collected and cleaned, usually by means of electrostatic or fabric filters. The dust consists exclusively of particles of sinter which are recycled within the plant. On-strand sinter cooling, while offering certain cost advantages, also simplifies the requirement for dedusting facilities.

81. The following represents a typical analysis for sinter plant waste gas :

CO_2	5 - 7 %	SO_2	0.2 - 1.0 g/Nm^3
O_2	12 - 16 %	NO_x	0.4 g/Nm^3
CO	1 %	F^-	0.01 g/Nm^3
N_2	78 %	Cl^-	0.03 g/Nm^3

Although sintering plants generally are fitted with high chimneys to ensure adequate dispersion of the waste gases, use of high sulphur raw materials may lead to certain air quality problems with sulphur dioxide when combined with other contributions from both industry and domestic sources in densely populated industrial areas. A few sintering plants around the world are therefore provided with desulphurizing equipment. The sulphur dioxide in the waste gases usually arises predominantly from sulphur contained in coke fines, which is of the order of 0.8 - 1.6 %. Some sulphur containing iron ores may also be a major source of sulphur dioxide.

82. Waste gas desulphurization, as a whole, requires further development to become more economic and better established technically on a production basis. The installation of desulphurization equipment has so far mainly been attempted on new sintering plants where the appropriate equipment can be accommodated as part of the new sintering machine. Analysis of waste gas indicates that the sulphur dioxide profile varies over the length of the sintering strand in the different wind boxes. An optimum approach of connecting only the wind boxes exhibiting a high sulphur dioxide level (approximately 40 - 50 % of total waste gas) to desulphurization equipment will, for example, achieve a 70 - 80 % reduction in sulphur dioxide emissions. In existing older plants, retrofitting of sinter plant waste gas desulphurizing equipment has up to now been scarcely practicable for economic and technical reasons.

83. When low sulphur raw materials are used there may be no nececessity to install expensive desulphurization facilities where local conditions are not critical in this respect. Researcn and development is therefore aimed at reducing the input of sulphur associated with the fuel of the sintering mixture. Examples of research areas include development of low-sulphur coke breeze from lignite and reduction of the proportion of coke breeze by improvements in energy balance such as preheating the suction air, or alternatively using low sulphur content fuels in the ignition hoods.

84. Other gaseous pollutants in the waste gas, such as hydrogen fluoride and nitrogen oxides do not cause problems in most countries, since adequate dispersion is achieved in order to overcome air quality problems. Only in Japan are nitrogen oxides from sintering currently controlled due to the very strict regulations regarding these compounds. Steel works in that country are therefore striving to develop plants which achieve effective removal of both sulphur oxides and nitrogen oxides. It should be noted that very high levels of fluoride in some iron ores may give rise to emissions of fluorides which could result in a hazard to humans and animals if the emissions are not properly controlled.

(vi) Pelletizing

85. Another method of agglomerating fine ores is pelletizing. Pellet plants although found in certain steel production sites are more frequently located adjacent to ore mining operations. In pelletizing, fine ores are mixed with a binding agent and fluxes and tumbled to form "green" pellets and then finally indurated by firing in a rotary kiln, shaft furnace or travelling grate. Whilst in contrast to sintering, this firing does not lead fusion. There is significant grain modification of the iron ore with the formation of hematite which produces the required mechanical strength in the pellet. The ore has to be so much finer that in general a grinding stage is necessary prior to pelletizing. After firing, the fines are screened out and returned to the grinding stage.

86. In handling the fine ores, particularly in the dry grinding process, emissions in the form of dust are produced. For reasons of working conditions and environmental protection, the transport, handling and grinding plants must therefore be fitted with dust extraction equipment. Centrifugal dust extractors have in the past been used to arrest dust from the kiln waste gases, but today electrostatic precipitators are favoured.

87. The firing process may also produce gaseous emissions of sulphur dioxide and nitrogen oxides. Sulphur dioxide emissions depend on the fuel used for pellet

drying and firing. The energy situation of the country concerned is a decisive factor in the choice of fuel, and in this respect, the availability of sulphur-free natural gas is an advantage.

88. When using ores with high fluorine contents, emission of gaseous fluorine compounds may occur, and a wet washer or possibly dry removal technique is required to control these, especially where the surrounding area is particularly sensitive (e.g. commercial bulb growing in the Netherlands).

89. There is little evidence to date to identify any serious problem concerning nitrogen oxide emissions. As are all combustion processes, nitrogen oxide emissions are influenced largely by the choice of burner and the fuel.

(vii) Ironmaking by the Blast Furnace Route

90. Sources of air pollution in blast furnaces are associated with three distinctly separate aspects of operation :

- blast furnace gas,
- cast house emissions,
- slag handling and processing.

Blast Furnace Gas

91. Reducing conditions in the blast furnace produce top gas of the following analysis :

CO	23 -24 %
CO_2	20 - 22 %
H_2	2 - 4 %
N_2	50 - 55 %

Rate of gas production is linked to smelting efficiency with the new higher top pressure furnaces offering major advantages in reduction of the volume of gas produced (approaching 1,000 - 1,400 Nm3/t iron).

92. Blast furnace gas is a pollution-free fuel when stripped of its dust burden. Large production units are frequently linked to combined power and furnace blowing stations. For other uses, however, it is customary to increase its calorific value by mixing with coke oven gas. Blast furnace gas is essentially sulphur-free since the sulphur in the furnace largely passes into the slag. Apart from the desire to maintain sulphur contents in the hot metal as low as possible and achieve a high quality product, high sulphur auxillary fuels can be safely injected into the tuyeres. Indeed in many operations, fuel injection provides a means for disposing of oil, oil emulsions and tarry wastes arising elsewhere in the steel works.

93. However, before the gas can be used as a fuel, it has to be cleaned to a degree that is not customary in other dust and fume arrestment plant. A combination of cleaning methods is generally adopted involving two or even three stages starting with inertial dry collection at a "dust catcher" followed by high energy

scrubbing and possibly wet electrostatic precipitation. Thus the cleaning of blast furnace gas is not generally considered a pollution control activity, although there are associated water pollution and waste disposal problems which are referred to later.

94. Blast furnaces producing ferro-alloys, in particular ferro-manganese, give rise to a dust burden in the top gas which is pyrophoric when handled dry and exposed to atmosphere, so particular care has to be taken to avoid this hazard. Intermittent occurrences where the blast furnace burden does not progress evenly down the furnace can lead to surges in top gas pressure and consequent bleeder or safety valve opening, but air pollution from this source is not a major problem.

Cast House Emissions

95. Molten metal and slag are run off from the furnace in troughs or runners extending from tap-holes to receiving ladles. Fume emission arises as a direct result of exposure to air and oxidation. Further emissions arise from vaporization of alkali oxides from slag and even from combustion of tars and resins in impregnated refractory clays. In addition, the emission of sulphur dioxide from molten slag exacerbates the problem. The potential health hazard of manganese fume in ferro-manganese operations is of particular concern.

96. It has been possible in the past to provide sufficient natural ventilation within the cast house to maintain acceptable working conditions, whilst avoiding excessive emissions to atmosphere. The economies of scale in ironmaking plant have, however, dictated the requirement for control equipment in the workplace. Choice of equipment is governed by severity of the problem and constraints of access. The following factors affect the severity of fume emissions :

- Size of blast furnace,
- Iron type and quality,
- Slag volume and basicity,
- Arrangement and length of runners,
- Iron temperature,
- Height of free fall of molten metal.

97. Collection hoods may be installed over the tap holes, slag dam, and tilter or pouring spout as found necessary with, in some cases, refractory-lined runner covers. In certain very large production units a flame-proof curtain can be lowered over the tap-hole to direct fume to a roof-mounted canopy during tapping. Suppression of fume generation through operating conditions may help reduce the collection problem. Success in controlling fume and noxious gas emissions near the source generally removes any necessity for additional roof collection. Bag filtration or dry electrostatic precipitations are normally adopted for fume arrestment with the collected material (normally up to a maximum 2 kg/t hot metal) being fed back to the sintering blend. These systems lend themselves to new furnace construction but can be very difficult to install on old blast furnaces.

Slag Handling and Processing

98. Handling and treatment of blast furnace slag can give rise to air pollution problems and these are discussed here. Other details of slag usage are given in section (e) below.

99. Coarse aggregate is prepared by pouring the molten slag into a slag pit in layers either adjacent to or remote from the furnace. Solidification in open pits is dependent on the rate of heat transfer and water spraying is frequently required to accelerate cooling with consequent formation of hydrogen sulphide odour. Attempts to inhibit sulphide formation by chemical additions to the spray have not altogether been successful and strict attention has to be paid to maximizing heat loss through air cooling in order to avoid unacceptable pollution.

100. Those processes requiring the mixing of molten slag with water are generally more amenable to effective extraction and control of air pollution as the equipment is confined to one location with a point source of emission. A condensation chimney is often sufficient to scrub out any noxious vapours. These latter processes are now finding increasing favour as more convenient methods of handling the volumes of slag produced from large furnaces.

101. Further processing of material from slag pits is required to produce aggregate of certain size ranges. Clearly effective dust control measures are required in handling, crushing and grading of the material.

(viii) Steel Making

102. The growth in size of production units in steel making and more recently the rapid gains in production rate arising entirely from the use of injected or blown oxygen, have markedly increased pollution potential. Whereas an open hearth furnace not using oxygen produced 200 tons of steel in 12 hours tap-to-tap time, the same quantity can now be produced in one-twentieth of the time. The quantity of fume formed over that short period, however, might be 3 tons, a much larger quantity than from open hearth furnaces, which themselves require dust control devices (precipitators). Concentration of production and the move to larger steel making plants adopting oxygen steel making technology took place particularly in the decade 1960 - 1970. At that time, process technology tended to oustrip environmental control technology, but during the following decade environmental control technology has caught up.

103. Without detailing all the stages of development, either in steel making or in air pollution control, certain key features of the current situation are explored here in an attempt to identify difficult areas and problems that remain.

104. Both with modern oxygen steel making and also high powered electric arc melting, over 90 % of the fume and gases emitted during the entire process can be efficiently collected and also cleaned. There will continue to be active debate on the design of primary extraction systems in each case and also the type of gas cleaning plant selected for any one application. However, it is the secondary fume emissions that escape the primary collection system that continue to be the main object of attention. These secondary emissions arise either as escapes from the main process or during charging, pouring, desulphurization and other ancillary processes. Most alternatives to date for secondary emission control have proved expensive both to install and to operate.

Oxygen Steel Making

105. Basic oxygen steel making involving the blowing of gaseous oxygen on to the molten metal surface is the most common process in use today. Fume formation can result in a loss of 1.5 % of the total charge weight over each

cycle or blow. The waste gas, mainly carbon monoxide, is either burnt above the vessel mouth in excess air to yield carbon dioxide, or handled in a so-called suppressed combustion system. Suppressed combustion, the most common approach in more recent installations, offers advantages in terms of lower gas volumes handled and the potential for energy-saving fuel gas recovery. Whereas many of the earlier full combustion units included electrostatic precipitator dust arrestment facilities, the majority of suppressed combustion installations have now adopted reliable high-energy scrubbing techniques with associated slurry handling. Electrostatic precipitators suitable for suppressed combustion systems have been adopted in some recent installations. Combustible waste gas is, at the majority of installations, burnt at the flare stack. However, there is recent Japanese experience of gas recovery for further energy utilization.

106. A small proportion of fume can escape capture by the main extraction system, particularly when the converter is tilted out of line with the gas collection hood. Charging operations in particular can create violent reactions in the converter with consequent fume and combustible gas emissions, the extent of the problem being largely proportional to the quantity and quality of scrap recycled. As hot metal is charged on to scrap, paints, plastics, oil and grease volatilize, air is rapidly entrained into the fume, and gases emitted burn rapidly. It is difficult to capture the plume which rises and passes out through the roof. Depending on the quality of the scrap, this intermittent emission may occasionally approach 0.3 - 0.4 kg/t hot metal produced where 25 % of scrap is included in the charge.

107. Initially two types of approach were used to deal with secondary emissions. One was the provision of a fixed or movable collection hood as close to the source as practicable so as to capture the major portion of emissions arising during charging, tapping and ladle metallurgy. The other was roof collection of the steel making shop air. The latter is expensive due to the large volume of dust-laden air involved. Retrofitting of existing plant is frequently difficult because of constraints in locating collection hoods at optimum positions due to the building structure. Reducing fume evolution by reduction in the volume of scrap charged and by pouring hot metal into the converter slowly have operational penalties but are effective. Increasing suction can improve fume capture, but increases energy requirements.

108. With the evolution of bottom blown converters in oxygen steel making (Q -BOP, OBM, LWS) and other mixed processes, such as LBE, it was necessary to develop complete enclosures in order to control the hot spark and fume emissions during lowering and raising of the converter during which oxygen blowing continues. These enclosures, called doghouses, enable very high fume collection efficiency and have subsequently also been developed for BOF top blown installations.

Electric Arc Furnace Steel Making (2)

109. Fast driving electric arc furnaces using oxygen lancing to assist decarburization and occasionally supplementary heat input from oxy-fuel firing can reach rates of fume emission comparable with basic oxygen steel making. Well established means of direct extraction can handle the main bulk of this with the heavily fume-laden gases being passed to a combustion chamber prior to fume arrestment.

110. Even the most effective primary collection system with direct evacuation from the furnace, plus an evacuation hood close to the ladle will only handle about 94 % of the total fume and dust generated during the entire tap-to-tap

cycle. A small proportion escapes as leakage through electrode ports and other openings at the furnace during arcing, but it is the intermittent operations of charging and tapping that contribute most of the "fugitive" fume and dust, the furnace roof being swung out of position for charging whilst the entire furnace is tilted for tapping. As with oxygen steel making the character of emissions arising during charging is highly dependent on the quality of scrap and the nature of the fluxes used.

111. The most common approach to control roof emission to acceptable levels is canopy hood collection at roof level that can be linked to the primary system with a common fume arrestment plant. Certain plants have, however, adopted the radical alternative of total building evacuation with all process fume emitted being collected in the roof space. Like the oxygen steel making situation, options for fume collection are essentially governed by cost. Strategic siting of extraction hoods is important, together with an acceptance that capital costs in particular are directly proportional to total volume to be extracted. For instance, it is extremely important to determine the point at which gains in collection and extraction efficiency become only marginal with increase in extraction volume. When tackling an intermittent emission of this sort, it is appropriate, for instance, to focus design attention on capacity of hoods to cope with accumulation of very heavy fume surges over short periods. In multi-furnace shops, flexibility of operation by means of dampers can direct suction capacity to where it is required at any one time.

112. For new electric arc furnace shops the most efficient dust control system is total enclosure of furnace and ladle, which combined with direct furnace evacuation enables control of up to 98 % of total emissions generated during the operation cycle. This doghouse system also helps control noise produced by the furnace.

113. Developments in process techology involving facilities for continous feeding of raw materials such as small pieces of scrap and pre-reduced iron, also assist in containing fume emission on newer installations by eliminating the central emission problem of bath charging.

114. Whilst in the past the choice of equipment for fume arrestment and gas cleaning has often been wet electrostatic precipitation or wet scrubbing, the necessity for roof collection has increased overall volumes extracted as has the cooling of hot gases from direct extraction by dilution. Combined systems incorporating bag filtration are now common. There is a need here to develop efficient but more simple and reliable devices that are cheap to install and run, yet capable of handling large volumes of air containing low dust burdens. Conceivably a computerized dust control system could be developed based on particle flow rather than gas flow, if adequate sensors were available. The roof mounted electrostatic precipitator which exploits the buoyancy of the rising plume to drive dust-laden air through the cleaner offers one, as yet unproven, alternative.

Ancillary Processes

115. A number of other sources of fume and dust are generally associated with steel making activities. Some are well established unit operations that, as a result of increased scale of operations, now have to be included as potential contributors to air pollution at work or outside the plant, demanding the installation of collection and arrestment equipment. There is frequently a choice

of either linking air pollution control at these units with the larger comprehensive equipment described earlier, or alternatively, treating each case individually.

116. Hot Metal Desulphurization - The increasing demand for high grade steels with low sulphur content has dictated the need for efficient sulphur removal from molten iron. This is achieved through chemical reaction to produce an insoluble sulphide that can subsequently be removed as a component of slag. Both the chemical reagents and the process have developed from the rather simple approach of batch additions of bagged chemicals such as sodium carbonate and lime to sophisticated pneumatic injection or paddle stirring systems using calcium or magnesium carbide or carbide/lime mixtures. Quantities of calcium or magnesium carbide required are significant, reaching 3 kg/t hot metal, the fume produced being arrested by means of bag filtration or wet scrubbing. Certain safety provisions have to be included to avoid the risk of contact with water and possible explosion and fire. Furthermore pneumatic addition of lime can be a source of air pollution in the plant.

117. Hot Metal Transfer and Slag Skimming - This operation is common in all major oxygen steel making shops with hot metal being transported from the blast furnaces in large torpedo ladles or "bottles". Metal transfer increases the potential for oxidation and fume formation. It also cools the molten metal sufficiently to accelerate precipitation of carbon in the form of graphite platelets or "kish". The extraction system at this point is essentially a hooding arrangement frequently linked to the secondary fume installation. There can also be arrangements in the plant design for batch addition of desulphuring agents. Similarly, ironmaking slag, particularly residue from desulphurization, has to be removed prior to converter charging. A similar hooding arrangement over the slag removal station prevents emission of kish into the steel plant atmosphere.

118. Steel Making Slag - The situation contrasts with the blast furnace in that smaller volumes arise and the material generally gives off little sulphurous and odorous gases on water quenching. However, here again by close attention to design of plant, this waste material can be removed speedily from the building without creating excessive dust entrainment through unnecessary excavation and vehicle transfer operations. At the present time slag from the furnace is often poured on the shop floor and its subsequent removal often creates more emission than the quantity of fumes generated during tapping and in ladle refining. Pouring the slag into slag pots and removal from the steel shop by pot carrier or overhead crane to a large extent solves this problem at an additional cost of slag handling of approximately US $ 3 per ton of molten steel.

(ix) Rolling and Finishing Operations

119. Although attention is required to effectively limit atmospheric emissions there are no major sources that merit specific detailed discussion. Air pollutants can arise from the following operations :

Reheating furnaces,
Soaking pits,
Scarfing machines,
Acid recovery plants,
Galvanizing lines,
Organic coating lines.

The practice of oil firing of soaking pits and reheating furnaces can give rise to unacceptable levels of gaseous sulphur compounds in the workplace and contribute to SO_2 in the atmosphere. The use of alternative fuels, including coke oven gas and natural gas can mitigate the problem, but this solution may be affected by energy considerations.

120. Automatic scarfing, namely oxy-flame treatment, to remove surface imperfections on semi-finished rolled products, produces small amounts of iron oxide fume. Dry electrostatic collection is inadequate and irrigated precipitators are normally adopted for this application because of the high moisture content of the waste gases.

121. Spent pickling acids present problems in disposal and it is customary for some form of recovery to be practised on large continous pickling lines to overcome waste disposal problems in addition to gaining an economic advantage. Frequently these recovery processes involve heating the spent acids, but effective operation of associated gas scrubbing equipment will prevent what would otherwise be acid fume emission. Alternative ion exchange processes for acid recovery present no such emission potential.

122. On hot dip galvanizing lines there is generally a requirement for adequate extraction and ventilation to remove fume formed from salt fluxes used in the process. Organic coating lines again require well designed ventilation in order to limit solvent content in the working atmosphere. It may also be necessary to recover solvent vapours as a control measure against photochemical pollution.

(x) Gaseous Pollutants from Steel Making

123. While the steel industry has been able to greatly reduce the emission of dusts, less action has been taken against gaseous pollution. The reasons vary with the pollutants. The dispersion of gaseous emissions from tall chimneys is being used until economic abatement alternatives are found.

124. For carbon monoxide there are as yet no large scale abatement processes. A modern sinter plant with a surface of 400 m^2 emits some 2 million m^3/h of waste gas with about 1 % CO into the atmosphere. Dilution and dispersion is achieved through the tall chimneys commonly used in sintering plants. Blast furnace gas and BOF gas are major sources of CO but they are collected and used as a fuel or flamed. Waste gases from electric reduction furnaces also contain carbon monoxide.

125. As for sulphur oxides, there are efficient processes which are industrially used in Japan in many sintering plants. These processes consist of washing the fumes with a lime or a basic solution (composed mainly of calcium or ammonium hydroxide) and of obtaining as a by-product gypsum or ammonium sulphate. The desulphurization yield is about 90 % for an initial content of about 400 ppm SO_2. The cost of such an operation is very high and, except for Japan, steel producers consider it unacceptable. It may be noted that the level of SO_2 in exhaust gases from sintering plants (typically 400 ppm) is comparable to that from coal or oil fired power stations after desulphurization and much lower than those from power stations which do not desulphurize their stack gases. Desulphurization is only practised where the sulphur content of raw materials is high.

126. For nitrogen oxides, scrubbing techniques exist in Japan but have only begun to be applied on an industrial scale in some coking or sintering plants. It appears preferable to seek alternatives of improving process techniques (better regulation of combustion in reheating furnaces) rather than to utilize sophisticated techiques for NO_x removal).

127. Lastly, certain classical particulate removal techniques seem adequately efficient for the trapping of the gaseous components of fluoride (HF) (e.g. dissolution in vent scrubbers, trapping in the dust cake on the bag filters).

(xi) Emission and Air Quality Monitoring

128. Pollution monitoring is an essential part of any effective pollution control policy. It is only by having regular, quantitative information on atmospheric emissions and ambient concentrations that it is possible to judge whether the pollution control measures taken are adequate.

129. At plant level, emission monitoring can provide an early warning service for management on control plant malfunctions, thereby enabling remedial action to be taken speedily. Emission monitoring can also be used to demonstrate the capabilities of gas cleaning plant, to satisfy legal requirements relating to emission levels and to build up a data bank on emissions for future reference. Because the relationship between emissions and ground level pollutant concentrations is very complex, ambient air monitoring is often carried out as a complementary exercise to the measurement of emissions.

130. Until recently emission monitoring has been based mainly on manual sampling and analysis techniques, which, although involving well-established methods, can only be carried out infrequently. There is now available a range of automatic continuous monitoring instrumentation for certain of the emissions and ambient air concentration measurements associated with iron and steel industry processes. Systems based on this type of equipment offer great advantages in giving a more detailed picture and in providing a prompt indication of developing situations which may lead to a deterioration in pollution control performance.

131. If the need exists to install pollution control equipment, then the provision of appropriate monitoring equipment should be considered as part of the pollution control system.

c) Water Requirements, Water Pollution and Effluent Treatment

Quality and Quantity of Water

132. The iron and steel industry does not need large quantities of prime quality water : it can generally operate satisfactorily with the bulk of its requirements met from second or third grade water sources. Where supplies of water of the required quality are not available, it is necessary to pre-treat water of poorer quality. Typical treatments, in ascending order of complexity and generally costs, are :

(i) Simple clarification to reduce suspended solids followed, if necessary, by filtration,

(ii) lime and lime soda softening to reduce scale-forming salts,

(iii) demineralization to remove dissolved salts (e.g. in water for steam raising) and finally,

(iv) treatments for potable water.

In certain circumstances de-salination techniques may also be applicable either as a pre-treatment for demineralization (e.g. reverse osmosis) or as a source of high quality water, from poor quality or saline water (e.g. flash distillation). Sea-water can be used for indirect cooling.

133. Treated sewage effluent can provide a useful source of general industrial water when appropriate pre-treatment is carried out to overcome problems such as foaming. Saline water can also be used for certain cooling applications but precautions must be taken in design and maintenance of the plant to overcome or cope with potentially severe corrosion problems.

134. The overall requirements in regard to quantities of water are represented by the quantities which must be circulated in the various items of plant to maintain satisfactory operation : this is termed "water in circulation". This does not, however, in many cases represent the actual demand on resources because recirculation and re-use of water can reduce water requirements considerably. To avoid confusion, the term "water intake" is used to denote the water which must be taken from source to supply the works system. The quantities of water in circulation shown as an example in Table 4 are for an actual works making general products (billets, bars, rods, section and plates), but these can be taken as fairly typical of the water requirements for any integrated iron and steel works. The main variable will be the degree to which the works generates electrical power from its own waste heat or waste fuels.

135. The quantities of water in circulation do not, however, necessarily represent the actual water intake requirement. There is a wide spectrum of possible water management practices that can be adopted according to particular local circumstances. The main factors affecting this choice can be summarized as follows :

136. Availability of water : This is governed primarily by climate and, of course, geographical siting and is perhaps the most important factor in deciding the water systems to be adopted. The availability of the desired quantities is more important than quality aspects since pre-treatment is generally possible to achieve adequate quality levels. Continuity of supply all year round is also of great importance and specially built reservoirs may be necessary in some cases. Clearly where water supplies are restricted there is a need to reduce the intake of water to an iron and steel works accordingly, but where abundant supplies are readily available such as at a coastal or estuary based works, reduction of the intake requirement may be of much less significance.

137. Constraints on effluents : Taking the simple premise that a large intake of water gives rise to large volumes of effluent, it can be seen that the water management practice adopted must take into account the ability of the environment to cope with liquid effluents. The use of once-through water circuits leads to large volumes of effluent with relatively low concentrations of contaminants which are difficult to treat because of the low concentrations. Thus there is a tendency to discharge a large pollution load which would, for example, be quite intolerable in a small freshwater river or in a confined space of water such as a lake. It might create less of a problem when discharged to a large water body with sufficient natural assimilative capacity to render the pollutants harmless, for example a major river or the sea.

Table 4

QUANTITIES OF WATER IN CIRCULATION IN AN INTEGRATED STEEL WORKS PRODUCING 4 MILLION T/ANNUM CRUDE STEEL

Plant	Main Purpose	Quantity m^3/min	Quantity % of grand total
A. Main indirect cooling water systems			
Coke Ovens	Gas primary coolers	75	7.9
Sinter plant	Furnace ignition hoods & fans	10	1.0
Blast furnaces :	Furnace cooling	170	17.8
	Furnace blowing (condenser cooling)	180	18.9
Steel furnaces	Furnace & equipment cooling	70	7.3
Continuous casting	Moulds & machine cooling	35	3.7
Hot rolling mills	Cooling electrics & hydraulics	30	3.1
Power generation	Condenser cooling for say 20 MW	85	8.9
Miscellaneous	Air compressors, exhaust fans, etc.	20	2.1
Total indirect cooling		675	70.7
B. Main direct cooling water systems			
Coke ovens	Gas cooling & purification	15	1.6
Blast furnaces	Gas cooling & cleaning	75	7.9
Steel furnaces	Fume cooling & cleaning	35	3.7
Continous casting	Quenching hot steel	10	1.0
Rolling mills	Roll cooling product, quenching scale washdown	130	13.6
Total direct cooling		265	27.8
C. Other water uses			
Process water	Coke quenching, sinter, mix miscellaneous	7.7	0.8
Boiler feed	Steam raising	4.8	0.5
Domestic & amenity		1.5	0.2
Total other uses		14.0	1.5
GRAND TOTAL		954.0	100.0

Source : International Iron and Steel Institute.

However, at the other extreme, low intake water recirculation systems will lead to much smaller volumes of effluent which are more amenable to treatment to remove pollutants prior to discharge and thus give rise to a much smaller polluting load. In hot climates where river flows are very low it may even be necessary to prevent any discharge of pollutants to the river and recourse has to be made to evaporation in lagoons.

138. Costs : Whilst the costs of various water management practices are significant, in terms of choosing the right overall water systems for a given situation, costs probably play a secondary role to the two major factors mentioned above of water availability and constraints on effluents. Thus, where a choice of water system still exists after the main factors have been taken into account, comparative cost studies should be made in order to ensure that the optimum is chosen. Relevant cost data will include the price of water as supplied or directly abstracted from source ; the costs of pre-treatment, the costs of delivering water to the works or running recirculation pumps, etc. Generally, the higher the charges for water and the higher the costs of pre-treatment, the more attractive becomes recirculation and re-use as opposed to once-through use. The biggest single item in the cost of water recycling is the electrical power used for pumping. This represents about 50 % of the costs, with capital depreciation, maintenance, manning, chemicals etc. accounting for the remainder.

139. Table 5 outlines the possible extremes of the water intake required for the works outlined in Table 4, firstly assuming once-through water circuits are used and secondly, assuming a high degree of recirculation and re-use is practised. It should be noted that the intake figures relating to the extensive utilization of recirculation and re-use techniques are based on actual consumptions at an integrated works during 1977.

Table 5

Water Intake Requirements for Different Water Management Practices
(4 million tons crude steel/annum integrated steel works)

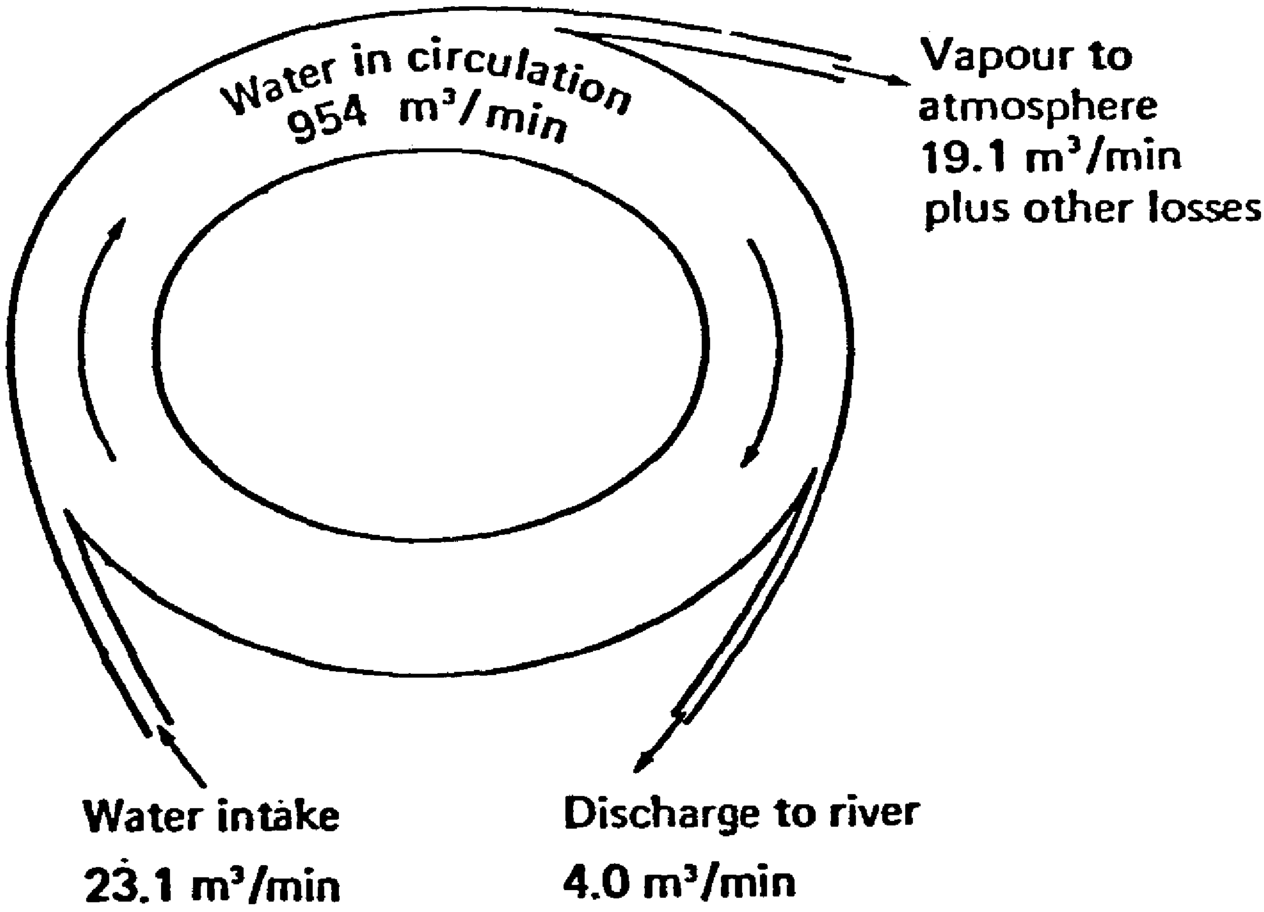
Water use	Quality required	Water intake m^3/min (% of total)			
		Once-through system		Extensive Recirculation	
Indirect cooling	General Industrial	675	(70.7)	7.4	(32.0)
Direct cooling		265	(27.8)	6.2	(26.8)
Process water	Low grade Industrial	7.7	(0.8)	5.1	(22.1)
Stream raising	High grade Industrial	4.8	(0.5)	2.0	(12.6)
Domestic & amenity	Potable	1.5	(0.2)	1.5	(6.5)
TOTALS		954.0	(100.0)	23.1	(100.0)

Source : International Iron and Steel Institute

140. The water usage system at a works using a particularly high level of recirculation is shown diagrammatically in Figure 6, from which it can be seen that water losses, mostly to atmosphere, represent 83 % of the intake and the effluent discharge 17 % of the intake.

FIGURE 6

DIAGRAM OF WATER USAGE AT WORKS USING EXTENSIVE FRESH WATER-RECIRCULATION



Source: International Iron and Steel Institute

141. The much reduced intake requirement is achieved by using recirculating systems on indirect and direct cooling applications and by re-using waste water from one process as the intake for another which does not require as high a quality of water. For example, plant drainage containing bleed-off water from various water circuits, boiler blowdown and collected rainfall can be used for coke and slag quenching. Care has to be taken of course, to ensure that water re-used in this way does not contain undesirable constituents which can give rise to health hazards or atmospheric pollution problems.

142. The water management techniques available to reduce drastically the iron and steel industry's demand on resources through retrofitting of effluent treatment equipment and recirculation systems to old plants are very expensive compared to the new plant situation. There is frequently also a problem of lack of space for such facilities at old congested sites. This emphasizes the importance of careful planning ab initio of the water system. However, it is an important area environmentally both from the point of view of a nation's water resources and the wholesomeness of its waterways.

143. As to the future, the general trend towards more sophisticated production processes emphasizes the need for continuity and security of water supply. On large BOF plants for example, premature failure of the oxygen lance would be very serious in terms of lost production compared to a failure on the cooling circuit of one of, say, eight open hearth furnaces. As a consequence, careful design of BOF lance cooling with a closed circuit using high quality water is advisable. Failure in water supply to a blast furnace could cause a serious hazard with the furnace structure disintegrating.

Water Pollution

144. As emphasized in the previous section, the risk of water pollution from the iron and steel industry depends to a large degree on the water management plan adopted. Pollution of the following kinds can arise :

Thermal (i.e. increase in the temperature of the water used),
Suspended matter including oil and tar,
Toxic substances such as some phenols, cyanide, soluble heavy metals,
Waste acids, solutions and rinse waters from finishing processes.

Thermal Pollution

145. About 70 % of the water needed for iron and steel making is used for cooling, and it contains a considerable amount of heat, for example about 75 kWh per metric ton of crude steel produced. To avoid thermal pollution problems where the receiving water is of limited size, the water must be cooled prior to discharge and the techniques for this are relatively well known. Installation of recirculation systems has the effect of lowering the volume of water discharged and raising its temperature. The smaller volume can be more easily cooled, if necessary, and even though the temperature of the discharge may be comparable with a once-through system, the total thermal load placed on the receiving water is much less.

Suspended Matter

146. The water in circulation in the direct cooling systems (e.g. gas cleaning, continous casting and rolling mill water circuits) at an integrated works is likely

to become contaminated with particular matter in the form of iron oxide particles, coke particles, oxide scale, oils and greases. Removal of this suspended matter is necessary within recirculation systems to prevent blockages, etc. and also prior to discharge of the water as effluent. There are no major technical difficulties in removing the majority of such solids and there is a wide range of settlement, clarification and filtration equipment available which can perform the required duties, provided that the plant is efficiently operated by trained personnel. There are still some problems in effectively separating oil and water. A typical example of a combination of such equipment in a hot rolling mill water recovery system is shown in Figure 7.

147. Mention should also be made of the pre-treatment of incoming water which can give rise to removed solids and lime sludge from water softening. The lime sludge can be utilized to advantage as a soil conditioner on poor acidic land.

Toxic pollutants

148. The main effluents containing substances which, in sufficient concentrations, may be toxic in the aquatic environment arising in iron and steel manufacture are from the coke ovens blast furnace gas washing, steel making fume cleaning and some of the product finishing operations ; these are discussed below. However, it should be noted that some other trace compounds may be found in steel works effluents, those of most concern being the bioaccumulative chemicals (e.g. polycyclic aromatic hydrocarbons, benzene, chlorophenols).

(i) Coke Oven Effluents

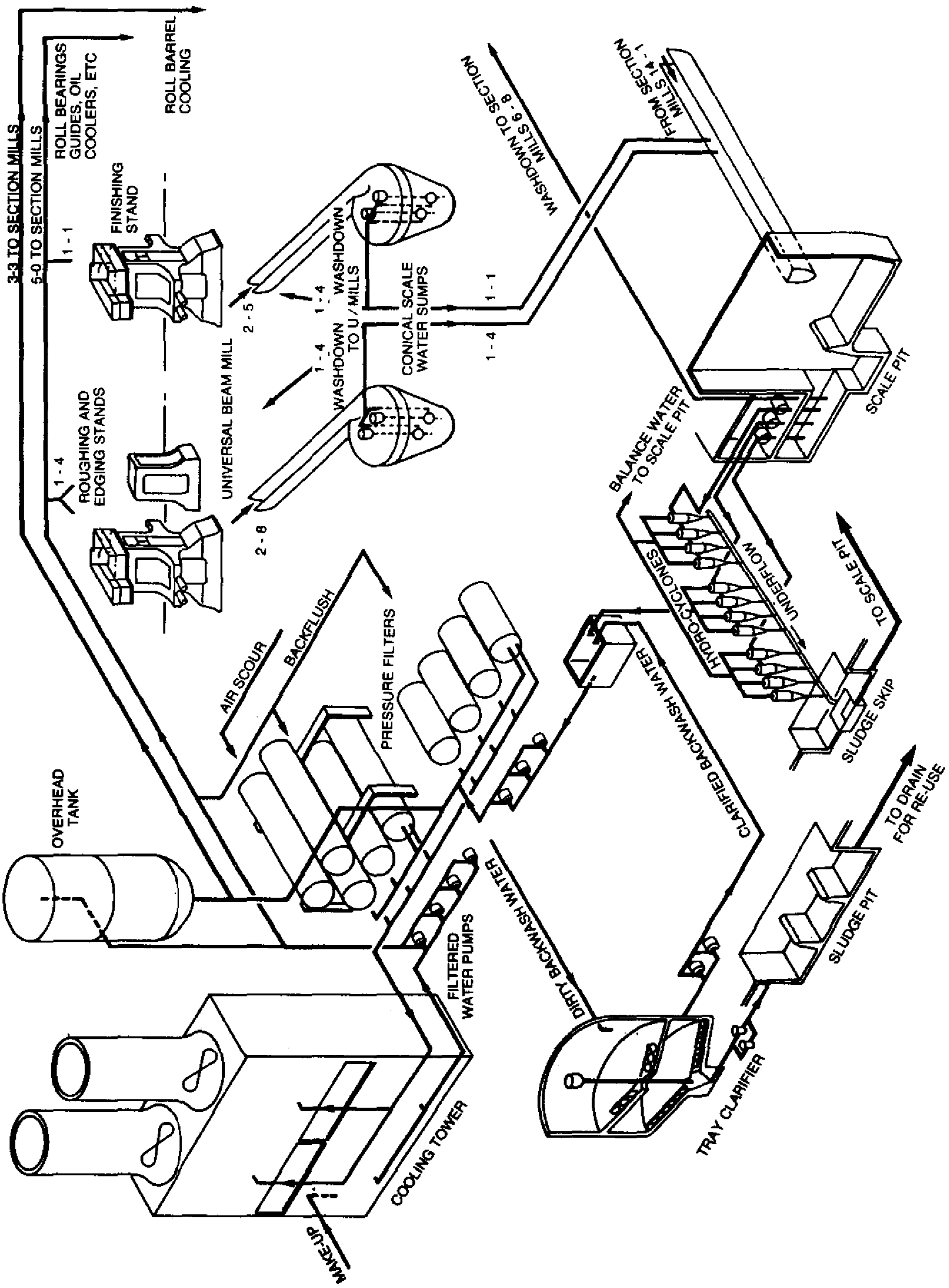
149. Carbonization of coal gives rise to waste liquors containing phenolic compounds, thiocyanate, cyanide, thiosulphate and ammonia, with an associated high biological oxygen demand. The levels of some of these contaminants can be reduced to a certain extent within the coke oven by-product processes, stills and dephenolization of the liquors by solvent extraction where applicable.

150. Numerous methods of treatment have been devised for treating the residual liquors from coke ovens, the treatments being of varying degrees of efficiency and at varying levels of cost, and, perhaps more importantly, not all proven in practice. The most common approach is to remove the major contaminants by biological oxidation, generally by the activated sludge method when treated alone, or possibly by percolating filters at a works treating domestic sewage where the coke works is situated close to a major city which has a sewage treatment plant of sufficient size to accept the coke oven liquors. Other approaches include, either independently or in combination, adsorption (e.g. with activated carbon), ion exchange, concentration and incineration. Cost factors, reliability and the dangers of transferring the pollution from one medium to another will be of importance in evaluating the practicability of some of these approaches.

151. Although the activated sludge treatment of coke oven effluents has much to commend it, not all potential pollutants may be removed. Residual ammonia in the coke oven liquor is not normally removed in the same biological process as the other major contaminants and pre-treatment and/or nitrification and dentrification stages may be necessary, thus representing a furthur extension of treatment. Coke oven effluent can be dealt with successfully under certain circumstances, for example where admixture with domestic sewage and combined treatment is possible. However, this is not always possible because of the large polluting load in the effluent and direct treatment is often required.

FIGURE 7

DIAGRAM OF SECTION MILL WATER RECOVERY SYSTEM



SECTION MILL WATER RECOVERY SYSTEM

ALL QUANTITIES BY CU M PER MINUTE

SOURCE : INTERNATIONAL IRON AND STEEL INSTITUTE

(ii) Blast Furnace and BOF Gas Washing Water

152. In blast furnace and BOF gas washing systems, it is necessary to bleed off a small proportion of the recirculating water in order to control the level of dissolved salts which can otherwise create problems of scale formation. Theoretically, the treatment of the bleed-off from these gas washing circuits should not present major problems since suspended particulates can be removed and the other contaminants oxidized (cyanide, thiocyanate) or precipitated (lead, zinc, fluorides). However, difficulties can arise in the blast furnace gas washing water, in particular on existing smaller operations with the wide variations that can occur in the level of pollutants, for example cyanide and thiocyanate in the intake to the treatment plant. These variations are understood to occur because of changes in burden and/or operating conditions. Cyanide can be oxidized by alkaline chlorination, at a cost, but there may be problems arising from chlorinated organic compounds which are produced thereby in the treated effluent. Waste water arising from slag treatment may have pH around 10 to 11 and a sulphide content from 300 to 600 mg/l, a COD from 400 to 800 mg/l and may also need to be treated before discharge.

153. The need is recognized in the design of effluent treatment plants, to accommodate for unpredictable variations in effluents. Consistency of raw material blends is a major factor leading to greater operational stability and consequently more efficient control of water pollution arising from large modern furnace operation. Ferro-manganese blast furnaces in particular can give rise to high levels of cyanide in the effluent which should be adequately treated.

(iii) Finishing Process Effluents

154. The treatments suitable for the variety of effluents arising from finishing processes especially for strip products (e.g. degreasing pickling, galvanizing, tinplating and organic coating) have to be selected on a case by case basis and it is sometimes possible to introduce judicious mixing of effluents to achieve some of the desired reactions. Many large plants employ recovery processes for spent pickling acids such as hydrochloric acid and sulphuric acid, and adoption of these processes removes one of the major effluents from this area. However, acidic rinse waters still have to be neutralized and the precipitated solids removed. In some cases acidic effluents can be used to split oil/water emulsions contained in effluents from the cold rolling process. In cold rolling processes oil/water emulsions are used as a lubricant and are generally recycled. Periodic batch dumping must be treated for emulsion cracking and oil/water separation before discharge. Solution and rinse waters containing phosphates, dichromates, alkalis, zinc salts, etc., can arise from the various finishing processes and appropriate chemical treatments are required prior to discharging the effluents. Strict segregation of contamined effluents and strong solutions from other drainage systems is highly desirable in order to optimize effluent treatment. This is particularly the case in the complex collection and treatment facilities which can be applied to finishing process effluents. Possibilities exist for the recovery of certain materials (e.g. tin, zinc) from the effluents during treatment. The neutralization, precipitation, clarification and filtering operations used for finishing effluent treatment, require careful control if a satisfactory effluent quality is to be maintained.

Other Effluents

155. Mention should be made of the use of conditioning chemicals in recirculation water circuits to inhibit corrosion and/or scale and slime formation. Careful choice of chemicals is very important to ensure that they do not create a pollution hazard in final effluents either on their own or by synergistic interaction with other pollutants already present in the receiving water.

156. Rainfall and site drainage can, in some circumstances, also present effluent discharge problems by becoming contaminated either by chance or accident. Collection and monitoring of the drainage might be advisable and in particularly sensitive areas (e.g. dry areas with low flow in the rivers), it may be necessary to dyke the whole site so that the whole drainage can be controlled. Removal of leachates from stock piles and raw materials may be necessary by containment and settlement prior to discharge.

157. Disposal of solids collected in air pollution control equipment must also be looked at carefully from the point of view of preventing rainfall run-off from dumped material leaching out contaminants and causing pollution of the aquatic environment. Similarly, a rainfall run-off from ore stockpiles can present problems.

Monitoring of Water Pollutants

158. An important but often neglected part of water management and effluent control is monitoring. Monitoring is carried out to provide information for control purposes in the incoming water, in the treatment of effluents and in the final discharge. It is of particular importance in water pollution because quick reaction to adverse levels of pollution is essential in avoiding consequences (e.g. major pollution of a water course which is used for abstraction of potable water). Monitoring of incoming water is essential to judge what pre-treatments are necessary prior to use, but it also provides essential information in regard to effluents discharged since the contaminants in the incoming water will still be present and perhaps concentrated in the final effluent. Proper monitoring of the inlet and outlet of any effluent treatment plant is also essential for ensuring that plant is operated efficiently and to give forewarning of failure to meet design treatment levels. At present much of the monitoring is carried out manually by wet chemicals analysis and a considerable manpower effort is required. There is a need also to update and improve analytical techniques in line with pressures for more accurate data. In the future careful selection of the parameters to be measured should lead to continous automated monitoring and analysis of effluent treatment plant operation which would give far better control than manual sampling and analysis.

159. Final effluent monitoring of selected parameters is also important and is generally required by the water pollution control authorities. Again some form of continous monitoring is desirable although this depends to an extent on the degree of susceptibility of the receiving water and on the design and layout of the effluent system. There is really only value in control terms of continously monitoring a final effluent discharge where the ability to institute remedial action in cases of high pollution levels exists. This ability to take remedial action could, if space is available, take the form of emergency storage lagoons into which the unsatisfactory effluent could be directed pending further treatment. In any case care and attention to detail in the design and drainage systems to avoid accidental contamination of water courses is important.

160. In the effluent treatment area there are still problems to be overcome in the treatment of coke oven effluents, blast furnace gas washing effluent and to an extent BOF gas washing effluents. Further work is still desirable to develop continous and/or automatic monitoring of selected parameters in order to provide better day-to-day control over specific efflüent discharges and to permit speedy remedial action when necessary.

d) Noise

161. The various production and ancillary processes in a steel works create noise and it is necessary to take appropriate steps to control or avoid this noise in order to overcome problems of community nuisance and annoyance outside the plant. Similar measures are required to remove the risk to hearing of the work force and improve working conditions in the plant and this aspect is discussed further in Chapter III. Techniques for measuring sound are well established and, although standards exist in a number of countries, for instance, for prediction of noise nuisance in the community, they have not yet been universally adopted.

Sources and Extent of Noise Emission

162. In a typical integrated iron and steel works, noise results from :

- Production and fabrication operations
- Handling and transport of raw materials, semi-finished and finished products,
- Aerodynamic and hydrodynamic sources.

Efforts to limit noise in steel works are aimed at lowering exposure to noise in the working environment to an acceptable level and removing noise problems in nearby residential areas. These two are frequently complementary with the solution to the in-works problem often providing a suitable answer to the community situation. A general rule is that the nearer to the source the problem is tackled, the more successful will be the remedial action.

163. Some examples of noise levels at present encountered in a steel works are given below.

Typical Peak Noise Levels

Production and Processing Operations

Ore crushing, 5 metre distance	98 dBA (continous)
Loading scrap pans, 25 metre distance	105 dBA (intermittent)
Electric arc furnace without dog-house (melt-down period) : 6 metre distance	109 dBA (semi-continous)

Handling and transport of raw materials, semi-finished and finished products :

Conveyor discharge point, 5 metre distance	85 dBA (continous)
Slab mill roller tables, 5 metre distance	95 dBA (intermittent)

Aerodynamic and hydrodynamic sources :

Valves and dampers, blast furnace cold blast mains, 1 metre distance	96 dBA (continous)
Blast furnace hot stove operation, 10 metre distance	91 dBA (continous)

It should be noted that some of these noises are intermittent in nature and the figures given above represent peak levels and not mean exposures.

Possible Measures to Decrease Noise

Production and processing operations

164. Production and processing operations in the steel industry are, by nature, noise sources of considerable importance. In attempting to decrease noise, elimination of the source is preferable to secondary measures such as insulation, damping and isolation of vibration sources. It is possible to achieve engineering design solutions to noise problems and, on occasions, quieter processes can be substituted for intensely noisy ones (pressing instead of punching, sand-blasting or grinding instead of chipping). It should be noted, however, that it is much more difficult and expensive to tackle noise on existing plant than it is to overcome noise problems in the design of new plant. Where the above-mentioned methods of noise suppression are either insufficient or impracticable, it is then necessary to provide acoustic shelters and introduce personal protection in the case of the work force and, in the case of neighbourhood noise, acoustically sealing plant buildings. An important new development for electric arc furnaces is the use of enclosures similar to the doghouse developed for emission control.

Handling and transport of raw materials, semi-finished products and finished products

165. In modern steel plants, methods of continously transporting materials, for example, by conveyor belt, are being increasingly used instead of batch transportation by road haulage or railway. Thus the trend is for noise sources to be reduced in this area. Conversely, noise emissions which occur in handling and transport of semi-finished products from the various production stages at steel works are very difficult to avoid, but at the same time are of major significance in regard to the quality of the working environment, and also from the point of view of community nuisance. Noise from rolling mill finishing departments represents a major source and indeed a major technical problem.

166. With light steel products, noise can be controlled by modifying the handling equipment, but for larger products this is generally not possible. It is frequently the product itself which gives rise to noise emissions during handling, and factors such as shape, weight, temperature and speed of transport play an important part here. Important strides have been made in the past to reduce noise from these operations, such as eliminating the many points of impact, but the problem has still not been completely solved.

167. Further research directed at solving problems at the finished end is required in order to develop techniques for designing out noise. A number of projects are presently being undertaken in various contries aimed at finding novel engineering and materials solutions for both new and existing plant.

Noise arising from flow and transport of gases and liquids

168. With the increasing size of production units in the steel industry the quantities of gases and liquids which have to be transported are naturally increasing. By-product gases of high calorific value are distributed throughout major integrated plant to achieve an acceptable energy balance in the works. Integrated distribution systems are generally used for blast furnace gas, coke oven gas, natural gas, steam and various types of oil. Aerodynamic and hydrodynamic noise may arise in various parts of the system due to turbulence from the high velocities encountered and also from pressure fluctuations. Noise during transmission of gases and liquids can be decreased by suitable pipework design, by covering the pipes with an insulating layer, and by isolating vibration sources from the rest of the pipework. Within certain limits, low noise valves and ventilators can be used to reduce noise in and around areas where pressure changes occur. A range of silencers can also be incorporated at strategic locations in the pipework. Distinction should be made between diffusion silencers which allow gradual pressure release while reducing turbulence and both absorptive and reactive sound absorption dampers which can be deployed to handle sudden pressure releases.

169. Silencers which do not remove the source of noise but rather restrict the transmission lose efficiency when dust levels in gases are high and they are liable to wear over a period of time : thus good maintenance is necessary. Reactive silencers (resonance absorbers) are least susceptible to dust by virtue of their advantageous design.

Protective Barriers

170. There are a number of passive noise abatement measures which include noise barriers, screens or mounds. Earth mounds for example prevent the linear undamped diffusion of sound from the source by means of a screening effect and they offer additional possibilities for landscaping the area by planting it with trees and shrubs. This can result in a more pleasing and therefore acceptable appearance of the industrial site from outside.

e) By-Products, Residues and Solid Wastes

(i) Materials and By-Products

171. Iron and steel making processes give rise to significant amounts of usable or unusable materials, the latter generally being termed waste. It is sometimes difficult to state at any one time which materials are by-products (re-used at the works or sold outside) and which are wastes that cannot be re-used or sold. Much depends on circumstances such as the local market for the material. This can itself vary from time to time with by-products which cannot be used or sold becoming wastes and vice versa. In general, these materials are inorganic and about 80 % are either utilized or passed to other processes ; the remainder should be disposed of using well-established waste disposal practices to avoid any environmental threat (see below). As far as good management of by-products and wastes in general is concerned, the following are of importance :

- minimizing the specific quantities of by-products and wastes produced,
- control of environmental problems during reprocessing, transport or depositing of by-products and waste,

- minimizing, through recycling, the quantities for ultimate disposal.

A schematic diagram of by-products and wastes arising, re-used, sold and dumped is given in Figure 8 based on an example from the French steel industry.

Ore Mining and Preparations

172. In general the waste product arising during mining of magnetite, Fe_3O_4 or hematite, Fe_2O_3, is the overburden which is re-used, among other ways, in the reclamation of open cast mining sites. The dust generated by ore crushing and at transfer points during ore transportation is collected in filters and returned to the process.

Coke Making

173. The process of producing coke gives rise to coal derivatives which are an important feedstock for the chemical industry. As well as coke oven gas, benzene, toluene, pyrene, napthalene and other aromatic hydrocarbons, phenol, tar, hydrogen sulphide for further processing, etc. are yielded. At some plants the coal dust occurring during charging of coal into the ovens and the coke dust arising during pushing of coke are now extracted and collected in filters. Quenching towers are also equipped with means of reducing the grit given off during the quenching process, and dry coke cooling provides an alternative means of coke quenching. The coke breeze arising is largely carbon and can be fed back into the production sequence.

Sintering and Pelletizing

174. Waste products do not arise during sintering of iron ore but the gases generated do contain significant amounts of dust consisting of ore and coke particles ; these are arrested by electrostatic and other filter methods. The material may then be fed back on to the sinter strand via the mixer drum. If it is necessary to eliminate SO_2 (S from the coke breeze) involved during the sinter process, a number of waste gas desulphurization processes are available. Depending on the type of plant used, the waste product is collected in the form of gypsum, $CaSO_4 . 2H_2O$, or ammonium sulphate, $(NH_4)_2SO_4$. Techniques also exist which provide elemental sulphur as the end product. Of the types referred to, the plant which has been most commonly installed is that yielding gypsum. This material is produced either in the form of pure gypsum, acceptable to the building industry for plaster and cement, or in the form of impure gypsum, which is either passed to the mining industry for use as back-fill or disposed of in special dumps. Ammonium sulphate can be used as a fertilizer whereas elemental sulphur can act as an important raw material for the chemical industry (e.g. sulphuric acid manufacture).

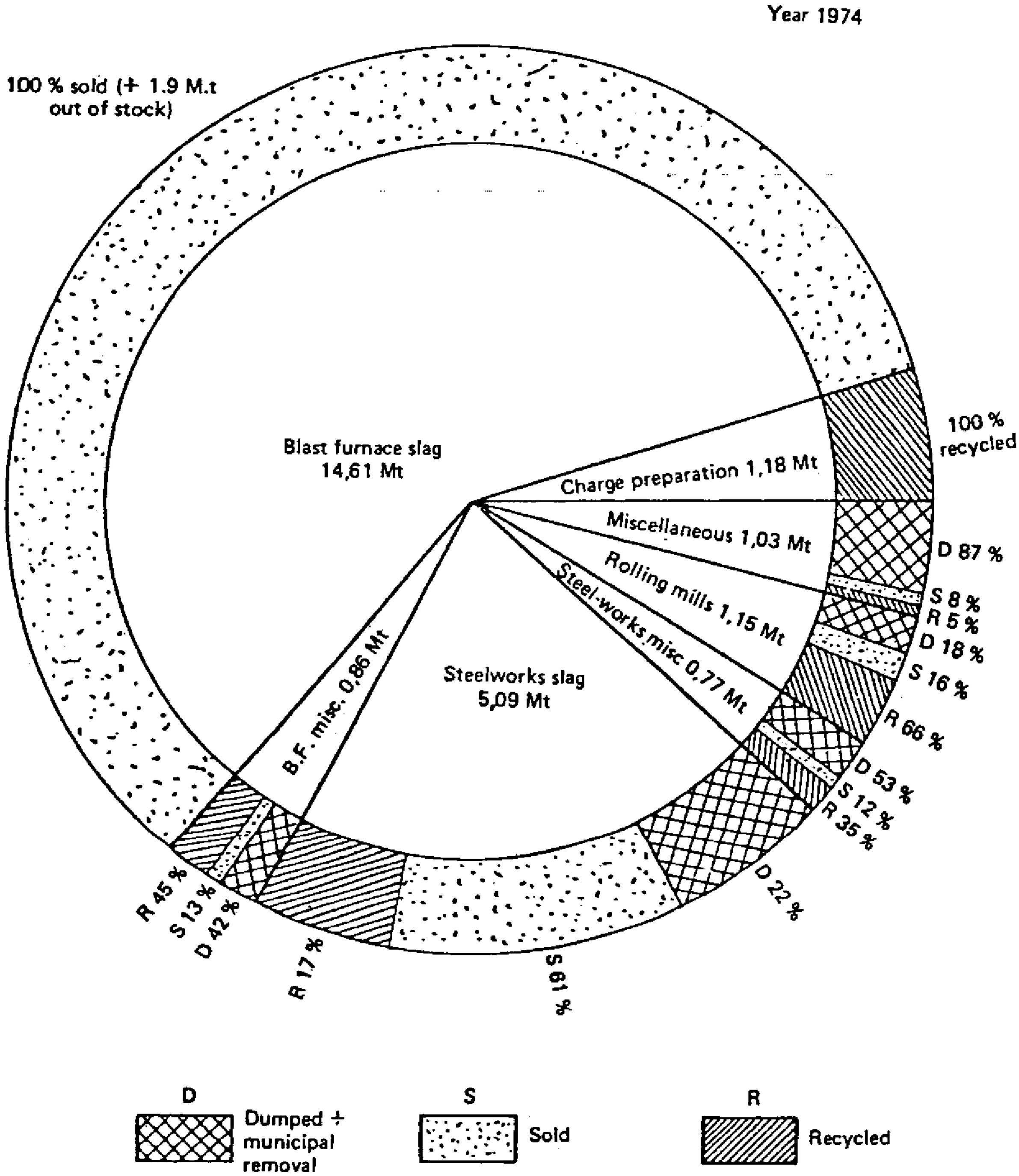
175. Pelletizing gives rise to a waste gas which is, like the sintering gas, dust-laden and which must be cleaned. The material collected is suitable for feeding back into the system.

Blast Furnace Process

176. The reduction of iron oxides in the blast furnace involves the evolution of a number of by-products. Generally, these are :

FIGURE 8

DIAGRAMMATIC REPRESENTATION OF BY-PRODUCTS AND WASTES ARISING, RE-USED, SOLD AND DUMPED IN THE FRENCH STEEL INDUSTY



Source : International Iron and Steel Institute

- blast furnace slag,
- dry dust and moist filter cake,
- casting floor fume,
- refractory waste (from the furnace, ladle or runners),
- ladle skull.

(a) Blast furnace slag

177. The ore gangue is formed into slag by the introduction of limestone in the blast furnace burden. Modern blast furnace practice using high grade ores typically gives rise to about 320 kg slag/t pig iron whereas 1 t slag/t pig iron may be produced when using low grade ores. The slag can be utilized in a number of ways such as a building material or as the raw material for blast furnace cement. There are several ways of dealing with liquid slag emerging from the furnace :

- It is allowed to solidify in thin layers with either air cooling or by the application of additional cooling with water. This yields a lump slag which can be crushed and ground to various grades mainly for use as an aggregate in road building. Use as a concrete additive is also common. In some countries, especially those with coastal steel works, blast furnace slag can be used for land reclamation. Normally, the slags are marketable and recently old slag tips have been quarried to extract saleable slag. During the process of crushing and grinding of slag there is some dust emission and this is extracted and filtered. The recovered dust can be used as a filler for bituminous mixes or sold as a fertilizer.

- The liquid slag is granulated in water. This is a quenching process yielding a fine grained slag valued as a raw material for blast furnace cement.

- The slag is formed by using a lesser quantity of water, producing a porous material used in road construction especially in conditions where the ground has poor load-bearing capability, or as an insulating material.

- The slag is pellitized.

- Depending on the basicity of the slag, slag wool can also be produced.

The slag arising from the production of common pig iron has the following chemical analysis :

Chemical analysis of blast furnace slags (common pig iron)

CaO	36-43 %	SiO_2	28 -36 %	Al_2O_3	12-22 %
MgO	4-11 %	Fe	0.3- 1.7 %	S	1- 2 %

Source : International Iron & Steel Institute.

(b) Cast house fume

178. The dust collected in filters on extraction systems at cast houses can be fed into the sinter plant.

(c) Refractories

179. During furnace wrecking or rebuilding, a good deal of used refractory material arises. Fireclay bricks are normally sorted and the re-usable portion passed for evaluation, the remainder being dumped or fed into the furnace as an additive for slag formation. Carbon blocks are often crushed and used as a fuel, but sometimes they are dumped. Fire-clay ladle linings are similarly sorted but dolomite and runner materials are dumped. Dolomite refractories can be recycled in some cases. Dumped refractory material does not usually give rise to environmental problems.

(d) Dust and slurries

180. Dust arrestment at blast furnaces is normally carried out in two stages :

(i) Coarse dust separation in a dust catcher and/or cyclone. This dust consists largely of iron oxides and coke residue and has the following approximate analysis :

Chemical composition of coarse blast furnace dust

Fe	25.0 - 38.0 %	Mn	0.2 - 0.3 %
SiO_2	5.5 - 7.0 %	Al_2O_3	2.1 - 2.9 %
CaO	4.6 - 6.6 %	MgO	0.7 - 1.3 %
S	0.2 - 0.5 %	C	24.1 - 45.4 %

Source : International Iron & Steel Institute

(ii) Wet scrubbers of varying types and possibly wet electrostatic precipitators are incorporated in the second stage of gas cleaning. The residue is a slurry with a range of compositions :

Chemical composition of wet scrubber material (dry basis)

Fe	10.0 - 32.0 %	SiO_2	3.0 - 8.0 %
CaO	3.0 - 7.0 %	Al_2O_3	2.0 - 4.0 %
C	10.0 - 30.0 %	Pb	0.2 - 10.0 %
Zn	0.6 - 20.0 %	S	0.5 - 6.0 %

Source : International Iron & Steel Institute

The analyses shown indicate a wide range of variation because the precise level of constituents can vary from works to works and from country to country.

181. The coarse dry dust is in general suitable for re-use in the sinter plant in the form in which it arises, but such re-use is not so readily applicable to the slurries because of the presence of lead, zinc and alkalis. The levels of lead and zinc encountered will vary according to the ores used and the extent to which the dust is recycled. They must therefore be either subjected to a further stage of treatment to remove the lead, zinc and alkalis or alternatively dumped.

Desulphurization of pig iron

182. Various techniques for pig iron desulphurization have been developed in recent years and consist of introducing a re-agent, such as calcium or magnesium carbide, in the hot metal to reduce the level of dissolved sulphur. The methods used are either based on mechanical stirring or lance injection. The resulting waste product is a carbide or soda slag which is further processed to separate metallic components. The desulphurization processing using calcium or magnesium carbide injection might make 8 - 15 kg slag/t pig iron. Carbide slags have the advantage of being re-usable in most cases in the sinter mix, and, where this is not possible, they are disposed of without difficulty once it is certain that no carbide remains.

Steel making processes

183. The solid waste arising from the steelmaking processes comprises :

- slag,
- arising scrap,
- slurries and dust,
- refractory material.

A Steel making slags

184. Quantitatively the largest by-product from the present steel making processes is slag. The chemical composition of slags arising in the production of large tonnages by the BOF or bottom blown oxygen methods is as follows :

Chemical composition of BOF slags

CaO	38.0 - 46.0 %	SiO_2	10.0 - 16.0 %
MgO	2.0 - 4.0 %	MnO	3.0 - 6.0 %
Fe	15.0 - 28.0 %	P_2O_5	1.0 - 3.0 %
Al_2O_3	1.0 - 4.0 %	S	0.2 %

Source : International Iron & Steel Institute

185. The composition of slags arising from electric arc furnace steel making is somewhat different, oxidized slags having the following composition :

Fe O	10 - 30 %	Mg O	5 - 10 %
Ca O	30 - 60 %	Mn O	4 - 8 %
Si O_2	10 - 20 %	P_2O_5	1 - 3 %
		Al_2O_3	1 - 3 %

If the melt down is with an insufficiency of oxygen the slags have the following composition :

FeO	17 - 35 %	SiO_2	10 %
CaO	45 - 60 %	MgO	5 %
		P_2O_5	2 - 3 %

186. The specific slag quantity depends very largely on the quality of steel being produced and on the scrap iron ratio in the charged materials. If the proportion of high-grade sorted scrap is large, the slag quantity is correspondingly smaller since the process is really one of remelting and refining. The reverse is true if the proportion of pig iron in the charge is high since the slag quantities have to be greater in order to achieve the refining process. Specific slag quantities can therefore vary over the range 70 - 170 kg/t liquid steel.

187. Applications for steel works slags are :

- blast furnace feed via sinter mix (slag forming agents and iron oxides)
- civil engineering applications
- fertilizers.

188. As referred to above slags arising from steel making operations are normally poured off into contained areas within or outside the steel shop and allowed to cool. Slag transporters are always used for BOF slags but not always for EAF slags. The slags are broken up, iron is removed by magnetic separation and the product is size-graded.

189. Certain quantities of BOF slag can be added to the iron making or sinter plants as lime or iron carriers but there are constraints on this use in the context of the basicity of the blast furnace slag or the phosphorous content of the pig iron. Over the past ten years an increasing quantity of BOF slag has been used in civil engineering projects such as the reinforcement of river and canal banks. In this case only slags of large lump size (over 40 mm) are used. Recently, increasing quantities have also found application in road building or as ballast for railway tracks. Even greater growth in this area is predicted over the next few years. Here the prerequisite is that the material should be stable and not swell, and this is only possible when the free lime content is controlled.

190. Where ores containing relatively high levels of phosphorous (e.g. from Colombia, France and Luxembourg) are used, slags have high P_2O_5 content (commonly greater than 15%), and may be ground and used as fertilizer in agriculture. Large steel works are moving more and more towards the processing of low-P ores with the result that the slags contain less and less P_2O_5 and in order to obtain a material with the correct level of citric-acid-soluble phosphates (a measure of fertilizer quality) slags have natural phosphate rock added to them in the grinding process.

B <u>Filter products from primary and secondary de-dusting</u>

191. Different qualities and quantities of scrap charged to modern oxygen and electric steel making processes govern the chemical composition of the fume collected. For primary fume cleaning in oxygen top blown and bottom blown steel plants there are many designs of equipment in use, and according to the actual system, specific quantities of 12-16 kg/t steel arise as dust or slurry. The slurries are filtered and pressed or are de-watered in a separate installation. Residual water varies between 18 and 39 %. A typical analysis of the arrested dust is as follows :

Chemical composition of wet dust from BOF primary fume-cleaning plant (dry basis)

Fe	43.0 - 65.0 %	Mn	0.5 - 2.0 %
SiO_2	1.0 - 3.0 %	CaO	5.0 - 10.0 %
S	0.1 - 0.4 %	Zn	2.0 - 7.0 %
P	0.5 - 4.0 %		

Source : International Iron and Steel Institute.

Certain works feed the primary fume cleaning dust back to the sinter plant stage of the integrated process. In many cases, however, this is not possible since accompanying elements like zinc and lead, which are mainly introduced via the scrap charge, can be detrimental to the blast furnace operation. The possibilities for removing lead and zinc prior to re-use of this dust are discussed below.

192. In secondary fume cleaning in top and bottom blown oxygen converters, the important areas are fume extraction at the hot metal transfer station and at the hot metal mixer, fumes arising during charging of scrap and hot metal, and finally fumes during tapping of the vessel. The dust quantities concerned in these stages vary considerably according to the process and works practice. The dusts collected are very largely a fine grain iron oxide and can be recycled either directly to the sinter plant or via some form of pre-treatment.

193. Primary and secondary fume cleaning installations in electric arc furnace plants give rise to collected dusts, the nature of which vary very much according to the steel quality being produced. Sometimes they are suitable for recycling in the steel process and this is usually done by pelletizing and recharging to the electric furnace. In some cases, however, it is not possible to recycle the dust, for example, because of the presence of lead and zinc or in the case of alloy and stainless steel making, the presence of Ni and Cr oxides. Where dusts must be disposed of, care has to be taken with material containing heavy metals to ensure no harm to groundwater. Secure dumps are therefore necessary. It is possible to recover Pb and Zn by the Waelz process employing direct reduction. Ni and Cr may be recovered by the Inmetco process by direct reduction followed by electric arc furnace reduction. However, both of these processes using high technologies have so far limited application due to their cost.

C. Refractory waste

194. Refractory material arises from the relining of steel making vessels, ladles and tundishes at the continous casting plant. Metallic components from these refractory materials are recovered, usually by magnetic separation, and re-usable bricks are sorted. Any remainder is dumped and in general such material is innocuous.

Hot forming processes

195. The important residues and wastes are :

- steel scrap,
- millscale,
- soaking pit and scarfing residues,
- refractory material,
- used oil and grease.

(i) Scrap

196. Scrap from the hot rolling mill is used as a feedstock for the steel making plant.

(ii) Millscale

197. According to the type of hot rolling mill in question, millscale consists of something like 90 % virtually pure Fe_3O_4 in almost oil-free form. This can be recycled to the sinter plant. The water used in rolling mills carries small quantities of oil to the clarification plant and this is separated and removed by various techniques. Fine millscale is entrained in the water and this is separated as oil-containing scale. The actual oil content can be up to 10 %. Charging of such material to the sinter plant is only possible if the sinter plant is not equipped with electrostatic filters. Unburnt or partially burnt oil would be spattered into the filters and on to the electrodes, and in some works this has caused damage in the filters. The present day limit to oil content in the mix on a sinter strand equipped with electrostatic filters is about 0.1 - 0.2 kg oil/t prepared sinter.

198. In order to avoid contamination of the scale pits by oil and grease, three methods of handling oil-containing scale are under consideration : solvent extraction, extraction with detergent and mineralization in a fluidized bed heater. At present, millscale containing large amounts of oil usually has to be dumped or stored and special precautions have to be taken to prevent water pollution by oil.

(iii) Soaking pit and scarfing residues

199. Residues of this type are treated and, according to size, passed either to the sinter plant or the iron making plant following removal of non-metallic components.

(iv) Refractory and other wastes

200. Disposal of used refractory material has been dealt with in paragraph 186. This kind of waste also arises in the rolling operations, from soaking pits, reheating furnaces and similar plant. It is sorted to separate re-usable material and the unusable residue can be disposed of safely.

(v) Used oil and grease

201. In the case of oil, equipment exists for refining or safe incineration, but proper disposal may present problems where such facilities are not available ; used grease is mixed with inert solid material such as sawdust or fine slag to consolidate it prior to disposal on special dumps.

Pickling lines

202. Acid pickling generally precedes cold rolling. Sulphuric acid, hydrochloric acid or mixtures of hydrofluoric and nitric acids (in the case of special steels) are used. Spent acid from sulphuric and hydrochloric acid pickling can be treated to regenerate the acids themselves. The regeneration of sulphuric acid can give rise to ferrous sulphate monohydrate or ferrous sulphate heptahydrate. The heptahydrate is a soluble compound and may be marketable as a useful chemical, for example it can be used as a flocculant or in the production of herbicides.

However, the monohydrate is an insoluble compound and may have to be dumped where no market for it exists. If for various reasons the heptahydrate is not marketable, it may be preferable to make the insoluble monohydrate which can be more safely dumped. Some hydrochloric acid regeneration processes give rise to very fine grained ferric oxide, which finds application as a pigment.

203. In a number of pickling operations, small amounts of acid are used and recovery is not worthwhile. Various uses can be found in a works for such small quantities of acid, for example for neutralization in the works water clarification plant. Acid neutralization sludges can be accepted within the works effluent treatment system and disposed of with other treatment sludges or the neutralization sludge is itself dumped.

Cold rolling mills

204. Scrap arising during cold rolling is re-used in the steel making plant. Rolling oil emulsions are recycled until spent. Used rolling mill emulsion is sometimes injected into blast furnaces as a fuel, or disposed of by incineration. A further and more attractive innovation now being applied is ultra-filtration and the oil recovered can be refined and re-used. If spent emulsions are to be discharged as effluent, it is necessary to crack the emulsion and remove the oil prior to discharge. Contaminated water vapour given off from tandem and finishing mills is extracted and filtered, the emulsion oil being recycled.

Surface treatment

205. Some cold-rolled sheet and strip is passed to galvanizing, tinning or plastic coating lines. The first two processes mentioned work either on an electrolytic principle or by hot dipping. The waste products are not quantitatively significant : the zinc dross for example can be recovered for re-use.

Treatment of iron-bearing wastes

206. Reference has been made earlier to the necessity for treating large quantities of iron-bearing wastes from the growing number of fume cleaning applications. As seen above, blast furnace and steel works dusts and slurries contain significant quantities of zinc and lead. Zinc is detrimental to the blast furnace process in that it leads to the formation of scaffolds (i.e. accretions are formed by the condensation of zinc compounds in the upper part of the furnace). Direct recycling of dusts and slurries is therefore not always possible. A few works have installed plant for processing these materials mainly in association with direct reduction plant using rotary kilns (2) ; pelletizing and pellet firing facilities are provided with such installations. The iron oxide is reduced to sponge iron by the use of reducing agents which are supplied in the form of gases or coke breeze and also partly from the carbon (10 - 30 %) contained in the filter cake from blast furnace gas scrubbing. At the same time, the zinc and lead are vaporized and are deposited in the form of oxides in a fume arrestment plant.

207. The zinc oxides are generally sufficiently concentrated to make zinc recovery worthwhile. The sponge iron pellets are passed to the ironmaking plant or, if the sulphur and alkali levels are low enough, directly to the steel works. Processing plants of this type will only slowly be introduced into the existing steel industry on account of the heavy investment and operating costs. Operating costs are approximately offset by the revenue from sale of zinc and lead oxides and the sponge iron, and by the avoidance of disposal expenses or taxes.

Other forms of waste

208. A large steel works must take account of waste products which do not arise as a result of specific production processes.

Earth and builders' rubble - Such material arises during the construction of new buildings and during rebuilding. This material can be used for the construction of embankments or landscaping projects.

Boiler ash - This can be dumped without danger but it is also re-used, for example, as a raw material for synthetic building blocks or road construction.

Slurries from water treatment plant - Deposits arising from water treatment processes are normally dumped. The calcium carbonate from boiler feed water can sometimes be taken by the sinter plant, and lime sludges may find application in agriculture as a soil conditioner.

Management of wastes

209. Large steel works employ departments for the control and organization of works waste economy. A number of companies have laid down guidelines to rationalize and facilitate waste disposal work. On economic grounds, iron and steel works have a vested interest in the optimum re-use and sale of by-products and wastes. The revenue realized in this way helps to offset the expenditure on environmental protection incurred by the industry. There has been an extensive exchange of views among the federations in various countries with the objective of increasing the possibilities of recycling materials. There is also extensive literature on the management of wastes in the iron and steel industry.

Trends, research and development

210. The potential for the sale of products such as blast furnace slag depends on market forces prevailing in different countries and a major factor in this is the local availability of alternative raw materials. Co-operative work with sales and research departments is carried out with a view to improving the quality of by-products sold to the building industry. Many countries have standards relating to the chemical and physical properties of these materials, for example, sizing and mechanical strength of blast furnace slag used as aggregate for road building. Further research possibilities lie in the direction of treatment of slurries and dust. Furthermore, new outlets for steel works by-products and wastes need to be found, for example, replacing natural raw materials for building blocks.

211. In summary the industry is therefore aiming at high rates of recycling and selling wastes wherever possible in order to reduce the amount of wastes to be deposited. It has been demonstrated in the past years that it is possible to deposit blast furnace slag at times of weak demand and recover it at more favourable times for sale to the construction industry. Studies are underway to recover valuable raw materials from the iron-bearing dusts which potentially present the main problems in regard to toxic content but the technology is costly and further research work is necessary. Further investigations are also needed to improve techniques for separating oil from millscale so that a greater proportion can be recycled.

Disposal of Wastes

212. The waste material arising in the iron and steel industry which must be disposed of varies according to local circumstances and the problems of waste disposal are mostly related to the bulk of material that has to be deposited. The number and quantities of toxic material are relatively smaller than the large quantities of inert material. The relatively inert materials include mining wastes, techniques for disposal of which are detailed in the literature ; those blast furnace and steel making slags which cannot be utilized ; some refractory materials ; waste sand from foundry and casting operations ; building and demolition rubble. Techniques for waste tip management are referred to in paragraph 219 below.

213. The toxic or potentially toxic materials which may need to be dumped include blast furnace and steel making gas cleaning dusts and sludges if they contain tramp elements such as zinc and lead ; tarry and lime bearing wastes from coke oven by-product operations ; oily wastes, including oil millscale or residues from rolling operations ; acid neutralization effluent treatment and finishing process sludges. The United States EPA has listed as hazardous wastes from specific sources in the iron and steel industry : ammonia still lime sludge from coking operations ; dust and sludge from air pollution control devices on electric arc furnace steel production ; spent pickle liquor in steel finishing operations : sludge from lime treatment of spent pickle liquor and sludge from tar decanting in coke operations. Furnace slag has been demonstrated to be non-hazardous in accordance with EPA procedures. Techniques to destroy some of these wastes, for example by incineration, may be possible in some cases, but generally speaking are only adopted where they can be justified on economic grounds. One possibility is the injection of tarry or oily wastes into the blast furnace. Recycling and re-use of these potentially toxic materials are clearly desirable and some opportunities may be available for recovering valuable material.

214. Where land dumping is carried out, care must be taken with potentially toxic materials to ensure that no environmental hazard is created (8). For example, access to toxic waste tips by humans or animals must be controlled ; protection of groundwater from toxic leachates from tips must be ensured either by using a tip with a sealed base or by monitoring possible leachates from the tip. It is also important to control pollution due to run-off from tips into surface water and it may be necessary in some cases to dyke (or bund) the waste disposal site and effect appropriate effluent treatment prior to discharge. Particularly hazardous materials e.g. cyanide wastes, asbestos wastes, which may arise in small quantities in iron and steel operations must be disposed of with the greatest of care and if deposited on secure tips the area in which they are placed should be clearly marked and recorded.

215. As mentioned above, there are various residual materials unsuitable for further processing which must be disposed of. In the case of large quantities, especially of inert material dumping in disused gravel or other stone pits is common. It may also be possible to build landscaping embankments with the waste and when such embankments become covered with plant life they provide an environmentally satisfactory barrier between industrial and residential areas. Where such possibilities do not exist, dumping of material in waste tips becomes necessary. The modern method consists of creating an outer embankment which can be disguised by planting of trees, and then further dumping takes place in the area of the tip made less visible by the screening embankment. When the first

layer is complete, the second stage begins once again from the outer area, the outer screening mound being covered with plant life as rapidly as possible. With careful planning this kind of waste disposal area can be converted into an amenity area for the public.

216. An important source of iron and material input for the industry is iron and steel scrap. In 1975 the world-wide consumption of scrap in steel making represented 45 % of crude steel production (290 m tons scrap compared with 646 m tons crude steel). This figure does not include the scrap recycled to the iron making processes (blast furnace and iron foundries). In many countries (e.g. Denmark, Italy, Spain) well over 50 % of steel production is from scrap. Some steelmaking routes, e.g. the electric arc process, are based entirely on scrap. This route represents only 15 to 25 % of the energy needed to make steel from virgin ore. However, this does not take into account the consumption of energy for transporting raw materials which may be significant for scrap because it must be collected from numerous relatively small arisings.

217. There are three distinct sources of ferrous scrap : that arising in the industry itself known as circulating home scrap ; ferrous scrap from engineering and other iron using installations called process scrap ; household and other rejected ferrous material called capital scrap. Home scrap, which is essentially clean, is recirculated extensively within the industry itself. The amount generated depends on the type of processes used. For example, at old plants scrap can amount to about 20 % of total production, whilst at new installations using continous casting, home scrap can be as low as 7 - 8 % of total production.

218. Process scrap arises in many different forms at engineering works and various industries using iron and steel. This material may be in the form of turnings or large and small pieces of metal. It is fairly clean, the main contaminants being usually oils and grease. The scrap is stocked on site then transported to the steel works.

219. The third source of scrap, capital scrap, arises from used iron products and is usually contaminated with other materials. In this category falls domestic waste, particularly cans, old household appliances, wrecked cars and the demolition of old buildings, bridges, ships, etc. In each case the ferrous scrap has to be separated from other materials. This is now a highly mechanized and well organized activity in the industrialized countries involving collection, treatment and transportation of scrap. Large crushing, searching and compressing machinery is used. Valuable materials such as tin, copper and other non-ferrous metals are recovered. It is important to remove tin, for example, since this element has a deleterious effect on the material properties of iron.

220. The scrap industry is generally independent of the iron and steel industry. The global use of scrap is not known, but a considerable international trade in scrap exists involving transportation of many millions of tons per annum. This transportation has its own environmental consequences. Stocking and separation of ferrous scrap is undertaken normally within an industrial area in the vicinity of the urban sources. Since the machinery used in treating scrap (such as grinders and shredders) is noisy, it is important to site scrap yards away from residential areas, to avoid a nuisance. Air pollution is relatively small, unless waste is being burned, when there can be a problem of smoke and odour. Oil in turnings etc. should be recuperated to prevent it being a source of water pollution. Scrap yards may also be a visual disamenity.

221. Of the average cost of collection and treatment of ferrous scrap, about 50 % is accounted for by transportation and about 20 % in labour costs.

222. The constraints on scrap utilization are mostly the difficulty and/or cost of reclaiming a larger proportion of scrap arising from obsolete steel equipment and products. There are also technical constraints in the sense of tramp elements present in the scrap progressively building up as metallurgically undesirable impurities in the steel product (e.g. copper, tin) or being emitted as part of the fume from the scrap melting process (e.g. zinc from galvanized scrap, lead from lead painted scrap).

223. Whilst in developed countries up to 93 - 95 % of available ferrous scrap is recovered, which is probably the realistic recovery potential under today's conditions, there is potential for increased reclamation of ferrous scrap in other countries. Governments could stimulate, by means of economic and other incentives, increased recycling in some areas. At the same time technological developments to overcome the problems of tramp elements need stimulating in order to make more effective use of available scrap in an environmentally sound manner.

CHAPTER III

PROBLEMS OF THE WORKING ENVIRONMENT

224. Occupational health and safety is a major concern in the iron and steel industry, with the objective to provide safe and healthy conditions of work for those employed in the industry and at the same time to enhance job satisfaction. There are potential hazards at nearly all stages of the operation. Molten metal and high temperatures as well as heavy machinery and high tension power supply present an accident risk potential. Substantial amounts of particulate matter and a variety of toxic and explosive gases are generated in many of the processes. Toxic substances such as cyanides, chromium and acids are present in significant quantities at some stages of operations. A number of processes are inherently noisy.

225. Traditionally, work in the iron and steel industry has been characterized by physical exertion, stress, heat, noise, dust and exposure to toxic gases. Technological advances have brought far reaching changes to the industry particularly at new plants with improved worker protection and reduced accident risks. The increased scale and pace of operation from these technological changes have called for adaptation on the part of management and employees. Whilst accident risk may have been reduced, the consequences of accidents, or faulty operation and of poor maintenance may now be much greater because of the size of operation. Advanced technology requires a higher level of skills.

226. There are two main aspects to the working environment: the general aspects such as accident risk, heat stress, noise and vibration, which are common to many large scale heavy industries, and the specific potential problems associated with the iron and steel making process, such as dust and toxic gases. It is not intended to deal here in detail with accident prevention but rather to concentrate on the potential hazards more specific to the industry ; although it should be noted that in some circumstances the two aspects are inter-related, for example, excessive heat stress may give rise to increased accident risk.

Heat, Noise and Vibration

227. Heat exposure is a hazard for furnace operators, coke oven battery workers and also personnel involved in certain casting operations. Additionally, work may be strenuous and heat stress may well be accentuated in hot and humid climates. Processes may be designed to be operated by remote control from air conditioned cabins. Protective measures, such as shielding, adequate job placement, medical surveillance, rest periods, protective clothing and correct body salt balance and water intake are essential. Further study is required especially for tropical and sub-tropical areas.

228. A number of types of machinery (e.g. fans and blowers) and processes (e.g. electric arc furnaces, steel rolling, forging and finishing) are particularly noisy. Precautions to minimize these sources of noise should be taken when the building and equipment is designed. Noise reduction at source may be difficult to design due to the size and complexity of equipment and sound proof enclosures e.g. in cranes control rooms, etc. should be provided. The use of the doghouse enclosure for new electric arc steel furnaces is recommended as an effective means of controlling noise. These matters are discussed in Chapter II (d) . Noise levels within the plant should be regularly monitored to assess personnel exposure. Many plants have specific hearing protection programmes for employees.

229. Protective ear muffs/plugs and shorter periods of exposure are approaches where equipment design is not adequate in reducing noise levels and are particularly appropriate for operations which are intermittently noisy, i.e. a significant source of noise only during limited periods e.g. melting of charge in an electric arc furnace, whilst the remainder of the cycle is far less noisy.

230. Vibration is another problem area, calling for careful design of observation platforms, seats, and operation of vibrating equipment, as well as for controlled duration of exposure. Hand tools can be a source of occurrence of vibration and investigatory work is proceeding on this problem in a number of areas.

Particulate Matter

231. Inhalation of fine particulate matter (size ranges from 0.1 to about 5 um) is a major specific potential hazard associated with many of the iron and steel operations, and lung diseases rate high amongst the occupational hazards of the industry. The fume may be contaminated with a whole range of potentially toxic substance such as fluorine, lead, zinc and manganese. Whilst iron oxide itself is not regarded as readily giving rise to pulmonary diseases, the presence of other more toxic substances make operations such as the blast furnace and steel making potentially hazardous. In design of fume arrestment equipment attention must be given to the particle size collection efficiency. Crane drivers, in particular, should be protected from the fugitive fumes arising from oxygen lancing and electric arc furnaces.

232. A serious hazard is that of exposure to dust containing free silica which can cause silicosis. This is particularly important for workers involved in lining or repairing furnaces and ladles with refractory bricks, which may contain more than 80 % silica. There is also appreciable hazard in "shake out" operations in foundries, where sand moulds are broken, unless there is efficient local exhaust ventilation, as well as in the use of "silica flour" in moulds. The extensive use of such materials in iron and steel works and foundries means that this is a problem of major significance. Extensive environmental control measures (e.g. ventilation, enclosures) and personal protection (particularly appropriate respirators) are essential where silica dust (especially crystalline silica) arises, as well as replacing silica bearing materials with less hazardous ones where practicable. Asbestos may be a problem in old plants where asbestos containing lagging has to be removed.

Toxic and Dangerous Gases

233. Large quantities of flammable gases are both produced and used, particularly in the blast furnaces, converters and coke ovens. These gases contain large proportions of carbon monoxide and, where leaks occur, may not only be a source of explosion and fire hazard, but also of a monoxide poison risk to workers in the vicinity. Blast furnace workers are at greatest risk, especially during repair work or from leaking valves. Workers should be well trained to deal with these risks and in reanimation techniques. Monitoring of carbon monoxide levels in working areas is an essential precaution. Excess carbon dioxide may also cause asphyxiation.

234. In addition to carbon monoxide and carbon dioxide, nitrogen oxides, sulphur oxides, hydrogen sulphide and hydrogen fluoride may arise from various processes. Sulphur compounds may be found where sulphur containing ores and fuels are used. Nitrogen oxides arise from all combustion processes and may be found

at all stages of the operation from sintering to hot forming of steel. They also arise in nitric acid pickling operations. Fluorides are found where fluoride containing iron ores and fluxes are used, and may in some circumstances represent a hazard. The toxicity of each of these substances is well known.

Use of Oxygen, Acetylene and Toxic Solvents

235. Oxygen is used under pressure in a number of steel making operations and presents accident and fire hazards which must be minimized by careful procedures. Acetylene is used in cutting and welding. It may contain phosphine and arsine impurities and is itself an asphyxiant as well as being explosive. A whole range of organic and inorganic solvents including acids are used in various treatment processes and present potential hazards. Adequate worker safety precautions must be taken in each specific case, with appropriate first aid measures established in case of accidents.

Water Pollution

236. Whilst air pollution control is the most important aspect of protection of the working environment, water pollution must not be overlooked. Often effluents contain toxic and corrosive substances which may evaporate into the working atmosphere or be absorbed through the skin on contact. Care should be taken to avoid accidental discharge of effluents in the working environment and adequate clean-up procedures prescribed.

Specific Processes Presenting Unsolved Problems

(i) Coke Ovens

237. The coking operation is one of the processes presenting a major problem in the working environment. Besides carbon monoxide, sulphur and nitrogen oxides, a whole range of hydrocarbons, including carcinogenic polyaromatic substances and benzene are evoluted during the operation. Whilst modern techniques enable the most potentially polluting parts of the operations: charging, pushing and quenching, to be undertaken during controlled conditions, there are frequently leakages, especially at old coke ovens. The working atmosphere associated with coke making is one particularly dependent on the level of management, and the standard of maintenance and operation. A conscientious team can help keep ovens well maintained and operated, so as to minimize escape of pollutants into the environment. Working conditions (e.g. hydrocarbon concentrations) should be regularly monitored and adequate engineering controls (e.g. ventilation and personnel enclosure) designed and implemented to protect workers against hazardous emissions. Measures, such as medical surveillance and personal protection (particularly appropriate respirators), as well as hazard information (labelling, education on health hazards, etc.) should be made available to workers in order to complement the environmental control measures.

(ii) Charging and Casting of Liquid Metal

238. Fume and gaseous emissions occurring during blast furnace tapping and steel furnace charging and tapping operations are potential problems for the working environment. Complete capture of these fugitive emissions is difficult, even where extraction hoods are provided. Good ventilation is essential. More research is needed into the better design of effective hoods, integrated into

the cast-house or steelshop, which allow ready access for maintenance. As far as feasible, plant operations should be undertaken from air conditioned control rooms. Furnace enclosures offer the best protection for workers at new steel making plants.

(iii) Sintering

239. Gaseous emissions and dusts containing toxic substances such as lead, zinc and cadmium may also be potential problems for the working environment in relation to the sintering operation. Good ventilation and hooding is essential at hot sinter transfer points. At modern sinter works operations are controlled from air conditioned control rooms.

(iv) Manufacture of Ferro-alloys

240. A whole series of particular hazards in the working environment is associated with special processes involving ferro-alloys. These may involve additional toxic substances such as phosphine (in nodular iron and ferro-silicon metals) and a whole range of metals, e.g. antimony, arsenic, cadmium, chromium, cobalt, lead, nickel, manganese, molybdenum, selenium, tellurium, tin, tungsten, vanadium and zinc. Regular monitoring is required to ensure that control equipment is functioning effectively. Special care and protection is required during casting operations. Modern closed furnace designs have reduced this particular hazard.

Protective Policies for the Working Environment

241. Protection of the health and safety of the work force is a primary responsibility accepted by industry and public authorities. In each works there should be a systematic analysis of potential sources of accident as well as of the incidents which occur, so that suitable preventive measures may be incorporated at new installations. There are three main aspects in relation to safety. The first is the avoidance of the common type of accident such as tripping and slipping due to obstructions, carelessness, lack of cleanliness, etc. The second is one of plant integrity depending on adequate design of machinery, use of suitable materials (e.g. to avoid corrosion), proper maintenance of equipment, management of resources, especially water for cooling purposes. The third is the question of avoiding major incidents, e.g. explosives due to hot metal and water or leakage of combustible gases. There should be appropriate contingency plans for accidents.

242. Policies in relation to protection of the working environment should be directed towards control of potential pollution at the source and adequate industrial hygiene monitoring programmes to check on the quality of the working environment. Where control at source is not possible or feasible, the individual liable to exposure should be protected either by personal equipment (the use of which may be restricted by climatic conditions) or removal from the polluted working environment (by job rotation or automation). These two approaches inter-relate. Whilst an ideal solution may be to have a fully automated operation with workers enclosed in air conditioned control rooms or protected cabins, this may not be practicable or too costly under certain circumstances. In any case, maintenance has to be undertaken on the plant, which will call for adequate worker protection. A high level of cleaning of the working atmosphere may

minimize the risk under most circumstances, but there are operating conditions where extraction equipment may not function effectively. Under these types of conditions personal protection (respirators, clothing, etc.) is essential. There may be conditions where job rotation may be an effective means of guaranteeing that workers are not subjected to undesirable exposures to hazards.

243. Improvement in environmental control, economy in energy and resources and enhanced working conditions may be attained with costs savings through ergonomy. It is important to design installations and processes with the human factors in mind, as well as to involve employees and their representatives in the consideration of operating methods. Reference may be made to the Jishu Kanri activities in the Japanese steel industry (9).

244. All factories should be equipped with medical centres for dealing with initial emergency treatment in the case of accidents and for regular medical supervision of employees, including initial fitness for the job, audiometric checks, checks on personal uptake of potentially dangerous substances, etc. Those responsible for inplant monitoring of conditions, particularly air pollution and safety measures, should be in regular contact with the medical centre to ensure adequate liaison with health supervision.

245. Mention may also be made of the need for contingency plans in the case of accidents, particularly for major incidents and disasters. All factories should have emergency plans for ensuring that essential services have ready and rapid access to the disaster area. Procedures, tailored to each specific operation, should be established for the proper and safe shutting down of operations, e.g. blast furnaces, in the case of accidents. All personnel should be trained in emergency procedures appropriate to their functions and this type of training should also be incorporated into the initial instruction of new employees. Appropriate labelling of emergency equipment, etc. is also essential.

246. The right management attitude and management-worker relationships are indispensable to a high level of protection of the working environment. It is essential that pollution control equipment is properly designed, maintained and operated to cater not only for normal situations but also for peak loads. The processes themselves must be correctly run. An outstanding example may be seen in the case of coke oven batteries, notorious in many companies for the difficulty in achieving and maintaining acceptable working conditions. Correct charging, operating and pushing of ovens, with regular maintenance from the outset by a dedicated management and a conscientious work force, are essential in minimizing the emissions from these operations, as well as guaranteeing an overall energy efficiency of the process. Where a work force operates and maintains coke oven batteries in a slovenly way, there is a greater likelihood of leaks, of poorly fitting doors and charge-hole lids, of unnecessary emissions during pushing arising from incomplete coking, etc. Proper operation and maintenance calls for not only a high degree of management co-ordination and worker cooperation, but also a high level of training and a concern to impart a consciousness to the work force concerning environmental protection matters. All new workers should receive adequate training for their functions as well as medical examination for fitness for the job, and health education concerning potential hazards in the work place. The work force should also be trained in the proper use of protective equipment, e.g. clothing and face-masks, which should be designed for function and comfort.

247. Running of the steel making process, whether it be charging or tapping furnaces, are other important areas where good operating conditions are necessary to minimize emission of pollutants to the working environment. Good practice may be a question of the correct rate of pouring of hot metal or charging of scrap, etc., to minimize the volume of emissions, so as not to overload the pollution extraction equipment.

248. Within the role of training at both management and worker level is the question of making the whole work force aware of environmental aspects, and a good example must be set from above. Workers' unions and organizations may play an important role in educating their members to be aware of environmental matters as well as through joint consultation with the management in establishing mutually agreed improved operating and maintenance procedures. The unions might even take a leading role in suggesting environmentally sound and resource conserving improvements in operating and maintenance practice. It should be appreciated that protection of both the working and external environment is of benefit to all employees and the community in general as well as to the company. Stability in the work force is important in attaining good operating practices and calls for good labour relationships throughout the industry. Job rotation, necessary to censure adequate worker protection from hazardous exposures under specific conditions, may require close co-operation between management and workers' reprentatives at all levels.

249. Finally, it must also be borne in mind that cleanliness or good housekeeping of the plant is a vital part of the working conditions. This should form the basis of all the efforts to control working environment hazards and in itself can improve motivation and morale. Housekeeping competitions within a plant may act as an incentive, particularly in developing countries.

250. For more detailed consideration attention is called to the activities of the International Labour Office (ILO) Iron and Steel Committee in the field of the working environment and the guidance resulting therefrom (10).

CHAPTER IV

ENVIRONMENTAL CONSEQUENCES OF NEW PROCESSES AND NEW TECHNOLOGY

251. Whilst considerable progress has been made in reducing the environmental impact of the iron and steel industry, a number of problems remain. It is logical, therefore, to look to the future to see what possibilities exist for reducing the environmental impact from the point of view of new processes and new technology, i.e. of implementing preventive rather than corrective policies.

Classical Blast Furnace/Steel Refining Route

252. The classical blast furnace reduction/steel making refining route to steel manufacture is by far the most important means of producing steel and it undoubtedly has a long term future as such. The works using these processes can be built either close to sources of coking coals or in situations which favour importation of the coals.

253. As has been seen in previous sections, there are significant environmental problems with the classical coking operation. Immediate new developments in the operation which will help reduce these environmental problems are pipeline charging of coal, dry quenching, and remote control and automatic handling of conventional batteries. The smoke emissions associated with charging coke ovens are eliminated by pipeline feeding of preheated coal, which furthermore reduces the coking time and improves the energy efficiency of the process. When integrated at a new plant, dry quenching may make a contribution towards energy conservation. The hot coke is quenched using an inert gas and the heat used to raise steam. The gas must be cleaned. Whilst not making a major contribution to the environment impact of the coking operation, dry quenching removes an important source of grit and the frequent intermittent steam plume, of the normal quenching process. The steam plume besides being a visual disamenity, may under unfavourable atmospheric inversion conditions be a serious nuisance in reducing local visibility and a danger to driving conditions on nearby roads under freezing temperatures. Remote controls and automation are being developed for coke ovens (e.g. in USSR) which will present an environmental benefit in terms of removing operating personnel from immediate exposure to hazardous conditions.

254. As regards new technology, one of the major prospects must lie in the development of the formed coke process which, if successful, should both reduce dependence on coking coals and reduce pollution by replacing the conventional coke ovens. Formed coke production is by a continuous process involving carbonization and briquetting within an enclosed system, thus overcoming the fundamental environmental problems inherent in the conventional batch production of coke in coke ovens. Some of the formed coke processes, however, produce a similar range of by-products and effluents to those of the coke oven process, which would have to be treated. Considerable improvement of the working environment in relation to coking operations would also be expected. The period over which this process might be introduced on a significant scale is difficult to predict, but it should be noted that coke oven batteries have a lifespan of up to 30 -35 years and can even then be rebuilt using part of the original structure. Mention might also be made of the possibility of utilizing coal via complete gassification and reforming to yield a reducing gas for further use, e.g. in direct reduction processes.

Direct Reduction (DR)

255. By replacing the coke ovens and blast furnace the direct reduction processes have a major potential for environmental benefit and provide a more readily transported and stored material (reduced pellets, etc. rather than liquid pig iron). Production of steel from the direct reduction route is a slightly higher consumer of energy/ton than the conventional blast furnace route, although calculations depend on primary assumptions, but what is perhaps more important is the form and cost of energy consumed. Furthermore, from the point of view of economics of scale the DR process is economical at a plant production size smaller than the classical route and consequently offers more flexibility. Currently natural gas is the main reductant, but coal based processes are also being developed (2). In the long term future, after 2010, it is conceivable that process heat from nuclear energy may be used in direct reduction, which would open up the possibility of using low grade carbon fuels such as lignite. Hydrogen is also conceived as a reducing agent for the future, generated, for example, by dissociation of water. It is important that the DR processes, and for that matter any other process developments, should be evaluated in the environmental terms as a whole, e.g. including the environmental impact of its associated energy generation requirements.

Mini-Steel Works

256. The trend in the classical integrated steel making route has been to larger and larger units (10 to 20 million ton/year capacity) in order to benefit from the economics of scale. These plants are normally associated with deep water ports to enable supply of ore by large carriers, so reducing transportation costs and providing flexibility in the source of ores. Even with foreseen long term growth in demand for steel, each year there would be very little demand for such large integrated works. Furthermore, the capital investment required for such large units is considerable, and not every country would be able to afford this type of investment.

257. During the last decade there has been an increasing production of steel at small or mini-steel works (0.5 milion ton/year capacity or less), using the electric arc furnace and manufacturing simple steel products. The raw material has been predominantly scrap and reclaimed ferrous material, the supply and cost of which has limited this approach to steel making. The direct reduction route, providing reduced pellets, now opens the way for much more flexibility and a potential large scale expansion of the mini-steel plant approach, particularly for countries which cannot afford the investment in the classical integrated steel plant nor would presently have the market demand for such a large steel output.

258. Besides the economic and flexibility aspects of the mini-steel works approach, there are a number of environmental advantages. In the first place these works are by definition small, handling a limited amount of material which may be readily controlled. There should be no fugitive emissions from ore stocking and blending, for example. Since these plants are using mainly scrap and/or high grade reduced pellets, the amount of fluxes required for refining and the amount of slag produced will be small. Thus there is no longer a major slag disposal problem. The external and internal working environmental problems associated with coking and the blast furnace operations are eliminated. There will, however, be the dust problems associated with steel making itself, i.e. the problems of dust and fume, particularly those containing non-ferrous metals and other substances contained in

the scrap. It is essential to have good primary and possibly secondary dust arrestment at these mini-plants. Furthermore, there is the problem of noise associated with the electric arc furnace. Where reduced pellets are used, one is trading a reduction in pollution problems at the steel mill for an increased waste disposal problem at the mine, where the ore is concentrated and beneficiated. The generation of energy for mini-steel plants and the associated environmental problems should also be taken into consideration.

Furnace Developments

259. A number of technical developments are taking place in furnace design and operation, particularly electric arc furnaces (2). Increased furnace computor control will improve efficiency. Continuous refining and tapping is being developed in France. A direct cement electric arc furnace has recently come into operation in the Federal Republic of Germany. Plasma arc furnaces are also being developed and small units are available in Sweden, USSR and the German Democratic Republic. Induction furnaces for direct reduced iron is also a possible development. Improvement in and new designs for furnaces have potential for environmental improvement, e.g. in the reduction of noise.

New Casting and Rolling Techniques

260. Continuous casting of steel is becoming standard practice at both integrated and mini-steel works. This process eliminates mould pouring, stripping and ingot reheating, allowing a much simplified layout and casting operation. It saves energy, reducing potential emissions of sulphur and nitrogen oxides from soaking and reheating furnaces, and leads to less waste of steel. There may possibly be developments in the next couple of decades of new processes, such as direct rolling, which would allow similar savings in energy.

Use of Renewable Sources of Energy

261. The use of alternative sources of energy, e.g. charcoal from wood or other plant life, and hydroelectric power, may be of particular importance in tropical or sub-tropical countries and countries geographically suited to the utilization of water respectively. Whilst use of renewable energy has certain environmental benefits, it is not without its environmental impacts.

a) Charcoal

262. Charcoal is the easiest and cheapest way of using solar energy in steel making. The use of wood charcoal as a carbon source in blast furnaces and electric arc smelting furnaces is practised in a number of areas (especially Brazil). Iron production capacity from charcoal based resources is in excess of 4 million tons iron/annum. It can also be used in the low shaft furnace method of producing pig iron. The main environmental aspects are the problems of land use to ensure renewability of the resource (trees), problems of erosion and other aspects of forestry operations, the logistics of production and transportation of wood/or charcoal in highly afforested areas and air pollution from the charcoal production process. In the last case, processes are available in which the by-products of wood distillation are recovered and this should ameliorate environmental problems.

b) Hydroelectric Power

263. Where hydroelectric power can be generated at low cost on a long term basis, there would be attractions in the use of this "clean" electrical power whenever possible in iron and steel making. At the present time this is restricted largely to such processes as electric arc furnaces and electric heating and reheating furnaces. The need for reducing agents at present means reliance on fossil fuels or wood charcoal. Looking further into the future it may be possible to generate hydrogen as a reducing agent by electrolysis of water.

Other Sources of Electrical Power

264. Similar arguments as for hydroelectric power apply to any other cheap form of electricity, be it generated by conventional thermal power generation or nuclear power. In each case there will be a range of environmental impacts typical of the type of power generation. These impacts may be directly associated with the iron and steel works if generation is in the close vicinity. Efficient use of gases, steam and other energy sources on the works site is, of course, also of interest in contributing to power requirements from the economic point of view.

Rate of Technological Change

265. The future technological development of the iron and steel industry is fairly predictable over the next twenty years or so, with direct reduction playing a significant role, but not replacing the conventional bulk iron and steelmaking processes. Electrical power may play an increasingly important role as may the use of renewable resources of energy such as wood charcoal. Perhaps it is inevitable in an industry as capital intensive as the iron and steel industry, that the rate of fundamental technological change is rather slow because of the heavy investment in existing plants and the need to amortize this investment. Some indication of the delay time involved in introducing new technologies may be seen from a consideration of oxygen refining and continuous casting which both required about two decades to become standard practice. This time delay reflects, despite the considerable economic advantages of these new technologies, the technical difficulties of bringing them into service on the scale of iron and steel operations, as well as the heavy investment involved. Such developments as do appear to be coming about seem to hold overall environmental benefits.

CHAPTER V

CONCLUSIONS : KEY ENVIRONMENTAL CONSIDERATIONS

266. The manufacture of steel and the fabrication of basic steel products cannot be regarded as other than a major intrusion in the environment. The processes themselves require considerable space and large quantities of materials have to be stockpiled. Inevitably there is a secondary impact arising from the transport in and out of materials in bulk and a tertiary effect from the existence, or growth, of a residential and commercial community in the vicinity of the works. In order to avoid the social insecurity of the single industry town the community plan associated with installation of a steel works should envisage a measure of industrial diversification as well as secondary industry directly dependent on the market for steel products.

267. Clearly in these circumstances the diversity of economic, social and environmental interests involved call for close co-operation of national and local authorities in the location and planning of new installations or in major reconstruction and modernization of existing works. Failure to take the environmental factors fully into consideration from the earliest stages of planning is likely to prove costly later. Retrofitting is expensive. While availability of resources and the economics of transport of materials must necessarily be major economic factors in the choice of site, the cost of environmental protection is far from negligible, more especially if it is incurred to rectify poor choices in planning.

268. Although a major intrusion in the environment, iron and steel manufacture need not be a major source of pollution of the environment. In general the technology exists to provide effective control of discharges and to recycle or to sell as by-products what would otherwise be large quantities of waste materials. The economic plan for a steel works should contain a careful analysis of the marketability of the slags and other by-products of steel production, including those resulting from water and air pollution control equipment. Some of these by-products could well form the basic input for associated new secondary industry. If no market is available they must be disposed of as waste thus considerably increasing the space needed for controlled dumping.

269. The physical plan for an installation must analyze the general impact on environment, especially as regards water resource and meteorological conditions. The former will affect materially the water management plan, especially as regards the degree of recirculation necessary for cooling water and possible effect on groundwater ; water actually used in processes will in any event need to be treated before discharge and in practice is often recirculated to the extent possible to reduce the volume of water for treatment. The large quantities of cooling water needed can, however, be supplied on a once-through basis and discharged without special treatment provided there is a large and reliable source of water and a receiving body for the discharge large enough to avoid thermal pollution. Otherwise there are efficient systems of recycling cooling waters with dissipation of heat to the atmosphere, or the sea where conditions are suitable.

270. Meteorological conditions will decide to what degree discharge to air can be permitted without dispersion becoming pollution. In principle all but

a small fraction of the particulate matter is removed. Modern economic practice captures the bulk of the combustible gases such as carbon monoxide for use as a fuel, any residuals being flared. Sulphur dioxide will be dispersed by stack or removed by desulphurizing emissions where site requirements make this necessary to avoid unacceptable ground level concentrations. The steel industry is not the major industrial source of SO_2 but there may well be need to generate electricity on site using sulphur containing fossil fuels and thus a potential level of SO_2 emission may arise which requires desulphurization prior to discharge. Nitrogen oxides are in general dispersed by stack discharge although some denitration processes are under development. There may be a number of other gaseous components, e.g. fluorine and chlorine compounds and hydrocarbons, and toxic metals dependent on the ore and fluxes used or the nature of the scrap, and the need for treatment before discharge has to be considered on a case by case basis.

271. The physical plan must also consider closely the immediate surroundings of the works. Local topography can be used to great advantage in reducing the environmental impact on the neighbouring community and in avoiding creation of an unacceptable environment. It is common practice to maintain a buffer zone around a works where no residential activity is allowed. A steel works by the nature of the processes operates 24 hours a day. Noise levels which are perfectly acceptable in works are not acceptable to a residential community beyond the factory fence. Some dust and vibration are inevitable and too close a location of some types of light industry is undesirable. Also, as the local community evolves the visual amenity takes on greater importance. These are not simply amenity aspects. They result inevitably in the imposition of environmental regulations considerably stricter and more expensive to satisfy than is necessary for protection of either the work force or the general environment. It is to be noted that this aspect of protecting the surroundings calls not only for a well prepared initial plan but demands constant vigilance by the local authorities to ensure that there is no gradual erosion of the buffer or zoning provisions.

272. As regards the plant itself the pollution potential of each major operation has been indicated in Chapter II together with the techniques available to prevent pollution. For installations on a new site careful choice of location in relation to other neighbouring land use permits the setting of pollution control standards appropriate to protection of the general environment and of working conditions in the plant. Where the site is located in an already developed area the pollution control standards appropriate to other industry or to residential areas may have to be met. These may well be stringent e.g. for noise in residential zones, and the additional costs to meet these standards have to be offset against possible gains in transport costs, by-products, market or social services.

273. It is also vital to check that the degree of recirculation of water in the plant processes is sufficient to reduce the water intake needs of the industry to an acceptable level at all times of the year, account taken of other external present and estimated future demand, while ensuring sufficient reserve to preserve the aquatic environment. The water regime in the works requires specific overall management to ensure efficient use of this environmental resource and to guarantee adequate control of quality in the discharge.

274. Although pollution control is well developed for the iron and steel industry there remain some critical areas. In general dust and fume are a permanent pollution risk for both in-works and external environment. Dust arrestment

and collection is widely practised by enclosures and hoods but much depends on the vigilance and skill of the operatives to ensure that the pollution control is fully effective. Coke ovens are another process area where the technological solutions available will only be effective if there is a high standard of maintenance of equipment and care and skill in operation of the ovens. The management plan for the works should provide adequate training facilities for operatives and staff on environmental hazards, and environmental responsibility in the works should be exercised at a high management level and its operations integrated closely with the production function. Speedy reaction to a pollution incident is essential given the large tonnage throughput and high rates of production of modern processes. Also there is need for prompt action should toxic or hazardous substances be found in discharges to air or water. Such a situation could arise even with all pollution control and effluent treatment operating normally through presence of unexpected elements in the initial ore or scrap. Monitoring needs to be continuously practised and the necessary equipment provisioned in the capital plan.

275. Finally there is the question of standards both for worker health and safety and in relation to emissions to the general environment. Though these exist in many countries no single national set of standards is necessarily relevant to the conditions to be found in another country. If standards do not exist already, and some may well do so even if it is a first iron and steel installation since the pollutants concerned are not unique to this industry, the relevant Government authority should establish appropriate national standards for at least the major potential pollutants. These are, in alphabetical order :

(1) Benzene
(2) Carbon monoxide
(3) Coke oven emissions
(4) Nitrogen oxides
(5) Oil mist
(6) Particulate matter
(7) Silicon compounds
(8) Sulphur oxides

To these have to be added the following physical agents :

(1) Noise
(2) Vibration
(3) Heat stress

276. The above list is not exhaustive of the influence of the iron and steel industry on pollution both within and outside works. For example, the relevance of ammonia, anthracene, napthalene, pitch fumes and smoke, chromium, lead, nickel, cyanides, fluorides, phenols, PCBs are recognized as important substances but are not considered to require the same degree of priority. The position on the various major priority areas indicated above is discussed below. Criteria for the major pollutant areas are in general available and these provide the best scientific information available at the time the criteria were established. The World Health Organization (WHO), International Labour Office (ILO) and UNEP's International Register of Potentially Toxic Chemicals (IRPTC) are sources of information on availability of criteria. The present state of availability for the major pollution areas are listed below.

(a) Benzene

277. Benzene may be found in the steel industry in the coke oven and by-products area. There already exists considerable criteria documentation, e.g. in the USA (NIOSH and EPA) on this subject and work is on-going. Benzene has been linked with aplastic anaemia and an association of leukaemia with benzene exposure has been documented.

(b) Carbon Monoxide

278. Carbon monoxide is to be found as a constituent in blast furnace and coke oven gas in addition to basic oxygen steel making plant emissions and at direct reduction plants. The criteria documentation is well established (11) and the acute effects of carbon monoxide are well known. Its longer term effects are not so well documented.

(c) Coke Oven Emissions

279. There is a considerable body of criteria documentation existing in relation to coke oven emissions. Epidemiological studies have been carried out on coke oven workers but there are differences in the conclusions which can be drawn from studies so far carried out. The criteria documentation needs to be constantly updated. There is little documentation relating to the external population and more work is required to adequately assess the external environmental impact.

(d) Nitrogen Oxides

280. Within the working environment nitrogen oxides do not constitute a major problem in the iron and steel industry. They may, however, present a hazard during certain operations such as plasma arc welding, particularly if carried out in unventilated confined spaces.

281. Toxicological information on nitrogen oxides is well documented and some criteria documents on the toxicity of nitrogen oxides are available (WHO Environmental Health Criteria No. 4 : Oxides of Nitrogen, Geneva, 1977). Epidemiological studies on effects of nitrogen oxides on the general population are relatively scarce. However, there may be some contribution, in certain circumstances, from the industry to atmospheric pollution by nitrogen oxides, with also the possibility of a contribution to photochemical oxidant air pollution (12).

(e) Oil Mist

282. The orthoergic and allergic effects of oil compounds on the skin are well known. There is also reference to the possibility of cutting and other oils containing some pathogenic microbes which may give rise to some skin infection. The possible health effects of mineral oil mist have been reviewed in a NIOSH/OSHA guideline (13).

(f) Particulate Matter

283. Iron and steel production generates various types of particulate matter contributing to community air pollution. A number of epidemiological and toxicological studies on the effects of particulate matter have been conducted and

criteria and guidelines have been developed. However, the chemical and physical composition of particulate matter, a key factor in relation to effects, varies substantially from place to place and this often makes it difficult to evaluate the health effects of exposure. The presence of sulphur oxides is also important (14). Particular attention must be given to the toxic components that may occur in particulate emissions e.g. lead and cadmium. WHO criteria already exist for many of these components.

(g) Silicon Compounds

284. Silicon compounds are constituents of the emissions from some operations in the iron and steel industry such as blast furnace dust and cupola gases. It is of importance to determine the percentage of free crystalline silica in the total silicon compounds. Free crystalline silica may present a serious health hazard depending on its particle size and concentration, since it is the causative agent of silicosis. Other silicon compounds can be considered as general particulate matter.

285. The hazard of silicosis is particularly important in foundries, if operations such as shake-out and sand blasting are not adequately controlled by ventilation, enclosure, etc., and in steel plants with open hearth furnaces during refractory demolition. The community pollution problem is one of particulate matter.

(h) Sulphur Oxides

286. Sulphur oxides, primarily SO_2, have been found in the emissions from sintering, open hearth furnaces, blast furnaces, electric furnaces and basic oxygen furnaces. The iron and steel industry also contributes to the community sulphur oxides pollution.

287. A large number of epidemiological and toxicological studies have been conducted and several criteria documents are available. Studies have indicated that SO_2 and particulate matter may have additive effects on health (14).

(i) Noise

288. The effects on the ear of continuous noise (20 to 2000 Hz) are well known and measurement as well as judgement methods are sufficiently standardized. Standardized definitions for impact noise which have a wider application for other industries are necessary. Evaluations and measurement methods for impact noise are in use. Psychological effects have received little study. Criteria have been developed by many agencies (15).

(j) Vibration

289. In some parts of the production processes of the iron and steel industry, for example where compressed air operated tools are used, vibration can be a problem in the working environment and there is a limited amount of documentation available concerning health effects. There is little knowledge of the dose effects of low frequency vibrations, which again have limited application in the iron and steel industry. Limited criteria in the form of guidelines are available from the Federal Republic of Germany (VDI) and the USA (NIOSH).

(k) Heat Stress

290. There exists a large amount of criteria and documentation concerning health effects of heat stress on workers in temperate climates. However, the question has been posed whether these criteria can be applied to other climates and populations, especially in developing countries. Criteria have been developed by Belgium and the USA (NIOSH).

(l) Thermal Pollution

291. Thermal pollution of receiving water bodies is a problem arising from some steel industry activities. The extent of the problem depends on the process, especially with respect to process cooling water and also to the characteristics of the receiving water body. The problem, when it exists, should be treated on a site specific basis. Various studies in North America and Europe have documented many of the effects in temperate climates. Work needs to be carried out to document the effects in other areas of the world and criteria developed in temperate countries are not necessarily valid in other parts of the world.

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Внешторгиздат. Изд. № 261А
ВТИ. Зак. 7089