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ENVIRONMENTAL ASPECTS OF THE IRON AND STEEL INDUSTRY WORKSHOP PROCEEDINGS

Geneva, 17-20 October, 1978.

Part 1

UNITED NATIONS ENVIRONMENT PROGRAMME

Environmental Aspects of the Iron and Steel Industry Workshop Proceedings

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FOREWORD

From the first session of the UNEP Governing Council, held in June 1973, the importance of environmental issues associated with industrial development was recognised and a programme of activities on environmental problems of specific industries was initiated by the Executive Director.

In accordance with the decision 87(V)A of the Governing Council at its fifth session, a review is being undertaken of the environmental problems associated with the iron and steel industry. A methodology, agreed by the Governing Council is being used for this purpose, according to which a preliminary meeting, organised as a Workshop of governmental and industrial experts as well as those from relevant international institutions, has been held and has identified the problems. Besides identifying the problems, the Workshop has assessed the extent to which these problems have already been studied and solutions found. In a subsequent phase of the methodology, outstanding problems or issues will now be examined by appropriate means on an international basis.

This document gives the Proceedings of the Workshop, which includes the background papers prepared for the Workshop as well as a report prepared by the Secretariat on the environmental aspects of the Iron and steel Industry.

The International Iron and Steel Institute (I.I.S.I.) was a major focal point of contact between the industry and UNEP and prepared a report for the Workshop.

The Secretariat gratefully acknowledges the advice and help of Mr. C.M. Davis of the British Steel Corporation in the drafting, revision and editing of this document.

TABLE OF CONTENTS

VOLUME I

PAGE

Agenda 1

Report by the Secretariat. Environmental Aspects of the Iron and Steel Industry 3

Record of the Workshop 125

VOLUME II

CONSULTANTS REPORTS

The Environmental Impact of the Steel Industry in Developed Nations 1

The Environmental Impact of the Steel Industry in Developing Nations 31

The Iron and Steel Industry in Eastern Europe and Pollution Control 91

Impact on the Environment of Various New Possible Methods to Produce Iron and Steel Materials 171

WORKSHOP ON ENVIRONMENTAL ASPECTS

OF THE IRON & STEEL INDUSTRY

HELD IN GENEVA AT ILO FROM 17TH TO 20TH OCTOBER, 1978

AGENDA

TUESDAY 17TH

9.30 a.m. OPENING CEREMONY

Presentation by the Secretariat on the purpose of the Workshop, including organisation of specialist working groups.

Presentation of the Report prepared by the Secretariat.

11.15 - 11.30 Coffee Break

11.30 - 13.00 PRESENTATION AND DISCUSSION OF BACKGROUND REPORTS

(a) "The Environmental Impact of the Steel Industry in Developed Nations" by Julian Szekely.

(b) "The Environmental Impact of the Steel Industry in Developing Countries" by Hidehiro Obata.

(c) "Impact on the Environment of Various New Possible Methods to Produce Iron and Steel Materials" by Jacques Astier.

(d) "Iron and Steel in Eastern Europe and Pollution Control by Lechoslaw Jarzebski.

(e) "Environmental Control in the Iron and Steel Industry" prepared by the International Iron and Steel Institute and presented by F.E. Tucker, Chairman of I.I.S.I. Committee on Environmental Affairs.

13.00 - 14.30 LUNCH

14.30 - 16.15	PRESENTATION AND DISCUSSION OF BACKGROUND PAPERS continued
16.15 - 16.30	Coffee Break
16.30 - 18.00	PRESENTATION AND DISCUSSION OF BACKGROUND PAPERS continued as necessary.
	FIRST GENERAL REVIEW OF SECRETARIAT'S REPORT AND CONFIRMATION OF SPECIFIC AREAS FOR EXAMINATION BY SMALL WORKING GROUPS.

WEDNESDAY 18TH*

DETAILED EXAMINATION OF THE SECRETARIAT'S REPORT

9.30 - 11.15	Introduction and Section I "Environmental Assessment"
11.30 - 13.00	Section II "Working Environment"
14.30 - 16.00	Section III "Resource Conservation and Recycling"
16.15 - 17.30	Section IV "Economic Aspects"
17.30 - 18.00	Film

THURSDAY 19TH *

EXAMINATION OF SECRETARIAT'S REPORT continued

9.30 - 10.30	Section V "Impact of New Processes and New Technology"
10.30 - 11.15	Section VI "Industrial Siting"
11.30 - 13.00	Section VIII "Environmental Management"
14.30 - 16.00	Annexes I, II and III.
16.15 - 18.00	FIRST REVIEW OF WORK BY SPECIALIST COMMITTEES

FRIDAY 20TH*

9.30 - 11.15	DISCUSSION OF PROPOSALS BY SPECIALIST WORKING GROUPS AS TO ISSUES AND THEIR FURTHER EXAMINATION.
11.30 - 13.00	DISCUSSION ON SECTION VIII OF REPORT : "CONCLUSIONS AND SUMMARY OF ISSUES".
14.30 - 16.00	APPROVAL OF WORKSHOP RECOMMENDATIONS AND CONCLUSIONS.
16.00 - 16.15	CLOSING CEREMONY

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* Coffee breaks 11.15 to 11.30 and 16.00 to 16.15 (except Friday) and lunch breaks 13.00 to 14.30.

ENVIRONMENTAL ASPECTS OF THE IRON AND STEEL INDUSTRY

REPORT BY THE SECRETARIAT

Originally issued as UNEP/WS/IS.2 (1st Revision)

PREAMBLE

A number of experts were requested by the Secretariat to prepare background papers for the Workshop covering different aspects of the subject. These background papers consist of the following:

(a) "The Environmental Impact of the Steel Industry in Developed Nations" by Julian Szekely, see UNEP/WS/ IS.3.

(b) "The Environmental Impact of the Steel Industry in Developing Countries". see UNEP/WS/ IS.4 ; and "Iron and Steel Industry in Brazil and the Environmental Control", see UNEP/WS/ IS.5 by Hidehiro Obata.

(c) "Impact on Environment of Various New Possible Methods to Produce Iron and Steel Materials" by Jacques Astier. see UNEP/WS/ IS.6.

(d) "Iron and Steel Industry in Eastern Europe and Pollution Control" by Lechoslaw Jarzebski. see UNEP/WS/ IS.7.

Additionally, the International Iron and Steel Institute (I.I.S.I.) prepared a report for UNEP entitled "Environmental Control in the Iron and Steel Industry".

The views of governments concerning the environmental issues of the iron and steel industry were sought through national reports which they were requested to prepare. Additional material was also provided by international organisations, in particular : WHO, ILO and the International Metal Workers' Federation (I.M.F.).

On the basis of the available reports and material the Secretariat prepared this report for the Workshop, the purpose of which was to provide a comprehensive summary of the environmental aspects of the iron and steel industry and to highlight the major issues which arise from the present situation. The report does not attempt to survey the state of the art in relation to environmental protection in the iron and steel industry, this being provided by the background reports of the experts and IISI, but rather seeks to provide an environmental assessment of the industry and point towards the environmental management needs in order to meet present and future requirements for environmental protection in relation to the industry. The assessment is set in the context of both the present situation and expected trends, particularly in view of the objectives of the Lima Declaration and the UN goal of meeting basic needs by the end of the century.

TABLE OF CONTENTS

		PAGE
PREAMBLE		5
TABLE OF CONTENTS		7
INTRODUCTION	- Size, Distribution and Future Prospects of Industry	9
	- Iron and Steel Industry Processes and Areas of Environment Concern	13
SECTION I	- Environmental Assessment	15
	- Identification of Physical Environmental Problems and their Solution	16
	(a) Air Pollution	16
	(b) Water Pollution	35
	(c) Disposal of Wastes	41
	(d) Noise	42
SECTION II	- Working Environment	51
SECTION III	- Resource Conservation and Recycling	59
SECTION IV	- Economic Aspects	87
SECTION V	- Impact of New Processes and New Technology	91
SECTION VI	- Industrial Siting	97
SECTION VII	- Environmental Management	103
SECTION VIII	- Conclusions and Summary of Issues	109
ANNEX I	- Iron and Steel Processes	117

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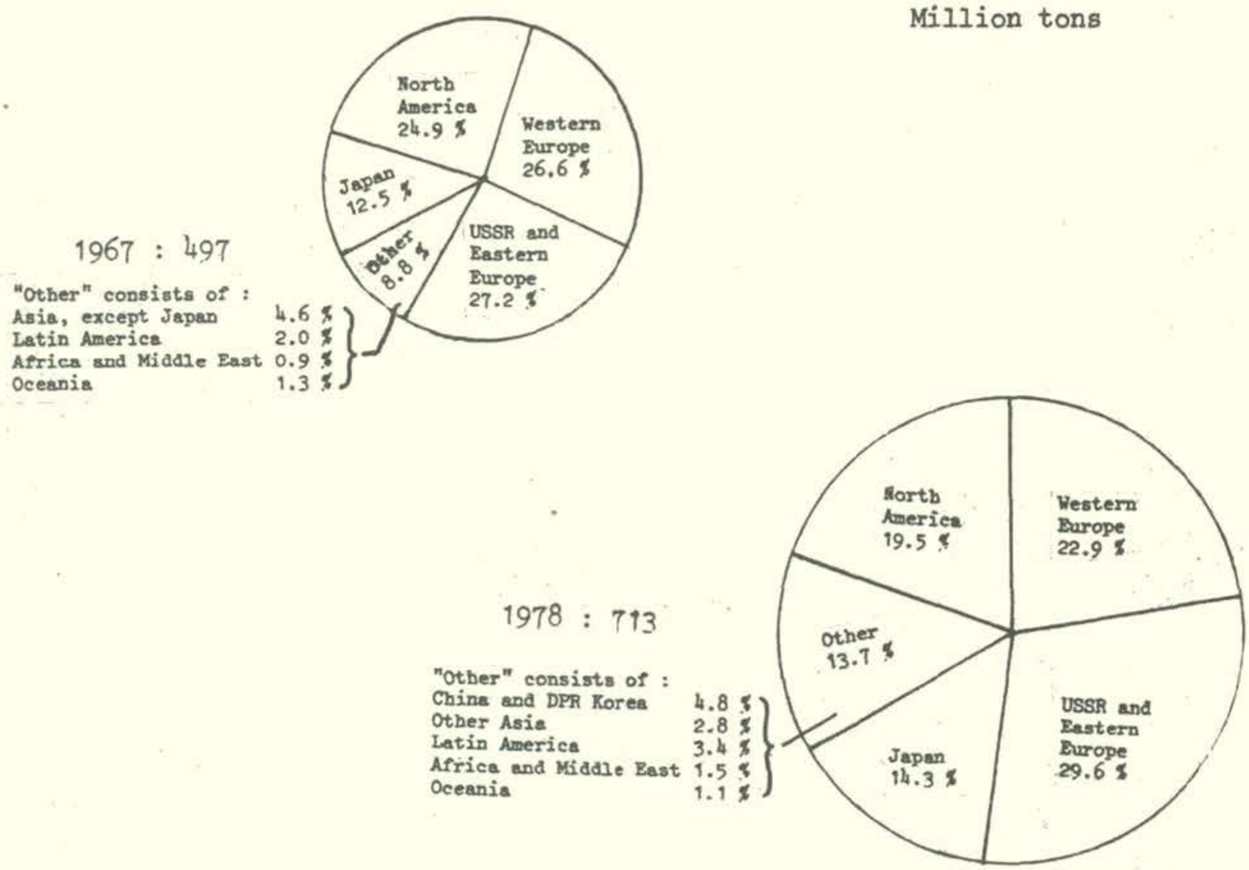
INTRODUCTION

Size, Distribution and Future Prospects of Industry

1. 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 713 million tons in 1978. Within that growth pattern, significant changes are occurring in the geographical distribution of production:

Table I

Steel Production : Geographical Distribution (1)



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(1) World Steel in Figures, 1978, International Iron and Steel Institute.

During the last ten years there has been a steady expansion of steel production in a number of developing countries (see table II).

Table II

The 30 Major Steel-Producing Countries[1]

1977 rank		Crude Steel Production (million tons) 1967	1974	1977
1	USSR	102.2	136.2	147.0
2	USA	115.1	132.0	113.1
3	Japan	62.2	117.1	102.4
4	Fed. Rep. Germany	36.7	53.2	39.0
5	China	E14.0	E26.0	E23.4
6	Italy	15.9	23.8	23.3
7	France	19.7	27.0	23.1
8	UK	24.3	22.4	20.5
9	Poland	10.4	14.6	18.0
10	Czechoslovakia	10.0	13.6	15.0
11	Canada	8.8	13.6	13.5
12	Rumania	4.1	8.8	12.2
13	Belgium	9.7	16.2	11.3
14	Brazil	3.7	7.5	11.3
15	Spain	4.5	11.5	11.1
16	India	6.3	7.1	10.0
17	Australia	6.4	7.8	7.3
18	South Africa	3.7	5.8	7.3
19	German Dem. Rep.	4.6	6.2	6.8
20	Mexico	3.0	5.1	5.6
21	Netherlands	3.4	5.8	4.9
22	Luxemburg	4.5	6.4	4.3
23	Rep. of Korea	0.3	1.9	4.2
24	Austria	3.0	4.7	4.1
25	Sweden	4.8	6.0	4.0
26	Hungary	2.7	3.5	3.7
27	Yugoslavia	1.8	2.8	3.2
28	DPR Korea	E 1.5	E 3.2	E 3.2
29	Argentina	1.3	2.4	2.7
30	Bulgaria	1.2	2.2	2.6
Total 30 countries		490.1	694.6	657.0
% of world total		98.6	98.0	97.6

E = Estimate

(1) World steel in figures, 1978. International Iron and Steel Institute.

4323

The geographical distribution of steel production and consumption are shown in table III (1).

Table III

Steel Production and Consumption, 1976 - Geographical Distribution

(million tons crude steel and percentages of world total)

Total steel production in 1976 was 677 million tons.

Production	Consumption
Western industrialised countries 416 million tons (61.5%)	Western industrialised countries 369 million tons (54.5%)
North America 130 million tons (19.2%)	- North America 143 million tons (21.1%)
- European Economic Community 134 million tons (19.8%)	- European Economic Community 118 million tons (17.4%)
- Japan 107 million tons (15.9%)	- Japan 60 million tons (8.9%)
- Other Western industrialised countries. 45 million tons (6.6%)	- Other Western industrialised countries 48 million tons (7.1%)
Developing countries 38 million tons (5.6%)	Developing Countries 74 million tons (11.0%)
Centrally planned economies 223 million tons (32.9%)	Centrally planned economies 234 million tons (34.5%)
- China and DRP Korea 24 million tons (3.5%)	- China and DPR Korea 32 million tons (4.8%)
- Eastern Europe 54 million tons (8.0%)	- Eastern Europe 56 million tons (8.3%)
- USSR 145 million tons (21.4%)	- USSR 145 million tons (21.4%)

(1) World Steel in Figures, 1978. International Iron and Steel Institute.

2. Broadly speaking, the western industrialised countries are net exporters of steel, and the developing countries are net importers. There are certain notable exceptions e.g. the United States of America, as may be seen from table III. 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. This share would have to increase from the 5.6% in 1976 to at least 25% in 2000 if the Lima Declaration objectives are to be met (1). One estimate by UNIDO of possible production growth gives a world wide production to 1.7 to 1.9 x 10^9 tons by the year 2000, with developing countries producing 22 to 25% of this total (2).

3. These changes are of major importance in the sphere of environmental control in the world iron and steel industry, because they indicate that a significant shift in the pattern of capital investment would have to be made for the Lima Declaration goals to be met. If the objectives of the Lima Declaration are to be met, capital investment must increase rapidly in the developing countries as new capacity is built, whereas in some industrialised countries less new capacity will be required to maintain levels of economic development, although there may still be considerable investment to replacement capacity of old installations. Environmental control measures are generally much more effective when installed as an integral part of new plant; partly because the latest technology can be used and partly because better planning of the whole new works can in itself make a major contribution to environmental acceptability. This presents the challenge and opportunity of establishing what environmental protection measures are required to ensure acceptable environmental conditions for new installations constructed in different parts of the world, predominantly in the developing countries.

4. Note must also be taken of the present situation in relation to the industry, where currently there is overcapacity globally, a lack of investment capital, particularly in some developed countries, for either new installations or modifications to existing plant, and some remaining serious pollution problems. This situation will influence not only the type of measures required to achieve clean up of these pollution problems but also the time frame in which effective action is feasible.

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(1) Second General Conference of the United Nations Industrial Development Organisation, Lima, Peru, 12 - 26 March 1975; Declaration, particularly paragraphs 4, 28 and 39.

(2) Draft World-Wide Study of the Iron and Steel Industry 1975 - 2000, UNIDO/ICIS.25, 15 December 1976.

Iron and Steel Industry Processes and Areas of Environment Concern

5. The iron and steel industry is made up of a number of major processes, some of which may be operated independently and some of which, when brought together on one site, form an integrated iron and steelworks. The processes involved are described in detail in the literature (e.g. "The Making, Shaping and Treating of Steel", US Steel Corporation 1971) and are also referred to in the consultants' reports. Brief mention only is made therefore in this report to the processes (see Annex 1), to give the necessary background to the discussion of environmental implications.

6. Within the context of UNEP's mandate, assessing the environmental impact of the iron and steel industry is a complex subject since virtually all environmental aspects are involved. The main areas of concern include:

   (a) The major processes from mining of ore, preparation of the raw materials through to the manufacturing and finishing processes (see Annex 1). Most of these processes may give rise to air and water pollution, noise and waste. These processes are also major users of natural resources, including energy and water.

   (b) The working environment, which may involve problems of dust, fume, noxious gases, noise and heat, besides safety and heavy work, and where again each of the major processes are of concern.

   (c) Recycling scrap, residue utilisation and disposal can present special environmental problems. These must be considered as aspects of effective and wise resource management.

   (d) Industrial siting, where especially the large integrated works can present significant environmental and planning problems from the point of view of pollution and amenity, and the extensive infra-structure associated with heavy industry, as well as the complex socio-economic aspects of industrial location. Storage and transportation are two of these associated aspects.

In a first section, on environmental assessment, the environmental problems are identified and existing solutions indicated. Outstanding environmental problems are summarised at the end of the section. The specific aspects of the working environment and resource conservation, with the particular environmental problems associated with recycling, are considered in subsequent sections. The economic aspects are dealt with in Section IV. Section V looks at the potential environmental impacts, including the benefits, of new processes and new technology. Industrial siting and the related issues associated with incorporating environmental aspects into the planning process are considered in Section VI. Environmental management and the implementation of corrective, preventive and resource conserving policies integrate each of the main preceding aspects. A final section gives the conclusions and summary of issues.

7. Finally, it must be borne in mind that this report does not attempt to provide detailed case-studies of the environmental aspects associated with specific installations, but gives an overall assessment, pointing to what may be achieved with present technology, particularly at new installations. No attempt either is made to give a quantification of global emissions and effluents from iron and steel manufacture. Each existing installation is different and needs to be considered in relation to the local circumstances. It is for each authority to survey the changes in environmental quality associated with specific installations, and to weigh the benefits and disbenefits in overall environmental terms, including the socio-economic aspects, of particular steelmaking operations. Serious pollution can arise particularly from the older installations, which may be providing the major source of employment in economically dying communities. The particular measures required, and the time scale for implementing them, to deal with specific cases is a matter for each authority and cannot be covered in this report. The report, however, as part of UNEP's overall environmental evaluation of this industrial sector, is meant to provide authorities with a basis for assessing the situation in their own countries and with guidance as to effective actions which may be taken.

SECTION I - ENVIRONMENTAL ASSESSMENT

8. Production of civilisation's principal and least expensive metal is often undertaken at large installations consuming considerable quantities of raw materials. In the past, both this type of integrated operation and the smaller scale individual operations have been frequently associated with measurable significant degradation of air and water quality and reduction of amenity. In recent years, considerable progress has been made by industry to incorporate pollution control into the design of new installations as well as to deal with some of the problems arising from older plants. The reports prepared by the consultants and IISI provide a good insight into the present state of the art in environmental control in the iron and steel industry. Some of this information has been utilised in preparing this report, but for greater detail, the original reports should be consulted. Here it is intended to present an overview assessment in order to identify the problems for which there are solutions and those which remain unsolved. This section deals specifically with the physical aspects of pollution, noise and amenity; other sections deal with the occupational and socio-economic aspects of environmental assessment. This assessment of physical aspects deals with the problems media by media and outstanding problem areas are summarised at the end of the section. Much of the information presented in this section is taken from the report prepared by the IISI for the Workshop meeting.

IDENTIFICATION OF PHYSICAL ENVIRONMENTAL PROBLEMS AND THEIR SOLUTION

(a) Air Pollution

(i) Mining and Quarrying

9. Many companies own and operate large underground or open-pit mines, either adjacent to integrated iron and steel works, or at some distance from their operations, and may often be abroad. 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 crystalline silica.

10. 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

11. 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. For example, in the United States emission factors range from 70 g/t to 380 g/t of stored material (1).

12. 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. Alternative bucket conveyor type unloaders, although more expensive, do offer advantages over conventional grab unloaders.

13. 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.

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(1) Fugitive Emissions from Integrated Iron and Steel Plants, Environmental Protection Technology Series, EPA- 600/2-78-050, March, 1978.

14. 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 wind-borne loss of fine material. For this reason, stocks of this type are kept moist in many iron and steel works by water spraying. Investigations carried out in 1976 - 1977 (1) showed specific material losses by wind-borne 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 steelworks 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.

15. 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

16. Air pollution arising from coking operations represents a seemingly intractable yet extremely challenging problem to defeat. 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 (2). While most attention is paid to the environmental aspects of the carbonisation 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 para 158), 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 every incentive to justify alternative approaches to steelmaking or to seek alternative yet commercially attractive routes to producing coke (see para 279 - 283).

17. Attention is drawn here to the traditional association of the coking industry with iron and steel and also foundry operations. In many cases this is reflected in iron and steel producers operating their own coke oven plants, but this is not universally so.

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(1) H. Kahnwald, Staubemission Beim Umschlag and Lagern feinkörniger Schüttgüter und Massnahmen zu ihrer Verringerung (Dust emission in handling and stocking fine-grained bulk materials and measures to reduce it) Stahl und Eisen 97 (1977) Nr. 2 S 79/84.

(2) Practical suggestions for the reduction of the emission of smoke, dust and grit coke ovens, BCRA Special Publications, Oct. 1974.

18. The potential sources of emission from the coking processes are well documented elsewhere (1), and the purpose here is to identify the most recent advances and trends towards more effective control and operation seen in the steel and coal industries around the world today.

Fume and Dust

19. Charging

Coal can be charged into the coke oven by gravity feed or by means of pneumatic transport through a pipeline. Pipeline charging is of necessity linked with coal preheating, the package providing certain process and ec nomic advantages, with a certain added benefit of environmental improvements (2, 3, 4).

20. Gravity charging through 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 (5, 6) 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.

21. 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 new technique of sequential charging (7).

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(1) Control of coke oven emissions, Battelle, Report, December 1973.

(2) Control of coke oven emissions by use of a closed pipeline charging system, G. E. Balch, JAPCA, 22, 187 (1972).

(3) Carbonisation of preheated coal at J & L W.C. Gohacki et al, paper presented at AISI 85th General Meeting, May 1977.

(4) Larry-car free charging of coke ovens, EPA Report 600/2-76-099, April 1976.

(5) Smokeless charging, M. R. Meades, GEC. Randall COMA.

(6) Stage charging reduces air emissions, Envir. Sci. Tech., 8, 1062 (1974).

(7) Stage charging of a single collector main battery, F. M. Clark, Ironmaking Proceedings AIME, 34, 1975.

22. 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 (1).

23. 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 utilise lower grade coals and the increase in production capacity of the cokemaking plant.

Coke pushing/discharging

24. Under normal operating conditions up to 20 tons of incandescent coke is discharged from each oven after 12 - 17 hours carbonisation 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 carbonisation 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 (2), certain other countries have adopted the environmental engineering approach. Choices for control as distinct from prevention are centred on such developments as:

(i) Hooded quench car with dust arrestment,
(ii) Separate mobile hood over quench car with dust arrestment,
(iii) Mobile hook linked to fixed duct and dust arrestment,
(iv) Coke side enclosure

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

Coke cooling/quenching

25. 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 continuous quenching

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(1) Air pollution control at Japanese coking plants, J. Fiedler, Berbgau, 28, 31 (1977) (BCRA Translation 147).

(2) Automation on a coking plant, A.A. Biescheuvel, G. de Jony, N.J.W. Thyssen, I & SM, August 1977, p. 20.

(1) allows for emission at higher level through a chimney with an overall reduction in volume of condensed vapour emitted.

26. World wide interest is focused on dry coke cooling (2,3) which, like many other developments in technology, offers a major commercial 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 worldwide offers the potential for energy conservation and improves air quality.

Leakage control

27. 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 on doors, ascension pipe caps and lids and then to clean these seals efficiently on a routine basis. Comprehensive workforce 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 (4) to seek improvements in door and seal design. Various developments of mechanical door scrapers and high pressure water jet cleaning have also proved beneficial.

28. 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 workforce exposure.

Heater emissions

29. 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 be no need for dust arrestment.

Gases and vapours

30 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 of the

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(1) Weirton Steel Div. Browns Island Coke Plant, R.M. Traubert, Iron and Steel Engineer, Jan. 1977, p. 61.

(2) The case of dry cooling of coke, J.E. Barker, Coke Oven Managers Yearbook 1976, p. 206.

(3) Dry coke quenching - Detailed review, R. Kemmetmueller, Paper to Ass. Iron and Steel Engineers, Chicago, April, 1973.

(4) A research approach to coke oven end-closure problems, H. Lownie et al, AIME Ironmaking Proceedings, 35, 109, (1976).

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 minimising 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.

31. The odour problem (1) is minimised 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.

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

33. Other good reasons for desulphurising 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 steelworks 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 desulphurisation processes (2) 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.

34. 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 desulphurisation.

35. 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 desulphurisation 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.

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(1) Gaseous and odorous substances in the vicinity of cokeries, P. Herman, F. Simon, Staug (eng), 33, 316 (1973).

(2) Coke oven gas desulphurisation - state of the art, C.W Sheldrake and O.A. Homberg, paper presented at AISI 85th General Meeting, New York, May 1977.

(iv) Charcoal

36. Where charcoal is used as a primary energy source in iron and steelmaking, 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 with in this evaluation, 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

37. 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 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.

38. In the strand sintering method usually employed today, waste gases of the order of 1.5 to 2 m^3/m^2sec. suction area are produced. Following deposition of coarse dust, the waste gases are passed to dust arrestment plants. Dry electrostatic filters are frequently employed for this duty (1), 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 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 either recycled directly within the sinter plant or alternatively because of its high content of non-ferrous metals and alkali chlorides, either dumped or passed to a waste recovery operation. Clean gas dust is generally less than 150 mg/m^3.

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(1) Rolf Bothe, Probleme der Sinterabgasentstaubung bei Eisenerzsinteranlagen (Problems of dust extraction from sinter waste gas in iron ore sintering plants). Stahl und Eisen 88 (1968) Nr. 25 S 1414/1422.

39. 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.

40. 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 room dedusting equipment available in which the secondary dust sources are collected and cleaned, usually by means of electrostatic or cloth filters. The dust consists exclusively of particles of sinter which are recycled within the plant.

41. On-strand sinter cooling, while offering certain cost advantages, also simplifies the requirement for dedusting facilities.

42. 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 number of sintering plants around the world are therefore provided with desulphurising equipment (1). 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. The waste gas desulphurisation methods mentioned still, as a whole, require further development to become more economic and better established technically on a production basis.

43. The installation of desulphurisation equipment has so far mainly been attempted on new sintering plants where the appropriate equipment can be accomodated 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 desulphurisation equipment, will for example, achieve a 70 - 80% reduction in sulphur dioxide emissions. In existing older plants, retrofitting of sinter plant waste gas desulphurising equipment has up to now been scarcely practicable for economic and technical reasons.

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(1) VGB Technische Vereinigung der Grosskraftwerksbetreiber e.V. Arbeitsgruppe Schwefeldioxide, Systemanalysen, Entschwefelungsverfahren (Working Party - Sulphur dioxide, systems analysis, desulphurisation methods), Essen, Nov 1974.

44. When low sulphur raw materials are used there may be no necessity to install expensive desulphurisation facilities where local conditions are not critical in this respect. Research 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 charged by improvements in energy balance such as preheating the suction air, or alternatively using low sulphur content fuels in the ignition hoods.

45. Other gaseous pollutants in the waste gas, such as hydrogen fluoride, nitrogen oxide 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. Steelworks 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.

(v) Pelletising

46. Another method of agglomerating fine ores is pelletising. Pellet plants although found in certain steel producing sites are more frequently located adjacent to ore mining operations. In pelletising, 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 Whilst in contrast to sintering this firing does not lead to 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 pelletising. After firing, the fines are screened out and returned to the grinding stage.

47. 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.

48. 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.

49. 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).

50. 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

The Blast Furnace Route

51. 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

52. 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 Nm^3/t iron).

53. 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 achieve a high quality product, high sulphur auxiliary fuels can be safety injected into the tuyeres (1). Indeed in many operations, fuel injection provides a means for disposing of oil, oil emulsions and tarry wastes arising elsewhere in the steelworks.

54. 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

(1) Japan Iron and Steel Monthly, Steel Industry in the 1970's - Progress towards a "clean" industry.

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.

55. Blast furnaces producing ferroalloys, in particular ferromanganese, 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 a recent study has concluded that air pollution from this source cannot be considered a major problem (1).

Cast House emissions

56. 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 vaporisation 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 ferromanganese operations is of particular concern.

57. 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 problem and constraints of access (2). The following factors affect the severity of fume emissions:

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(1) Blast furnace slips and accompanying emissions as an air pollution source, US Environmental Protection Agency, Report EPA-600/2-76-288 Oct. 1976.

(2) Blast furnace cast house emission control technology assessment, US Environmental Protection Agency, Report EPA-600/2-77-31, Nov. 1977.

(3) J.Phillip, R. Eschenberg, Staubfreie Hochofengiesshallen-Beitrag zu Umweltschutz und Ergonomie (Dust-free blast furnace cast houses - A Contribution to environmental protection and industrial hygiene), Handelsblatt, 28, Nr 44 Technis e Linie 1975.

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

58. 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 (3). 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. Success in controlling fume and noxious gas emissions near the source generally removes any necessity for additional roof collection. A maximum figure of 10 kg/ton hot metal has been quoted as the quantity of fume collected. Extraction of fume and gases probably increases production of fume and thus the figure of 10 kg/ton may not be representative of the actual problem. Bag filtration is normally adopted for fume arrestment with the collected material 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

59. 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 paras. 215 - 217.

60. 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 (1). Attempts to inhibit sulphide formation by chemical additions to the spray have not altogether been successful and strict attention has to be paid to maximising heat loss through air cooling in order to avoid unacceptable pollution.

61. 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.

62. These latter processes are now finding increasing favour as more convenient methods of handling the volumes of slag produced from large furnaces.

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(1) F.H. Rehmus, D.P. Manka, E.A. Upton, Control of H_2S emissions during slag quenching, J. Air Poll. Control Assn., 23 864 (1973).

63. 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.

The direct reduction (DR) route

64. In recent years, especially in countries with both high grade iron ore and also energy resources appropriate to formation of suitable reducing agents, a variety of methods for the direct reduction or iron ores have been adopted. This is particularly true of developing countries who desire to build up their own iron and steel industry. DR processes permit the construction of smaller production units generally of the order of 1,000t of sponge iron per day. Essentially, the process involves reaction between a gaseous reductant or solid fuel and the lump ore and/or pellets which are charged in a vertical shaft or rotating kiln, of fluidised bed to produce metallised products containing a minimum of 90% iron. This sponge iron can be refined into steel in an electric arc furnace.

65. The dust contained in the off-gases from DR plants is usually removed by wet scrubbing, the cleaned gases in some cases being returned to provide heat for gas reforming or alternatively to preheat the feed material. In those processes utilising solid fuels such as coke and coal, sulphur may be introduced into the system, a proportion leaving the system via the waste gases and the remainder combining with slag derived from added lime.

66. Nitrogen oxides are formed in DR plants, the amount being dependent on the type of burner, its adjustment, the nature of the fuel.

(viii) Steelmaking

67. The growth in size of production units in steelmaking and more recently the rapid gains in production rate arising entirely from the use of injected or blow 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 vast amount compared to the level of fume from the open hearth that in most cases did not warrant any special provision for arrestment. Concentration of production and the move to larger steelmaking plants adopting oxygen steelmaking technology took place particularly in the decade 1960 - 1970. At that time, process technology tended to outstrip environmental control technology, but during this decade environmental control technology has caught up.

68. Without detailing all the stages of development, either in steelmaking 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.

69. It can be confidently stated from international experience, both with modern oxygen steelmaking and also high powered electric arc melting, that over 97% 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 3% of fume that escapes the primary collection system that continues to be the main object of attention. This is not because an answer on how to deal with the problem is lacking, but because most alternatives to date have proved expensive both to install and to operate. It is not surprising then that the question of priorities for environmental control action is raised here, and that the main driving force for further investigation and development is centred on finding cheaper 'more appropriate' solutions, appropriate not only in terms of cost to build and run, but also in energy demand, particularly as energy generation itself usually creates pollution.

Oxygen Steelmaking

70. Basic oxygen steelmaking 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, but at the flare stack.

71. 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. Impurities in purchased scrap can include zinc and aluminium die castings, lead accumulators, paints, plastics and oil and grease. As hot metal is charged on to scrap, air is rapidly entrained into the fume and gases emitted with consequent combustion. The plume rises rapidly and passes out through the roof, this intermittent emission occasionally approaching 0.4 kg/t hot metal produced where 25% of scrap is included in the charge.

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(1) Collection of secondary fume on BOF steelmaking, S. Pilkington, Proceedings of Conference-Engineering aspects of pollution control in the metals industries, Metals Society, London, Nov. 1974. P.25.

72. The answer is efficient collection at low level as near the source as practicable, thus minimising air entrainment (1). The alternative of roof collection is expensive because the volume of dust-laden air is now large. In addition, the fume must pass through the upper levels of the plant first, adding to maintenance and cleaning requirements. Retrofitting on existing plant is frequently difficult because of constraints in locating collection hoods at optimum positions due to building structure. Under the circumstances increased suction can improve fume capture but a strain is placed on costs and energy demand. Operational penalties such as reducing the volume of scrap charged and pouring hot metal into the converter slowly, have to be equated against realistic costs for handling the peaks in fume emission rate over brief periods of time. Many newer installations throughout the world are now equipped with efficient low level secondary fume collection with additional roof extraction seen in some Japanese plants. Experience in the efficient running of large bag filter units has greatly increased as a result of this application.

73. One attractive option for new basic oxygen steelmaking plant largely follows from the necessity for coping with a fume arrestment requirement for bottom blown converters (Q-BOP, OBM, LWS) - the latest bulk steelmaking development. In this process oxygen blowing continues during turn down or up requiring complete enclosure of the converter (1). A further refinement is the linking of secondary collection, itself assisted by enclosure, to the primary fume arrestment system an engineering approach already adopted at certain new bottom-blown and BOF plant installations (2,3). The bottom blown processes differ from BOF in that higher blowing rates in the former produce an increased volume of waste gas, but much lower fume emission of approximately one-third to one-fifth the quantity. This advantage is, however, somewhat countered by the smaller particle size and hence greater difficulty in achieving arrestment.

Electric arc furnace steelmaking

74. Fast driving electric arc furnaces using oxygen lancing to assist decarburisation and occasionally supplementary heat input from oxy-fuel firing can reach rates of fume emission comparable with basic oxygen steelmaking. 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.

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(1) Q-BOP steelmaking developments, J. Pearce, Iron and Steel Engineer, pp.29 - 38 (Feb. 1975).

(2) Comparison of gas cleaning for BOF and OBM/Q BOP, J.P. Baum, paper presented at 2nd Conference of OBM/Q-BOP Licensees, Bodenmais, Oct.1975.

(3) The new LD-steel shop at Fried.Krupp Hüttenwerke AG. Rheinhausen Works, J.A. Kolsch, Iron and Steel Engineer, June 1976, p. 33.

75. Even the most effective primary collection system will only handle about 95 - 97% of the total fume and dust generated during the entire tap-to-tap cycle. A small proportion escapes as leakeage through electrode ports and other openings at the furnace during arcing, but it is the most 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. The character of charging emissions is highly dependant on the quality of scrap and the nature of the fluxes used and high contents of non-ferrous metals are frequently present. The fume rises to the roof of the shop, its pathway often obstructed by cranes and other features of the building structure, and unless it is collected, a portion of the fume is emitted to atmosphere through the roof ventilator.

76. 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 steelmaking 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 beoome only marginal with increase in extraction volume (1). 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 is is required at any one time. A detailed description of a design exercise for retrofitting of roof extraction is available in the literature (2).

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(1) Zero visible emissions : Energy requirements, economics, environmental impact, J.E. Barker, Proceedings of Conference-Engineering aspects of pollution control in the metals industries, Metals Society, London, Nov. 1974 p. 105.

(2) Containment of melting shop roof emissions in electric arc furnace practice, J.H. Flux, Proceedings of Conference-Engineering aspects of pollution control in the metal industries, Metals Society, London, Nov. 1974, p.32.

(3) Dust and gas evolution in arc furnace steelmaking and possible alternatives for reducing emission with suitable collection and cleaning systems, D. Marchand, Proceedings of Conference-Engineering aspects of pollution control in the metals industries, Metals Society, London, Nov. 1974 p. 47.

77. New developments on the other hand provide opportunities to introduce novel concepts of building structure to accomodate air pollution from electric arc furnaces including both noise and dust (3). Whereas total building evacuation is extremely expensive, isolation of the furnace bay or partial enclosure of each furnace restricts air entrainment and dilution, and thus provides a basis for more cost effective solutions to fume extraction above the furnace.

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

79. The choice of equipment for fume arrestment and gas cleaning has, in the past, been largely restricted to wet electrostatic precipitation or wet scrubbing, but the necessity for roof collection has increased overall volumes extracted and the ability to cool the 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. 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

80. A number of other sources of fume and dust are generally associated with steelmaking 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.

81. Hot Metal Desulphurisation - 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 carbide or carbide/lime mixtures. Quantities of calcium 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.

82. Hot Metal Transfer and Slag Skimming - This operation is common in all major oxygen steelmaking 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. Design can also accomodate for batch addition of desulphurising agents. Similarly, ironmaking slag, particularly residue from desulphurisation, 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 in particular.

83. Steelmaking 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 (1).

(ix) Rolling and Finishing Operations

84. Although attention is required to effectively limit atmospheric emissions from certain items of plant in these departments, 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,
Galvanising lines,
Organic coating lines.

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

85. 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.

86. Spent pickling acids present problems in disposal and it is customary for some form of recovery to be practised on large continuous pickling

(1) The modern approach to slag handling at basic oxygen steelmaking plants, E.C.Leary, Iron and Steel Engineer, September 1965.

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.

87. On hot dip galvanising 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 from heating oven exhausters, particularly in regions subject to adverse photochemical pollution.

(x) Gaseous Pollutants

88. While the steel industry has been able to greatly reduce the emission of dusts, not so much 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.

89. For carbon monoxide there are as yet no large scale 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.

90. As for sulphur oxides, there are efficient processes which are industrially used in Japan in many sintering plants (1). 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 desulphurisation 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 which desulphurise and much lower than those from power stations which do not desulphurise their stack gases.

91. For nitrogen oxides, scrubbing techniques exist in Japan (1) but have only begun to be applied on an industrial scale in some coking or sintering plants. It may be preferable to seek alternatives of improving process techniques (better regulation of combustion in reheating furnaces rather than to utilise sophisticated techniques for NO_x removal.

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(1) Japanese steelmakers make progress in fighting pollution, 33 Metal Producing (Feb. 1977), p.49-51.

92. 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). Fluorides can also be controlled by substitution of materials, e.g. a low fluoride flux instead of fluorspar in steelmaking.

(xi) Emission and Air Quality Monitoring

93. 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.

94. 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.

95. 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 and 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.

96. 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. The increment in costs is small.

(b) Water Pollution

97. Water pollution in the iron and steel industry is closely integrated with the whole area of water management which is referred to in section III of this report. In this section, it is only intended to outline the main kinds of water pollution arising from iron and steel making; these are:

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

Thermal Pollution

98. 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 0.075 Mwh 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 recirculating systems has the effect of lowering the volume of water discharged and raising its temperature. The smaller volume can be more easily cooled and even though the temperature of the discharge may be comparable with a one-through system, the total thermal load placed on the receiving water is much less.

Suspended Matter

99. The water in circulation in the direct cooling systems (e.g. gas cleaning continuous 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 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 reporting oil and water. A typical example of a combination of such equipment in a hot rolling mill water recovery system is shown in Figure 1.

100. 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 utilised to advantage as a soil conditioner on poor land.

Toxic pollutants

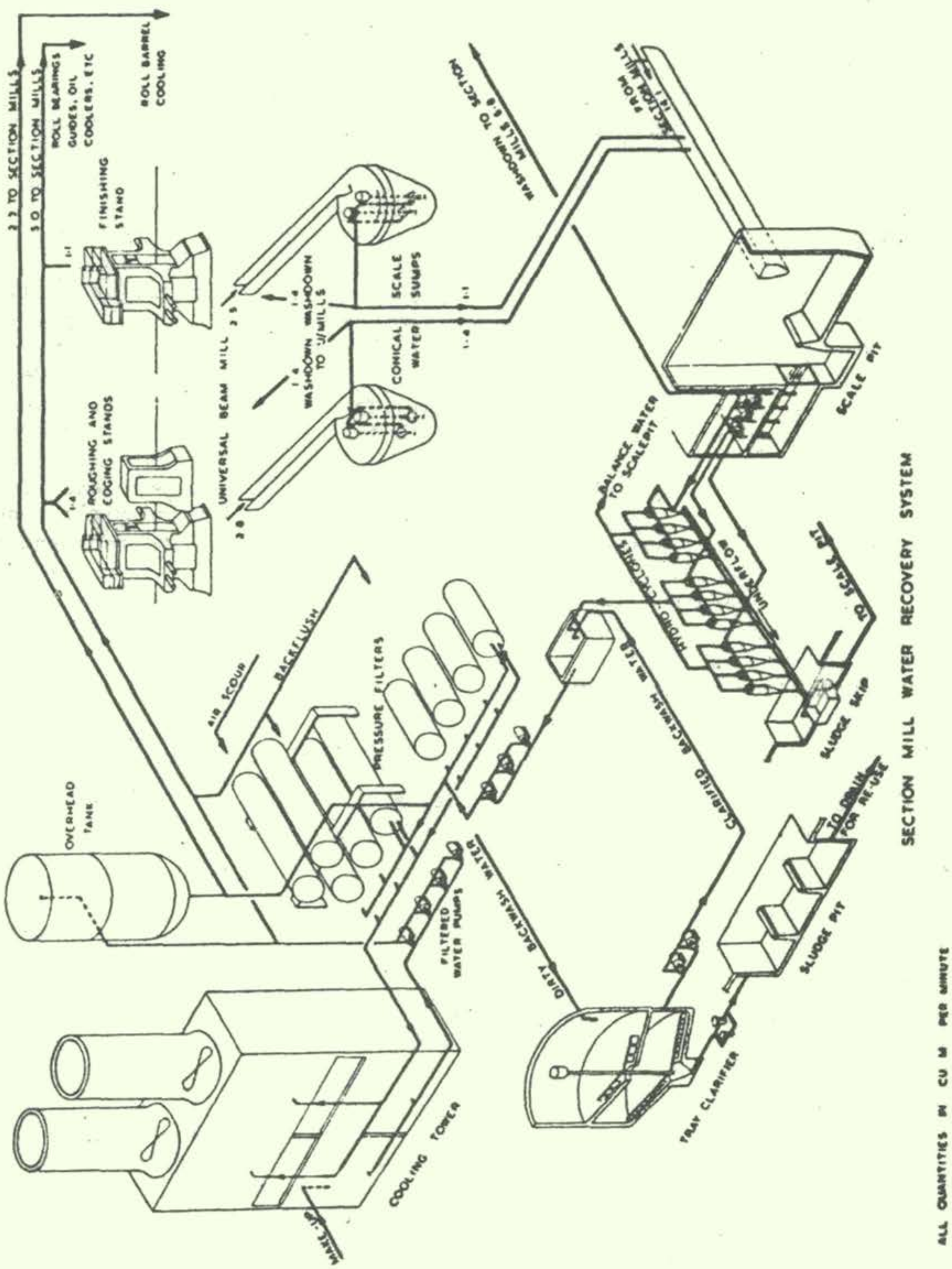
101. The main effluents containing substances which are toxic in the aquatic environment arising in iron and steel manufacture are from the coke ovens blast furnace gas washing, steelmaking fume cleaning and some of the producing finishing operations; these are discussed below. However, it should be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

(i) Coke Oven Effluents

102. Carbonization of coal gives rise to waste liquors containing phenols, thiocyanate, cyanide, thiosulphate and ammonia, with an associated high biological oxygen demand. The levels of some of these containments can be reduced to a certain extent within the coke oven by-product processes, for example the reduction of free and fixed ammonia at the ammonia stills and dephenolisation of the liquors by solvent extraction where applicable.

Figure 1

DIAGRAM OF SECTION MILL WATER RECOVERY SYSTEM



Source : International Iron and Steel Institute

103. Numerous methods of treatment have been devised from 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, however, 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.

104. Although the activated sludge treatment of coke oven effluents has much to commend it, its consistency of operation is not always certain under iron and steelworks conditions. Residual ammonia in the coke oven liquor is not normally removed in the same biological process as the other major contaminants and nitrification and dentrification stages may be necessary, thus representing a further 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. This direct treatment must still be regarded as one of the industry's outstanding problems in the water and effluent field and one for which further work is required to achieve a practicable treatment which will permit the discharge of the effluent with some confidence into most receiving waters of reasonable size.

(ii) <u>Blast Furnace and BOF gas washing water</u>

105. 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 oxidised (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 influent to the treatment plant. These variations are understood to occur because of changes in burden and/or operating conditions. Cyanide can be oxidised by alkaline chlorination, but there may be problems of producing chlorinated organic compounds in the treated effluent.

106. The need is recognised to accomodate for these unpredictable variations where they occur in the design of effluent treatment plants. However, 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

107. The treatments suitable for the variety of effluents arising from finishing processes especially for strip products (e.g. degreasing pickling, galvanising, tinplating 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 neutralised 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. Solutions 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 contaminated effluents and strong solutions from other drainage systems is absolutely essential if successful effluent treatment is to be achieved. 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. dichromate, tin, zinc) from the effluents during treatment. The neutralisation, precipitation, clarification and filtering operations used for finishing effluent treatment, require careful control if a satisfactory effluent quality is to be maintained.

Other Effluents

108. 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.

109. 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. Leachates from stock piles and raw materials may be necessary by containment and settlement prior to discharge.

110. 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

111. 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 chemical 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 continuous monitoring of effluent treatment plant operation which gives far better control than manual sampling and analysis.

112. Final effluent monitoring of selected parameters is also important and is generally required by the water pollution control authrorities. Again some form of continuous 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 continuously 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.

113. Retrofitting of effluent treatment equipment and recirculation systems to old plants is very expensive compared to the new flant situation and there is frequently also a problem of lack of space for such facilities at old congested sites. However, it is an important area environmentally from the point of view of a nation's water resources and the wholesomeness of its waterways.

114. In the effluent treatment area there are still problems to be overcome in the treatment of coke oven effluents, especially ammonia, blast furnace gas washing effluent and to an extent BOF gas washing effluents.

Care and attention to detail in the design of drainage systems to avoid accidential contamination of water courses is important. Monitoring of effluent treatment processes and final effluents is also of great importance and further work is still desirable to develop continuous and/or automatic monitoring of selected parameters in order to provide better day-to-day control over effluent discharges and to permit speedy remedial action when necessary.

115. Perhaps the stage is coming where more attention should be paid to the provision and operation of emergency storage and treatment for off-specification effluents or accidental spillages in particularly sensitive areas, rather than devising more sophisticated and costly individual effluent treatment systems. In other words the trend should be towards achieving the best practicable treatment of each effluent but accept certain limitations in availability and variability of operation, with a final emergency back-up system to cope with occasional serious pollution incidents.

(c) Disposal of Wastes

The waste material arising in the iron and steel industry which must be disposed of varies according to local circumstances. Much of the potential waste can in fact by recycled, re-used or sold and this aspect of overall management of wastes is dealt with in some detail in section III of this report. The following paragraphs, therefore, only review those materials which may have to be dumped and the environmental impact they may have. The problems of waste disposal in the iron and steel industry are most 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.

117. The relatively inert materials include mining wastes, techniques for disposal of which are detailed in the literature (1,2,3); those blast furnace and steelmaking slags which cannot be utilised; some refractory materials; waste sand from foundry and casting operations; building and demolition rubble. Techniques for waste tip management are referred to in paragraph 120 below.

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(1) "Tailings disposal today", Internation symposium, Tuscon, Arizona, Nov. 1972.

(2) A.V.Bell et al, "Some recent experiences in the treatment of acidic metal-bearing mind drainages", Canadiam Min. and Met. Bul., 1975, Dec., p.39.

(3) E.I. Robinsky, "Thickened discharge - a new approach to tailings disposal ibid, p.47.

18. The toxic or potentially toxic material which may be dumped include blast furnace and steelmaking gas cleaning dusts and sludges containing tramp elements such as zinc and lead, tarry and lime bearing wastes from coke oven by-product operations; oily wastes, including oil mill-scale or residues from rolling operations; acid neutralisation effluent treatment and finishing process sludges. 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 materials. These issues are discussed further in section III.

19. Where deposits on land are carried out, care must be taken with potentially toxic materials to ensure that no environmental hazard is created. 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 water 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.

20. 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.

(d) Noise

21. The various production and ancilliary processes in a steelworks 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 section II of the report. Techniques for measuring sound are well established (1), and, although standards exist on an international basis, for instance, for prediction of noise nuisance in the community, they have not yet been universally adopted.

Sources and Extent of Noise Emission

122. 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 steelworks (2,3,4) 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 the source the problem is tackled, the more successful will be the remedial action.

123. Some examples of noise levels at present encountered in a steelworks are given below.

Typical Peak Noise Levels

Production and Processing Operations:	
Ore crushing, 5 metre distance	98 db(A) (continuous)
Loading scrap pans, 25 metre distance	105 db(A) (intermittent)
Electric arc furnace (melt down period): 6 metre distance.	109 db(A) (semi-continuous)
Handling and transport of raw materials, semi-finished and finished products:	
Conveyor discharge point, 5 metre distance	85 db(A) (continuous)

(1) Stahleisen-Betriebsblatter SEB 905 001-005, Verlag Stahleisen, Düsseldorf.

(2) Handley, Schiff, "Feasible engineering noise control for the primary metals industry", Iron and Steel Eng. 52 (1975) Nr.3, p.45-55.

(3) Harrison, I.L., "Noise pollution and its control", Steel Times 202(1974) p.709-710 and 712-716.

(4) Schmidt, Schulz, "Stand und Kunitfge Aufgaben der Larmminderung in der Stahl industrie", Stahl und Eisen 92 (1972) Nr.6, p.238/45.

Slab mill roller tables, 5 metre distance	95 db(A)	(intermittent)

Aerodynamic and hydrodynamic sources :

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

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

124. Production and processing operations in the steel industry are, by nature, noise sources of considerable importance. In attempting to decrease noise, tackling the problem at source is preferred to secondary measures such as insulation, damping and isolation of vibration sources (1). It is possible to achieve engineering design solutions to noise problems (2), and, on occasions, quieter processes can be substituted for intensely noisy ones (pressing instead of punching, sandblasting 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 and noise problems in the design of new plant. Where the above-mentioned methods of noise suppression are either insufficient or impacticable, 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.

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

125. On modern steel plants, methods of continuously transporting materials, for example, by conveyor belt, are being increasingly used instead of batch transporting heavy goods by road haulage or railway wagons, and 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 steelworks, 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

(1) M. Heckl, H.A.Muller, "Taschenbuch der Technischen Akustik", Springer-Verlag, Berlin, Heidelberg, New York (1975).

(2) VDI-Richtlinie Nr. 3720, Bl.1. and 2, "Larmarm Konstruieren", Entwurf 1977, Düsseldorf.

finishing departments represents a major source and indeed a major technical problem.

126. 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 give 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 certainly 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.

127. 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 countries aimed at finding novel engineering and materials solutions for both new and existing plant.

Noise arising from flow and transport of gases and liquids

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 (1) can also be incorporated at strategic locations in the pipework. There is a distinction 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.

129. 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.

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(1) H.Hecke, H.A.Muller "Taschenbuch der Technischen Akustik", Springer-Verlag, Berlin, Heidelberg, New-York (1975).

Protective Barriers

130. 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.

SUMMARY OF OUTSTANDING PHYSICAL ENVIRONMENTAL PROBLEMS

131. The first part of this section of the report has attempted to identify the overall physical environmental impact areas of the iron and steel industry. This summary draws together the main problems which are still outstanding, i.e. the gaps, and points to possible solutions. These problem areas can be considered according to three aspects: fundamental technological problems; problems of high cost and high energy solution, especially where benefits may be marginal; problems of inadequate performance of existing plant and installed environmental protection equipment. All three aspects are interrelated: for example there are few technological problems which cannot by overcome by the application of sufficient resources. On the other hand, very high cost or energy solutions may be impracticable to implement and thus become a problem of seeking less costly technology. Similarly, poor performance with environmental control equipment already installed may indicate inadequacies in the technology adopted. The economic aspects of pollution control are discussed later (see Section IV). At this point it is important to note that a number of technical solutions are available for certain problems, but they involve high cost and/or high energy requirements. It must be borne in mind that energy generation itself may be a polluting process and the advantages and disadvantages of transferring a pollution problem from one industry to another and one place to another should be carefully taken into consideration. Care should also be taken not to transfer pollution from one medium to another in finding suitable pollution control solutions. The outstanding problem areas highlighted below fall into one or more of the categories mentioned above.

Mining Operations

132. The scale of operations in mining and ore processing, concentration and treatment, e.g. pelletisation at the mine site is increasing and although the technology of environmental control is available, this is highlighted as an area where considerable action will be required in the future.

Raw Material Handling and Stocking

133. Problems of fugitive emissions arising from dust entrainment during raw material handling and stocking vary in their intensity and occurrence. However, where the raw material is fine and dry and the meteorological

conditions adverse, the problems can be significant. The technology of control is not difficult but it may be costly and for this reason, this is highlighted as a problem area in which further investigation would be justified.

Coke Ovens

134. Coke making is perhaps potentially the most highly polluting operation in the classical route to steel manufacture. Air pollution both of the working environment and the general atmosphere and water pollution are major problems. The techniques devised to control pollution have made major improvements in recent years, but do not provide a total solution. In the longer term alternative less polluting technological solutions are required (this is discussed further in Section V). However, recently built conventional coke ovens will have a long life (up to 30 - 35 years) and further work on controlling pollution from existing plants remains a top priority.

Emissions from Sintering and Pelletising Plants

135. Adequate dust arrestment equipment is available but difficulties are encountered in the manufacture of high basicity sinter where high resistivity of the dust makes arrestment in electrostatic precipitators difficult. Alternative dust arrestment methods may have to be developed and/or adapted to meet this problem. Problems can also occur with hydrocarbon emissions and glow fires in precipitators where oily material is charged to sinter strands. Gaseous emissions as considered in para. 138 below.

Emissions from Tapping Blast Furnaces

136. Fugitive emissions occurring during tapping of hot metal and slag from blast furnace present environmental problems, the scale of which depends on the size of the furance. The technology for controlling unacceptable emissions is being developed but it is costly and energy intensive, particularly when not integrated into the plant initially.

Emissions from Steelmaking

137. Primary dust emissions from steelmaking, where collected efficiently, can be adequately controlled. Fugitive emissions (i.e. those which escape capture in the main fume extraction system) during charging and tapping etc. are difficult to collect. Whilst the more immediate solutions for fugitive emissions are being introduced, these are costly and energy intensive. In the longer term redesign of plant and some process changes or developments may well be more effective solutions.

Gaseous Emissions

138. The degree to which gaseous emissions from iron and steel processes need to be controlled varies to an extent according to local circumstances. There is considerable reliance at present on dispersion via

discharge from tall chimneys, although in some countries positive control of sulphur dioxide, nitrogen oxides and gaseous fluorides is being required. Sulphur dioxide arises from sinter plant waste gases and from the burning of fuel (oil, coal, coke oven gas). The technology for removing hydrogen sulphide from coke oven gas is well established, and this can result in up to 60% reduction of overall sulphur oxides emissions at an integrated works. The removal of sulphur oxides from waste gases (i.e. at the sinter plant) has been adopted at a number of plants, but the precesses are costly to install and operate, and further development work is required. Generally speaking, notrogen oxides emissions from combustion. Technology for nitrogen oxides control is being developed for sinter plant use in Japan. Gaseous fluorides can be removed where necessary by scrubbing and dry methods are being developed.

Waste Water from Gas Cleaning Equipment

139. Scrubbing waters from gas cleaning often contain toxic materials such as cyanides, as well as metals such as zinc and lead. Treatment processes for waste water which remove these are available, but improvements could be made in the cost and reliability of this treatment.

Effluents from Steel Treatment Processes

140. Rolling mill effluents, especially from cold rolling, and effluents from surface treatment processes, such as acid pickling and plating can give rise to relatively complex treatment problems. Although the basic control technology is generally available, treatment of these effluents still remains a problem in many countries.

Noise

141. Developments are in hand to reduce noise at source, by equipment redesign (e.g. product-handling), and to reduce noise by corrective measures (e.g. sound proofing, vibration isolation), but many problem areas still exist and further work is needed in this area.

Waste Disposal

142. Waste disposal is closely linked with resource utilisation. For the wastes that, at present, have to be disposed of tipping is used. A number of techniques are available for this purpose, and in the wider field of toxic waste disposal further research work on the safer operation of toxic waste tips is being undertaken, which will be of subsequent value to the steel industry.

Problems of Performance of Environmental Control Equipment

143. This is a particularly difficult and sensitive area to discuss as there is little objective information available on which to judge overall performance. However, there are problems associated with the operation and maintenance of pollution control equipment, the scale of iron and

steel operations and the size of individual process units being important factors. There is no doubt that the proper initial design of environmental control equipment and, thereafter, adequate maintenance is essential if good environmental control performance is to be achieved. Such equipment is, generally speaking, non-productive and may tend to become a low priority for maintenance compared to production plant. It is important to check performance of environmental control equipment regularly by proper monitoring of emissions, effluents and noise levels. There is a need for further research and development work on monitoring, especially continuous monitoring of air and water pollutants as an integral part of plant operation and control.

SECTION II - WORKING ENVIRONMENT

144. Occupational health and safety is a major concern in the iron and steel industry due to the nature of the operation. Clearly the objective is 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 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.

145. Traditionally, work in the iron and steel industry has been characterised 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, of 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.

146. The purpose of this section is to survey the scope of the problems of the working environment, in the iron and steel manufacturing processes by using examples, drawing attention to those aspects where worker protection is required. More detailed discussion of the various aspects may be found in the literature (e.g. ILO Iron and Steel Committee 9th Session, Geneva 1975, Report III, Working Environment in the Iron and Steel Industry; ILO Metal Trades Committee, 10th Session, Geneva 1977, Report II, Safety, Health and Working Environment in the Metal

Trades, New Approaches; IMF Iron and Steel Conference, Pittsburgh 1976, Occupational Health Hazards in the Iron and Steel Industry). It is not intended to give an overall state of the art as to environmental protection in the workplace since problems are complex and vary from installation to installation with different levels of protection being achieved. Attempt will be made, however, to highlight those aspects of the working environment which are still considered to present unsolved problems.

147. 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 steelmaking 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 interrelated, for example excessive heat stress may give rise to increased accident risk.

Heat, Noise and Vibration

148. 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 in the hot environment and heat stress may well be accentuated in hot and humid climates. 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.

149. 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 minimise 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. These matters are discussed in Section I of this report. Noise levels within the plant should be regularly monitored to assess personnel exposure.

150. Protective ear muffs/plugs and shorter periods of exposure are approaches where equipment design is not adequate in reducing noise levels. This approach is 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.

151. 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 whilst finger and investigatory work is proceeding on this problem in a number of areas.

Particulate Matter

152. Inhalation of fine particulate matter (size ranges from 0.1 to about 5 µm) 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 substances 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 steelmaking 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.

153. A serious hazard in this type of industry 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 steelworks 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 (esp. 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

154. 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, and monitoring of carbon monoxide levels in working areas is an essential precaution. Excess carbon dioxide may also cause asphyxiation.

155. 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

156. Oxygen is used under pressure in a number of steelmaking operations and presents accident and fire hazards which must be minimised 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

157. 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

158. 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 involved in the operation (1). The relative risk of lung cancer and possibly kidney cancer is reportedly considerably higher in coke oven workers than in the general population (2). Whilst modern techniques enable the most potentially polluting parts of the operation: 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, standard of maintenance and operation. A conscientious team can help keep ovens well maintained and operated, so as to minimise 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.

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(1) Tables E-6 and E-7 in "Industrial Process Profiles for Environmental Use", chapter 24, "The Iron and Steel Industry", U.S. EPA-600/2-77 023x, Feb.77

(2) NIOSH Criteria for Occupational Exposure to Coke Oven Emissions.

(ii) Charging and Casting

159. Fume and gaseous emissions occurring during blast furnace tapping and steel furnace charging and taping 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.

(iii) Sintering

160. 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

161. 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(1).

Protective Policies for the Working Environment

162. 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.

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(1) See for example "Double Rotation Paves the Way to Closed Ferrosilicon Furnaces", paper presented at ILAFA International Congress on Ferro-alloys, Acapulco, Mexico, May 14 - 19, 1978.

163. 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 interrelate. 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 minimise 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.

164. 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.

165 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.

166. 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 minimising the emissions from this 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 co-operation, 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 funtion and comfort.

167. Running of the steelmaking process, whether it be charging or tapping furnaces, are other important areas where good operating conditions are necessary to minimise 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 minimise the volume of emissions, so as not to overload the pollution extraction equipment.

168. 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 organisations may play an important role in educating their members to be aware of environmental matters both with the management in mutually agreed improved operating and maintenance procedure through joint consultation. 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 ensure adequate worker protection from hazardous exposures under specific conditions, may require close co-operation between management and workers' representatives at all levels.

169. 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.

SECTION III - RESOURCE CONSERVATION AND RECYCLING

170. The iron and steel industry is a major user of resources such as iron ore, coal, limestone, refractory materials, water and energy. It is important that such resources are used efficiently with as little waste as possible.

171. 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 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.

Energy

172. Energy consumption by the iron and steel industry ranks high. Production from iron ore of 1 ton of finished steel requires about 37GJ. The industry itself has traditionally paid attention to reducing energy consumption in order to reduce costs, which has been highlighted by the rapid increase in the cost of energy in recent years.

173. 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 steelmaking

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 utilised. Process changes, for example the replacement of the open hearth process by the BOF process and the introduction to continuous casting in place of ingot casting and primary mills, have also had substantial effects in saving energy.

174. There are still areas where more saving should be possible, for example in the recovery of low temperature waste heat which is at present wasted. The economics has hindered doing so in the past. Further process changes to reduce energy consumption might also be possible, and the way forward has been highlighted in recent studies on energy conservation in the iron and steel industry, e.g. (1). 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), direct energy savings (e.g. dry coke quenching, use of turbines to recover energy from blast furnace gas in high top pressure systems, utilisation 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 desulphurisation of blast furnace hot metal, thus permitting use of high sulphur coke and coal). It should be noted that in relation to external desulphurisation 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.

175. It must be mentioned here that environmental control measures in themselves consume energy, especially where high rates of extraction are necessary to collect fugitive emissions. However, overall energy usage for pollution control is reported at present not to exceed 3 - 4% of total energy requirements at an integrated works (2). 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).

Water

176. Water is an essential raw material in iron and steel manufacture, the requirement for water at an integrated works being as much as 150 - 200 t/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 requirement. There is a wide

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(1) EPA "Environmental Considerations of Selected Energy Conserving Manufacturing Process Options : Vol. II - Iron & Steel Industry Report", EPA-600/7-76-0346, December, 1976.

(2) Analysis of Economic Effects of Environmental Regulations on the Integrated Iron & Steel Industry, EPA 230/3-77-015, July 1977, Vol.1, section 8.

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. The water engineering approach adopted and the control of liquid effluents discharged are closely interrelated and both should be considered as integral parts of water management. For convenience, however, liquid effluents have been dealt with in section I of this report and this part concentrates on water engineering practice.

177. To an extent, a major industry such as iron and steel will always 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 existance 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 decision making as to whether a particular environment can accept a major industry of this kind (see section VI).

178. The main reasons for using water in iron and steelmaking 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 which are discussed below.

Quality and quantity of water

179. 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.

180. 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) Clarification by simple filtration to reduce suspended solids,
(ii) lime and lime soda softening to reduce scale-forming salts,
(iii) demineralisation to remove dissolved salts (e.g. in water for steam raising) and finally,
(iv) treatments for potable water.

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

182. Treated sewage effluent can provide a useful source of general industrial water when appropriate pre-treatments are 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.

183. 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 IV 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.

184. 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 summarised as follows:

185. 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.

186. 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 fresh water stream 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 IV Quantities of Water in Circulation in an Integrated Steelworks Producing 4 million t/annum crude steel

Plant	Main Purpose	Quantity	
		m^3/min	% of grand total
A. Main indirect cooling water systems			
Coke Ovens	Gas primary coolers	75	7.9
Sinter plant	Cooling 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
Continuous 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 Inst.

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 of effluents in lagoons.

187. 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.

188. Having broadly set out the factors which should be considered in the design and selection of water usage systems, it is appropriate to study what levels of reduction in water intake are actually attainable.

189. Table V outlines the possible extremes of the water intake required for the works outlined in Table IV, 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 utilisation of recirculation and re-use techniques are based on actual consumptions at an integrated works during 1977.

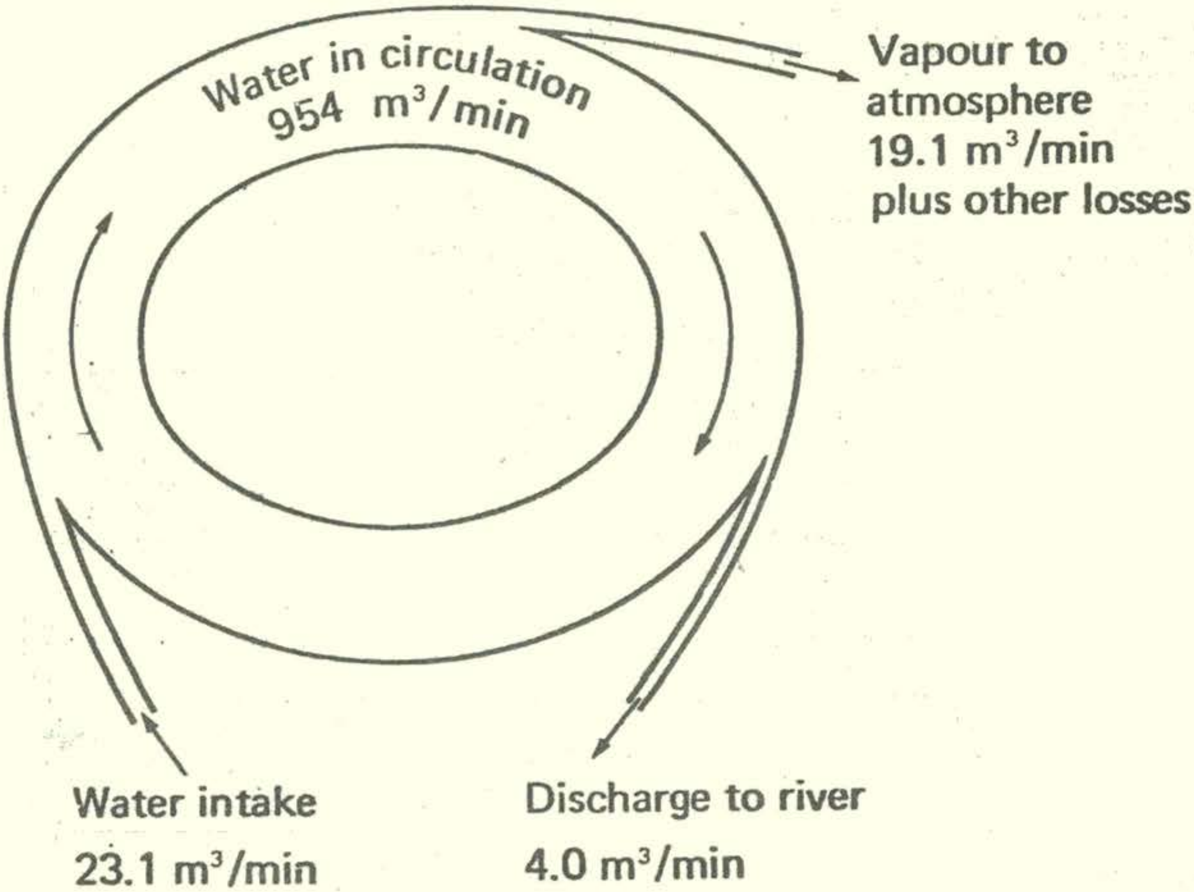
Table V Water Intake Requirements for Different Water Management Practices (4 million tons crude steel/annum integrated steelworks)

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)
Steam raising	High grade Industrial	4.8	(0.5)	2.9	(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.

190. The water usage system at a works using a particularly high level of recirculation is shown diagrammatically in Figure 2, 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 2 Diagram of water usage at works using extensive recirculation



Source: International Iron and Steel Institute.

191. 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.

Alternative approaches to minimising water intake

192. As previously mentioned, an optimum pattern of water usage has to be established for each works, some of the alternatives available are discussed below.

(a) Indirect cooling system

193. 70% or more of the water used in a works is contained in indirect cooling systems, the main purpose of which is to provide adequate cooling of plant and equipment. This water does not come into contact with products or by-products and does not therefore become contaminated with pollutants : it does however contain heat which could give rise to thermal pollution if discharged without cooling. It is important to establish the optimum level of plant cooling, on the one hand to maintain satisfactory operation and on the other to avoid over-cooling. Over-cooling of plant wastes energy, increases water demand and also creates an unnecessarily high amount of heat to be dissipated to the environment.

194. Generally speaking, the thermal load carried by the cooling water, whether in a once-through system or in a recirculation system, will be too high for direct discharge to inland rivers, lakes, etc. and cooling towers are installed to reduce the temperature of the water.

195. Coastal works have the facility of using saline water on a once-through basis for certain indirect cooling applications or as the secondary cooling medium in water/heat exchangers, the main drawback being a relatively high risk of corrosion problems. Many works, however, use recirculating systems which require only a fraction of the intake water. The intake need only match the quantity of water lost by evaporation in cooling towers and the quantity bled from the system in order to control the build-up of dissolved salts such as calcium sulphate which would otherwise cause deposition of scale in the cooling elements or other salts which cause unnecessary corrosion. This make up requirement varies according to the degree of cooling in each particular circuit and may be typically 1 to 2 % of the water in circulation. It should be noted that adoption of extensive recirculation is not always necessarily the best way to reduce demand on water resources. This is a matter for evaluation according to local circumstances.

196. Cooling of the water in circulation may be by natural draught or mechanical draught cooling towers, the decision as to which depending on capital and operating cost comparisons, availability of space and the particular applications. In both cases the air comes into direct contact with the water which will thus be liable to contamination from dusts and gases in the atmosphere. Although this normally presents no major problem, it may be desirable in some cases to prevent such contamination by using a completely closed cooling circuit in which the water is cooled in either water/water or air/water heat exchangers. Although power consumption is higher than in conventional cooling towers, space requirements are less and it is possible to use high quality water in the system without loss and without scaling problems, thereby giving a more reliable cooling circuit as a whole.

197. A more sophisticated approach to certain cooling applications and one which is attractive from the energy conservation point of view is to use evaporative cooling. The cooling circuit is operated at high pressure and includes a steam drum from which process steam can be drawn. In effect, the water system acts as a boiler and recovers otherwise wasted thermal energy in the form of steam. Although attractive and being adopted more widely, evaporative cooling systems require certain basic control equipment to reduce the possibility of malfunctioning and to ensure safe operating.

(b) Direct cooling and cleaning systems

198. The term direct cooling is used to denote those cooling applications where the water comes into direct contact with the substance being cooled. Thus the water can pick up contaminants from the substance being cooled and may require treatment prior to discharge or recirculation, for example in gas cleaning. Similar principles apply in regard to the choice of water practice in direct cooling systems as have been mentioned for the indirect systems but the direct link between water management and effluent production assumes greater importance. Once-through systems produce large volumes of effluent with comparatively low concentrations of pollutants which are difficult to remove because of their low concentration and which in such a large volume can represent a massive pollution load on the receiving water. In most countries this is becoming less and less acceptable in environmental terms especially where the assimilative capacity of the receiving water is limited. The trend is, therefore, towards using recirculating systems with appropriate treatment of the water in circuit to reduce its temperature and the contaminants which might create corrosion or solid build-up problems in the water system. Bleed off from the systems to control dissolved salts is from the clean side of the in-circuit treatment with additional treatment prior to discharge if necessary. Typical applications of direct cooling and the contaminants picked up by the water in circulation are shown in table VI. These effluents are discussed in Section I of this report.

199. Beyond straightforward recycling of the water, there is not a great deal of further scope in direct cooling systems for achieving further water economies because it is essential to use water in many of the applications, e.g. blast furnace gas cooling and cleaning, product quenching in continuous casting plants and rolling mills. There may be some choice in steelmaking fume cleaning where dry systems are possible. The decision here has to be made bearing in mind the overall environmental impact, weighing the relative advantages of the reliability of wet scrubbers, energy consumptions, possible effluent problems and whether the collected iron oxide fume is easier to handle in wet or dry form.

(c) Miscellaneous water uses

200. Miscellaneous uses of water include boiler feed water, water for coke and slag quenching, water for rinsing products in the finishing operations and water for dust suppression at ore stockyards and during materials handling. Water for steam raising in boilers must be of high quality and the cost of achieving this quality makes it well worth-

while to condense the steam not lost as process steam and re-use the condensate as boiler feed. Water used for quenching and dust suppression is generally all evaporated and should not give rise to effluent problems. It is worth mentioning here that dry coke quenching will not in itself achieve a large saving in water requirements and its installation would have to be justified on environmental, energy and process grounds. It does, however, eliminate the unsightly charact-ristic plume of water vapour arising from wet quenching. As previously mentioned, recovered plant drainage and rainfall may be suitable for these applications ; its poor quality certainly precludes its use elsewhere on the works.

Table VI <u>Major Pollutants Entering the Water in Direct Cooling Systems at a 4 million t/annum Integrated Steelworks</u>

Plant	Process	Flow (m^3/min)	Major pollutants entering water
Coke Ovens	Gas cooling and purification	15	Tar-oils, ammonia, phenols, cyanide, thiocyanate, thiosul-phate.
Blast furnaces	Gas cooling and cleaning	75	Dust particles, cyanide fluoride, lead, zinc.
Steel furnaces	Fume cooling and cleaning	35	Flume particles, fluoride, zinc
Continuous casting	Quenching hot steel	10	Scale, lubricating oil, hydraulic fluids
Rolling mills	Roll cooling, product quenching, scale washdown	130	Scale, lubricating oils. greases, hydraulic fluids

Source: International Iron & Steel Institute.

201. To summarise, water management techniques are available which drastically reduce the iron and steel industry's demand on resources. No major technical problems from this point of view need highlighting (although some have been already highlighted in regard to effluent treatment) except that all the alternatives should be carefully evaluated especially when constructing new plant, so that an optimum design can be achieved which meets resource constraints whilst not severely penalising the industry cost-wise.

202. Retrofitting of effluent treatment equipment and recirculation systems to old plants is very expensive compared to the new plant situation and there is frequently also a problem of lack of space for such facilities at old congested sites. 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.

203. As to the future, the general trend towards more sophisticated production processes emphasises 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.

204. Of the new processes, mention should be made of direct reduction of iron ore. Knowledge of water requirements and effluents arising is in the early stages, but it is anticipated that water requirements will be similar to those for blast furnaces and the contaminants picked up by the water can be expected to be similar to those arising at blast furnace gas cleaning.

Materials and By-Products

205. Iron and steelmaking processes give rise to significant amounts of useable or unuseable 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 utilised or passed to other processes the remainder should be disposed of using well-established waste disposal practices to avoid any environmental threat (this is dealt with in Section I of the report, paragraphs 116 et seq.). As far as good management of by-products and wastes in general is concerned, the following are of importance :

- minimising the specific quantities of by-products and wastes produced,
- control of environmental problems during reprocessing, transport or depositing of by-products and waste,
- minimising, through recycling, the quantities for ultimate disposal.

206. A flow diagram is shown in Figure 3 representing the possible production sectors of a steelworks and the by-products and wastes arising (1). A schematic diagram of by-products and wastes arising, re-used, sold and dumped is given in Figure 4 based on an example from the French steel industry.

207. 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. Details of this and of tailings disposal are given in the literature quoted earlier in paragraph 117).

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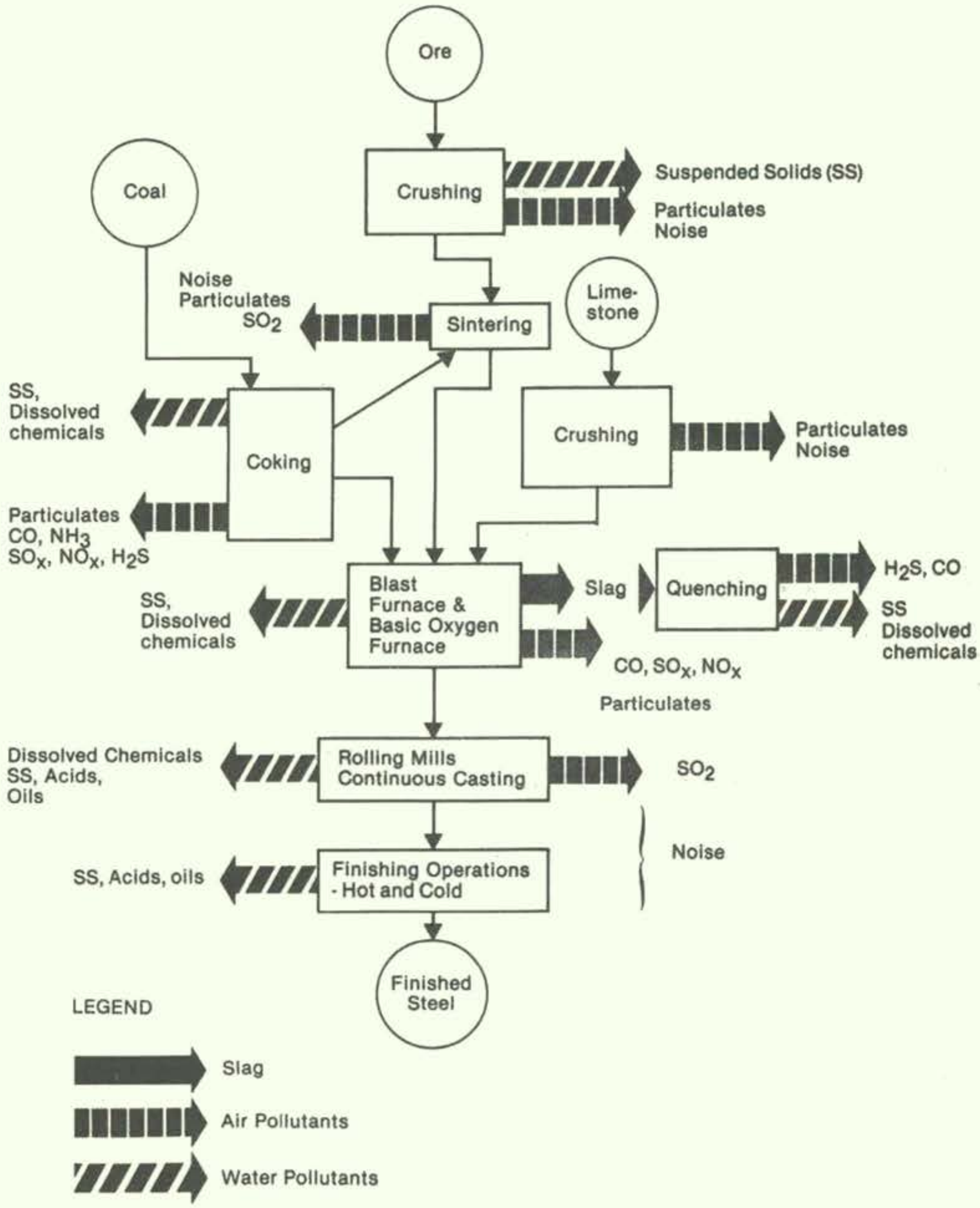
(1) Steel Times, December 1979.

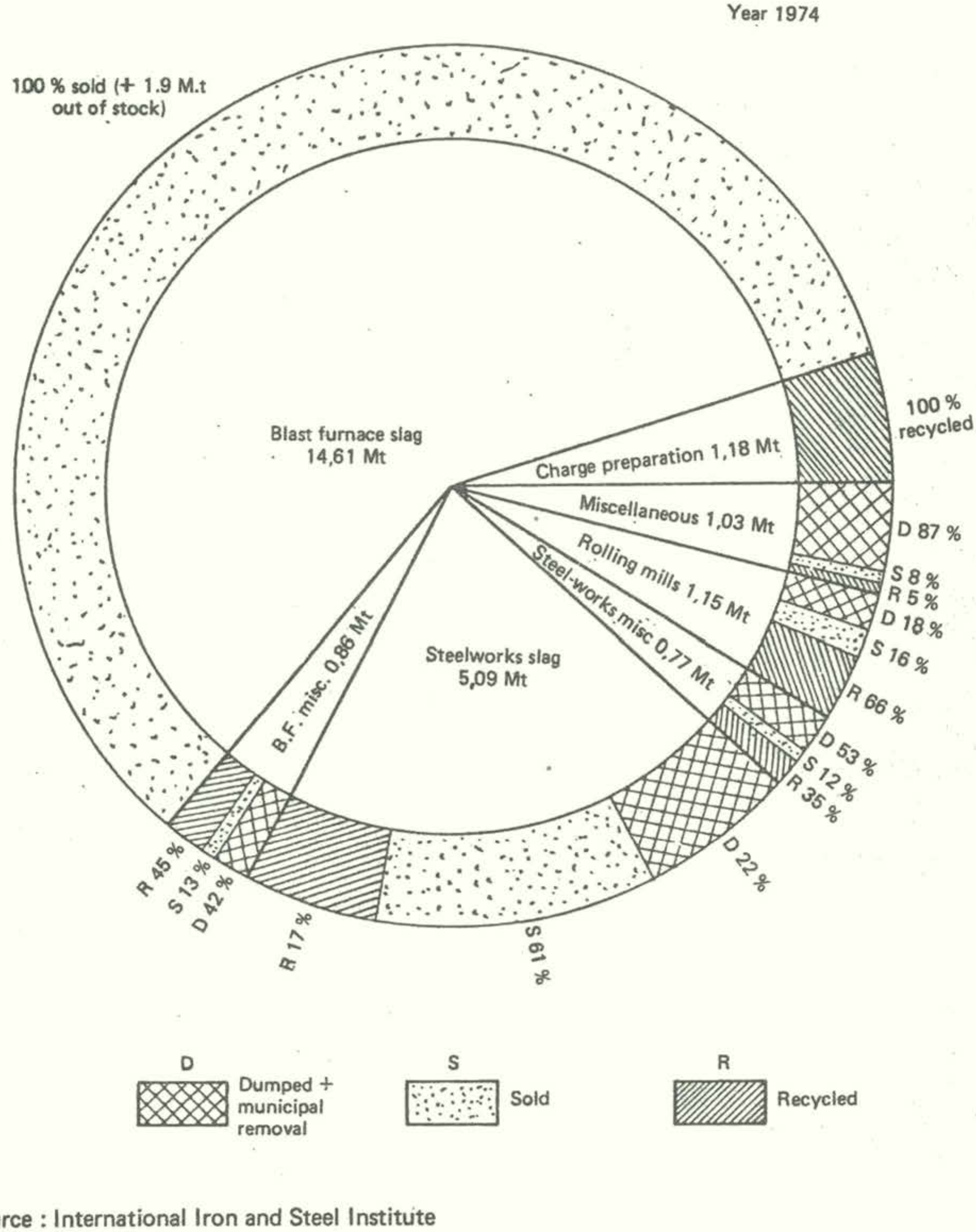
Figure 3 Materials flow diagram for an integrated iron and steel works indicating main by-products and wastes



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

Figure 4

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



Source : International Iron and Steel Institute

Cokemaking

208. Coke is used in the blast furnace as a fuel and as a reducing agent. Ironmaking plants either manufacture their own coke or buy it from the coal industry. 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, napthalene and other aromatic hydrocarbons, phenol, tar, hydrogen sulphide for further processing, etc. are yielded.

209. At some plants the coal dust 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 (see paragraphs 25 and 26). The coke breeze arising is largely carbon and can be fed back into the production sequence.

210. Ore preparation

Sintering and pelletising require the various kinds of iron ore to be crushed to certain sizes and blended. The dust generated by ore crushing is collected in filters and returned to the process. The ore fines are dampened and the belt conveyor transfer points are covered to avoid dust arising.

Sinter plant

211. 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 is then fed back on to the sinter strand via the mixer drum.

212. In order to eliminate SO_2 (S from the coke breeze) evolved during the sinter process, a number of steel producers have installed desulphurisation plant for the waste gas. 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 fertiliser whereas elemental sulphur can act as an important raw material for the chemical industry (e.g. sulphuric acid manufacture).

Pelletising plant

213. In order to provide the green pellets with sufficient strength for

charging into the furnace they must be fired and this process 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

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

- 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

215. The ore gangue is formed into slag by the introduction of limestone in the blast furnace burden. Modern blast furnace practice typically gives rise to about 320 kg slag/t pig iron. The slag can be utilised in a number of ways such as a building material or as the raw material for blast furnace cement (1,2).

216. There are three basic ways of dealing with liquid slag emerging from the furnace :

(i) 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 a a concrete additive is also common. In some countries, especially those with coastal steelworks, 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 fertiliser.

(ii) 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.

(iii) The slag is foamed 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.

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(1) F. Schröder, "Slag and slag cement", 5th International symposium on the chemistry of cement, 1968, Tokyo.

(2) J.J. Emery, "New uses of metallurgical slags", Canadian Min, and Met. Bull., 1975, Dec., p.60

(iv) Depending on the basicity of the slag, slag wool can also be produced.

217. The slag arising from the production of common pig iron has the following chemical analysis (Table VII) :

Table VII 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

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

(c) Refractories

219. During furnace wrecking or rebuilding, a good deal of used refractory material arises. Fireclay bricks are normally sorted and the reuseable portion passed for evaluation and 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. Fireclay ladle linings are similarly sorted but dolomite and runner materials are dumped. Dolomite refractories can be recycled in some cases.

(d) Dust and slurries

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

(i) Coarse dust separation in a dust catcher or cyclone. This dust consists largely of iron oxides and coke residue and has an approximate analysis as shown in Table VIII.

Table VIII 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 are incorporated in the second stage of gas cleaning. The residue is a slurry with a range of compositions shown in Table IX.

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

221. 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 (see paragraph 247) or alternatively dumped.

Desulphurisation of pig iron

222. Various techniques for pig iron desulphurisation have been developed in recent years and in all cases a reaction agent is introduced into the hot metal to reduce the level of dissolved sulphur. The methods used are either based on mechanical stirring or lance injection by which, for example, calcium carbide is introduced into the hot metal bath. The resulting waste product is a carbide or soda slag which is further processed to separate metallic components. The desulphurisation processing using calcium carbide injection (1) might make 8 - 15 kg slag/t pig iron. Carbide slags have the advantage of being re-useable 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.

Direct reduction

223. Direct reduction plants using either gaseous reduction with shaft furnaces or rotary kilns may be fed with lump ore or pellets. Where pelletising is used, the pellets are produced mostly from a single ore or possibly from a blend of a small number of different ores. The fines resulting from the screening of the pellets are fed back to the

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(1) H.P. Haaster et al, "Operational aspects of the injection process for desulphurisation of hot metal", Iron and Steel Eng., 1975.,Oct. p.71 - 77.

process. Gases are given off by the direct reduction process and these are normally cleaned in wet scrubbers and recycled. The resulting slurry is filtered, pressed and recycled. Depending on the actual process used, the furnace product is screened and the small fraction returned. In the case of the Purofer process both the product and the fines are passed to a briquetting installation (1,2). The non-metallic component is used as a slag additive in electric furnaces.

Steelmaking processes

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

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

(a) Steelmaking slags

225. Quantitatively the largest by-product from the present steelmaking processes is slag. Table X shows the chemical composition of slags arising in the production of large tonnages by the BOF or bottom blown oxygen methods.

Table X 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

226. The specific slag quantity depends very largely on the quality of steel being produced and on the scrapping 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.

227. Applications for steelworks slags are :

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

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(1) U.P. Pante, "The Purofer process", Rev. Met., 1975, Nov.

(2) U. Pohl and H.K. Schott, "Investigations into the storage and handling of sponge iron briquettes", ECE seminar, Bucharest, Romania, 1976, May.

228. BOF slags are normally poured off into contained areas and allowed to solidify. They are cooled until ready for removal and pass on to the preparation plant. The slags are broken up, iron is removed by magnetic separation and the product is size graded.

229. Certain quantities of BOF slag can be added to the ironmaking 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.

230. Slags containing relatively high levels of P_2O_5 (commonly greater that 15%) were produced in earlier times with the Thomas converter process. These slags were ground and used as fertiliser. This practice is still used in some steel works using high phosphorus hot metal. 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. Therefore, in order to obtain a material with the correct level of citric-acid-soluble phosphates (a measure of fertiliser quality) BOF slags have natural phosphate rock added to them in the grinding process. This product is in increasing use in agriculture (1).

(b) Filter products from primary and secondary de-dusting

231. Different qualities and quantities of scrap charged to modern oxygen and electric steelmaking processes govern the chemical composition of the fume collected.

232. 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 dewatered in a separate installation. Residual water varies between 18 and 39% Table XI provides a typical analysis of the arrested dust :

Table XI 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

(1) The phosphoric acids, vol.30,1973-74, Tellus Verlag,Essen, H.Platzen and H.Munk,"Zur Fragen der Phosphatwirkung von Konverterkalk und Thomaskalk"(Phosphating effect of converter and basic bessemer lime).

Certain works feed the primary fume cleaning dust back to the sinter plant stage of the integrated process (1). 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 in paragraphs 247 - 248.

233. 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.

234. Primary and secondary fume cleaning plant in electric arc plants gives rise to collected dusts, the nature of which vary very much according the steel quality being produced. Sometimes they are suitable for recycling in the steel process and this is usually done by pelletising and recharging to the electric furnace. In some cases, however, it is not possible to recycle the dust, for example, because o f the presence of lead and zinc or in the case of alloy and stainless steelmaking, the presence of Ni and Cr oxides. In the latter case the alloy and stainless steelmaking fume is recovered in order to make the Ni and Cr available for re-addition to the process. Where dusts must be disposed of, care has to be taken with material containing heavy metals to ensure no harm to ground water. Secure dumps are therefore necessary.

(c) Refractory waste

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

Hot forming processes

236. The important residues and wastes are :

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

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(1) U.S. Steel Corp. "The making, shaping and treating of steel", 1971, p. 422.

(a) Scrap

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

(b) Millscale

238. 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 quantity can be recycled to the sinter plant. The water used in rolling mills causes small quantities of oil to be passed 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 - 12%. 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.

239. A number of methods of handling oil-containing scale have been introduced. One works in Germany has developed a method for chemical removal of the oil by solvent extraction (1), and this is being tested on an industrial scale. Attempts have also been made to remove the oil by burning it off in a fluidised bed heater. At present, millscale containing large amounts of oil usually has to be dumped and special precautions have to be taken to prevent water pollution by oil.

(c) Soaking pit and scarfing residues

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

(d) Refractory and other wastes

241. Wastes of this type have been dealt with in paragraph 219. This kind of waste also arises in the rolling operations, from soaking pits, reheating furnaces and similar plant. It is sorted to separate re-useable material and the unuseable residue can be disposed of safely.

(3) Used oil and grease

242. 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.

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(1) Hoesch Hüttenwerke AG, Patent No. P/25 32 689.0-24, Deutsches Patenamt, Offenlegung 27. Jan. 1977.

Pickling lines

243. Acid pickling generally precedes cold reduction. Sulphuric acid, hydrochloric acid or mixtures of hydrofluoric and nitric acids (in the case of special steels) are used. Spent pickling 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 is normally dumped. 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.

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

Cold rolling mills

245. Scrap arising during cold rolling is re-used in the steelmaking 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

246. Some cold-rolled sheet and strip is passed to galvanising, 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

247. 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 Tables VIII, IX and XI show, blast furnace and steelworks 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 reudction plant using rotary kilns (1,2,3) ; pelletising 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 vapourised and are deposited in the form of oxides in a fume arrestment plant.

248. The zinc oxides are generally sufficiently concentrated to make sale for zinc recovery worthwhile. The sponge iron pellets are passed to the ironmaking plant or if the sulphur and alkali levels are low enough direct to the steelworks. Processing plant of this type will only slowly be introduced into the steel industry on account of the heavy investment and operating costs. Rough calculations indicate that the operating costs are just offset by the revenue from sale of zinc and lead oxides and the sponge iron, and by the avoidance of disposal expenses. There is, however, no return on capital at this present time.

Other forms of waste

249. A large steelworks must take account of waste products which do not arise as a result of specific production processes.

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

251. 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.

252. 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.

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(1) Sugaswa et al, "Direktreduktion von Hüttenwerksstauben" (Direct reduction steelworks dust), Stahl and Eisen, 1976, 96, 24, 1239-1245.

(2) Kossek et al, "Verabeitung von Hüttenwerksnebenprodukten nach dem Walzverfahren" (Treatment of steelworks by-products by rolling), Stahl und Eisen, 1976, 96, 10, p. 482 - 486.

(3) H. Maczek et al, "Versuche Zur Verarbeitung von Hüttenwerkasbfällen nach dem Walzverfahren in einer Betriebsanlage" (Industrial tests on reprocessing of steelworks waste products), Stahl und Eisen, 1976,96,24,p.1233-1238.

Management of wastes.

253. Large steelworks employ departments for the control and organisation of works waste economy. A number of companies have laid down guidelines to rationalise and facilitate waste disposal work. On economic grounds, iron and steelworks have a vested interest in the optimum re-use and sale of by-products and wastes. The revenue realised 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 (1,2,3,4,5).

Trends, research and development

254. 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.

255. Cooperative 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 slags used as aggregate for road building (6). Further research possibilities lie in the direction of

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(1) H. Takano, "Recycling of materials within an integrated steelworks", IISI panel discussion, 1977.

(2) R. Gorgen and W. Theobald, "Recycling in der Stahlindustrie der Bundesrepublik Deutschland" (Recycling in the German iron and steel industry), Stahl und Eisen, 1977, 97,14, pp. 657-664.

(3) G. Relf "Recycling von Hüttenwerksabfallstoffen" (Recycling of steelworks waste) Steel times, 1976,204,8,pp. 718-724.

(4) M. Haucke, "Abfallwirtschaft und Abfallbeseitigung in der Stahlindustrie" (Waste economy and waste disposal in the steel industry,)Techn.Mitt., Essen, 1974, 67, 1, pp. 37-40.

(5) M. Haucke, "Abfallwirtschaft im Hüttenwerk" (Waste economy in the iron and steel works), Stahl und Eisen, 1970,90,7,pp. 348-354.

(6) G. Wysocki, "Erfahrungen mit KBM-Ultrafiltrationsanlagen" (Experience with the KMB super filter), Wasser, Luft, Betrieb, 1977,21,6,p.346.

treatment of slurries and dust. Progress must be made towards cheaper, high technology processing systems and it is desirable that this work be supported by national and international funds, for example European Community finances are being applied in this area. Furthermore, new outlets for steelworks by-products and wastes need to be found, for example, replacing natural raw materials for building blocks.

256. 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.

Recycling of Scrap

257. 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 steelmaking represented 45% of crude steel production (290 m. tons scrap compared with 646 m. tons crude steel)(1). 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 a low energy consumption means of producing steel (only 15 to 25% of the energy needed to make steel from virgin ore) if the energy used in the production of the scrap from raw iron ore is not counted. 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.

258. There are three distinct sources of ferrous scrap : that arising in the industry itself known as home scrap; ferrous scrap from engineering and other iron using installations; household and other rejected ferrous material (2). Home scrap, which is essentially clean, is recirculated extensively within the industry itself. The amount

(1) Source : International Iron and Steel Institute.

(2) L. Lazar "Sources and Treatment of Ferrous Scrap", Report and Proceedings of IISI 11th Annual Conference, Rome, October 10 - 12, 1977.

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 continuous casting, home scrap can be as low as 7 - 8% of total production. 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 steelworks.

259. The third source of 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 (1). This is now a highly mechanised and well organised activity in the industrialised countries involving collection, treatment and transportation of scrap. Large crushing, shearing and compressing machinery is used. Valuable materials such as tin, copper and other non-ferrous metals are recovered (2). It is important to remove tin, for example, since this element has a deleterious effect on the material properties of iron.

260. 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.

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

262. The constraints on scrap utilisation 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

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(1) See for example R.A. Petrone "Recovery of Ferrous Scrap from Municipal Solid Waste", Report and Proceedings of IISI 11th Annual Conference, Rome, Oct.10- 12, 1977.

(2) "Recovery of Tin Plate from Domestic Refuse", Iron & Steel International: December 1977, pp. 373-4.

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 galvanised scrap, lead from lead painted scrap).

263. Whilst in developed countries up to 93 - 95% of available ferrous scrap is recovered, which is probably the realistic recovery potential under todays conditions, there is scope on a global basis for increased reclamation of ferrous scrap so that it can be re-used by the steel industry. 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.

SECTION IV - ECONOMIC ASPECTS

264. An examination of the economic aspects of environmental protection in the iron and steel industry presents three main difficulties. First, there is no common agreement nor international acceptance as to the definition of environmental control measures. There are differences in the interpretation of what constitutes on the one hand pollution control equipment and on the other hand process equipment; for example blast furnace gas cleaning equipment, water recirculating systems. Secondly, evaluation of costs on a comparable basis is difficult since actual costs vary from country to country depending on the environmental regulations and the degree to which they have to be implemented at any given time. Thirdly, costs for construction and operation of pollution control equipment and of those parts of processes dealing with environmental protection, have not traditionally been collected separately by the industry from other construction and operating costs. There is presently a fourth complicating factor in that with many installations working well under capacity it is difficult to extrapolate costs to full capacity conditions.

Capital Costs

265. Bearing in mind the limitations mentioned above, the commonly quoted figures for the proportion of capital cost allocated to environmental control at a new integrated iron and steelworks range from 10% to 18%. However, the variations are wider than this. For example, a recent study of the current situation in North America indicates that environmental control facilities to meet legislative requirements at new installations account for 20% of the capital cost (1). Costs, as estimated in France, for new integrated works range below 10%, whilst

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(1) "Steel and the Environment. A Cost Impact Analysis" report by A.D. Little, Inc. to the American Iron & Steel Institute, May 1978.

for specific installations above 20%. The proportion of the capital costs for environmental control at each production stage differs with "heavy" and (i.e. coking, sintering, steelmaking) accounting for a substantial proportion of capital expenditure on air-pollution control, whilst rolling and finishing require expenditures on effluent treatment rather than air pollution control. Thus the overall proportion of capital allocated to environmental control will vary according to the type of works. The U.S. Study (1) indicates that under present circumstances at integrated works the breakdown of capital requirement shows a demand divided almost equally between water and air pollution control.

266. Generally speaking, the cost of retrofitting environmental control equipment is higher than for equipment installed at the outset at new plants, because advantage cannot be taken of integrating designs, nor of utilising construction services already on site. There may also be other site specific costs due to lack of space, production interruptions, technical problems associated with process design, etc.

Operating Costs

267. The problems of definition of costs mentioned above apply equally well to operating and maintenance costs, with the additional problems of separating these costs from process operating costs. For the U.S.A., figures quoted in 1977 for the additional operating and maintenance costs, of pollution control equipment installed indicate that the present levels are a few per cent only of total operating and maintenance costs, with the possibility of these rising to around 4 - 5% stricter pollution control measures are implemented (2). A more recent study indicates at least 6% for operating and maintenance costs, plus an additional 4% for capital recovery charges (1). Operating costs for pollution control equipment may well be higher in developing countries due to lack of infrastructure and higher maintenance costs.

Impact of Costs

268. The impact of the costs of environmental control in the industry must be considered in a number of ways. In the sense of micro-economics, the impact can in some cases be major where the equipment to which the environmental control measures have to be added is of relatively low capital cost. An example might be a small foundry cupola where fume arrestment equipment could add up to 80% of the capital cost of the relatively simple production unit (3). Similarly for a relatively

(1) "Steel and the Environment. A cost of Impact Analysis" report by A.D. Little, Inc. to the Anerican Iron & Steel Institute, May 1978.

(2) "Analysis of Economic Effects of Environmental Regulations on the Integrated Iron and Steel Industry", Vol 1, EPA 230/3-77-015, July 1977.

(3) "Air Pollution Aspects of the Iron Foundry Industry", by A.T.Kerney & Co. Ltd., Chicago, Illinois (USA), February 1971. EPA Contract No. CTA 22-69-106, Page 1V - 44.

small steelworks the cost of, for example, primary and secondary fume cleaning on arc furnace could represent a major on-cost. On the other hand the capital and operating costs incurred at a major integrated works might be considered reasonable bearing in mind that it is a major potential source of pollution.

269. On the macro-economic scale, the overall costs of environmental control (total annual costs, including capital and operating costs) may well be considered as not excessive at the present time being below 10% of the average selling price of products (1). If considered in terms of their effects on profit then clearly the impact might be viewed as significant especially in the present context of economic recession in the industry.

270. There may also be some imbalance caused in trading advantage from country to country by difference in environmental control costs incurred. Evidence shows (1) that in OECD countries this is not yet the case but could become so in the future as national environmental control programmes proceed at different rates. It is perhaps worthwhile noting that there are also other factors involved in creating these imbalances, such as geographical siting in relation to markets, raw materials and import/export facilities (deep water harbours).

271. An even greater problem than assessing the impact of environmental control cost on the industry, is to attempt to assess the cost/benefit relationship in environmental terms. This involves an evaluation of the economic benefits, in direct and indirect terms, of different levels of environmental protection. Problems arise in quantifying damage functions and incorporating overall social costs and benefits. National priorities vary amongst different countries, particularly between developed countries, consequently the same value criteria may not be appropriate. As yet there is no experience in undertaking this type of analysis for the industry. The beneficial impact on agriculture resulting from removal of mining despoilation, reafforestation and preclusion of mining and industrial effluents from natural waters, may, however, be far easier to assess than the benefits to community health of reduction in ambient concentration of particulate manner. The present trend towards controlling fugitive emissions, for example from steelmaking, is an area where high capital and energy consumption costs are being incurred and such areas are certainly worthy of cost/benefit analysis, not only in terms of costs but also in terms of energy use. At the present moment, the best evaluation that can be made with existing data is a cost/effectiveness analysis such as that carried out by OECD.

Summary and Trends

272. There are insufficient data available on a comparative basis to carry out a proper analysis of the impact of environmental control costs on the industry. The OECD report (1) is one of the better attempts yet at this, but the data included are based, where possible, on actual costs incurred at a variety of new and old plants and are therefore

(1) "Emission Control Costs in the Iron & Steel Industry", OECD Paris 1977.

subject to site specific variations. This makes it difficult to establish overall cost/benefit relationships.

273. The trends in costs, both capital and operating, are generally rising with increased attention being given to the secondary pollution sources and to such problems as noise, mainly where there is pressure from governmental authorities to do so. It must be borne in mind that many of the current add-on type pollution control devices are expensive since they have not yet been integrated into new low-polluting technology In general, new processes are more efficient and less polluting than older processes and integrate residual pollution control. The cost of pollution control per ton of steel produced is consequently lower than similar control at an old plant with add-on type pollution control equipment.

274. Whilst more information on damage functions and valid methodologies for incorporating social costs are required to undertake overall cost-benefit analyses, where there is obvious emission of pollution and a dirty working environment, clean up should proceed without waiting for sophisticated cost-benefit studies. Not every aspect may, or necessarily should, be costed. In the longer term there should be mutual agreement as to what is acceptable, based on scientific criteria. There may then be differences in terms of the time frame when various levels of control are achievable, which will affect the costs of doing so. Some additional operating and investment costs are accepted as necessary in achieving environmental improvements, but it is important to look for the optimum cost/beneficial approach.

SECTION V - IMPACT OF NEW PROCESSES AND NEW TECHNOLOGY

275. The preceeding parts of this report indicate that the iron and steel industry in its present form can create considerable potential conflict with the environment and although it is possible to overcome much of this conflict, the technology may be complex and the costs high. 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

276. The classical blast furnace reduction/steelmaking 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 coal or in situations which favour importation of the coals.

277. 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, and 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.

278. 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 carbonisation 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. Full tests of formed coke in the blast furnace have not yet been completed and further experience must be awaited before the overall environmental significance of formed coke manufacture can be fully evaluated. Mention might also be made of the possibility of utilising coal via complete gassification and reforming to yield a reducing gas for further use, e.g. in direct reduction processes.

Direct Reduction (DR)

279. Direct (or solid state) reduction of iron ore relies on high grade iron ore which can be reduced to sponge iron (which contains the original ore impurities) for further processing and refining to remove impurities, for example in the electric arc process. At present, most processes available are largely based on gaseous reductants (usually hydrogen-carbon monoxide mixture from reforming natural gas), although certain methods are based on solid reducing agents such as coal or coke. The predicted growth of installed direct reduction capacity is substantial, from 15 million tons in 1977 to 32 million tons in 1980. 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 may be 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 of 1 million ton/year, compared with the classical route with plant production sizes ranging from 5 to 20 million tons/year.

280. Its dependence on abundant supplies of fuel for generating the reducing gases means that the DR process is attractive to those areas with low cost indigenous supplies of gas or oil at the present, and possibly of coal or other forms of solid carbon in the future. It enables low cost energy, e.g. natural gas that might otherwise be flared, to be utilised and easily transported as reduced pellets, which do not reoxidise if kept dry. It must be borne in mind, however, that natural gas is a premium and globally scarce fuel, and the priorities for its use will vary from place to place depending on the conditions. Electrical power will also be necessary for operating the associated electrical arc furnaces, but this power need not necessarily be generated by burning of fossil fuels, for example hydroelectric power may be cheaper in some areas. 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 environmental terms as a whole, e.g. including the environmental impact of its associated energy generation requirements.

Mini-Steel Works

281. The trend in the classical integrated steelmaking 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, very few such large integrated works each year would be required to meet demand. Furthermore, the capital investment required for such large units is considerable, and not every country would be able to afford this type of investment.

282. During the last decade there has been an increasing production of steel at small or mini-steelworks (0.5 million 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 steelmaking. 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.

283. Besides the economic and flexibility aspects of the mini-steelworks 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 steelmaking itself, i.e. the problems of dust and fume, particularly 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 account.

New Casting and Rolling Techniques

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

Use of Renewable Sources of Energy

285. 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 utilisation of water power respectively. Whilst use of renewable energy has certain envrionmental benefits, it is not without its environmental impacts.

(a) Charcoal

286. Charcoal is the easiest and cheapest way of using solar energy in steelmaking. 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 renewal 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

287. Where hydroelectric power can be generated at low cost on a long term basis, there would be attractions in the use of this "çlean" electrical power whenever possible in iron and steelmaking. 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

288. 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 steelworks 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.

Summary

289. 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 amortise 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.

SECTION VI - INDUSTRIAL SITING

Introduction

290. 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. 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, investment in environmental control then being made on the basis of requirements for the chosen site.

291. A forward looking approach of development without destruction, 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, minimising 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.

292. This type of approach requires close cooperation amongst 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 cooperation 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.

Mining Sites

293. As a general policy, land at mining sites should be restored to an equal or more useful a 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 effect decisions as to the viability of the whole operation. There are examples of land reclamation in Germany and the U.K. 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 as a great social benefit. There are sites, however, where due to the nature of the soil, the steep terrain and 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.

294. 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 and toxic substances present) and recreational purposes.

295. 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

296. A whole range of factors are considered in site selection for iron and steel production facilities whether the installation is an integrated works or not. Included amongst these factors are source of raw materials, market (domestic or export), transportation facilities, available communications, power supply, water supply available land and present local industrialisation pattern, social infrastructure, ancillary industries, e.g. foundries, engineering works, refractory brick works, and potential by-product markets e.g. for slag, coke oven by-products, etc. It may not necessarily be advantageous when infrastructure and social parameters are considered to locate ancillary services and downstream industries adjacent to the steel plant.

297. The environmental parameters involved in each of these factors must be taken into consideration in site choice. These parameters include meteorological conditions, existing air and water quality, present land use on the region, and noise. The large size of an integrated works must also be borne in mind when planning environmental protection measures. Consideration must also be given to local public opinion.

298. Meteorological parameters such as wind speed and direction, precipitation, temperature and relative humidity, are important factors to consider. Raw material storage yards and bulk loading facilities should be located to avoid loss of materials and minimise nuisance from wind blown dust and pollution of ground water. Temperature and relative humidity affect cooling systems and air-fuel combustion ratios. More important, they affect the working conditions. In tropical countries siting and initial building construction design are important for providing the necessary ventilation for comfortable working conditions. In colder climates workers may require adequate protection from adverse climatic conditions, particularly when working out of doors.

299. Whilst steelworks are themselves major potential polluters and amongst the larger industrial complexes, it is important to consider existing local industries and existing air and water quality. Coordination with local authorities as to air and water quality objectives for the region and their achievement is essential. If an urban industrial area is already heavily polluted, requiring vigorous clean-up action, emission and effluent controls at a new steelworks or for extension of facilities may require to be particularly stringent to avoid further environmental degradation. At other sites where present environmental quality, or one aspect of it, is satisfactory, less stringent control may be adequate to maintain acceptable conditions. It is also important in relation to existing agricultural and industrial activities. For example, under certain circumstances emissions from even a well controlled steelworks may make an existing sensitive activity less viable. Two examples might be considered, one where fine dust emissions would require a neighbouring factory to install complete air conditioning and cleaning, another where fluorides might affect bulb growing in the area. Other types of light industries and agricultural activities might in no way be affected by the presence of the steelworks. Noise and effects on water quality might be other areas where steelworks may interact unfavourable with existing or planned industrial and socio-economic activities.

300. 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 organisational aspects of the process itself, environmental and resource conservation aspects should be taken into consideration.

301. In the planning of a new steelworks with noise in mind, it is important to establish and maintain sufficient distance between the works and residential areas, and recommendations for such distances for various kinds of plant can be found in the literature (1). In older steelworks, residential areas have tended to be close to the works because employees prefer to live close to their work place. However, the increasing size of iron and steelworks units has led to higher noise levels which are no longer tolerated in such closely situated residential areas because the legally stipulated noise limits for the residential areas are frequently unattainable. In many traditional steel producing areas the solution regarding existing plant requires a degree of compromise. Moving existing large integrated iron and steel plants to areas far removed from residential zones is not practicable in view of the vast expense of such an operation. It is equally difficult to create buffer zones between existing works and residential areas except by means of firm long-term planning commitment by the local authorities.

302. For new sites a green belt and buffer zone should also be created around the site to ameliorate visual amenity and avoid construction of houses or other industries too close to the steelworks. Where possible, sufficient space should also be available for subsequent expansion as well as environmentally sound on-site disposal of unusable wastes.

303. Prevailing meterological conditions and topography will influence the decision on location of raw material stock yards and heights of chimneys, as well as installations likely to be an increased pollution or accident risk. Office buildings should be located at a safe distance from hazardous operations and be insulated from noisy equipment such as blowers, compressors, fans, oxygen producing plants, etc. Care should be taken in locating flare stacks, exhaust blower systems, especially where explosive and toxic gases may be vented.

304. Use of raw materials, especially energy and water, may be made more effective by close location of operations and proper design of the energy system and water cleaning/cooling system. Sufficient space should be left, however, for subsequent addition of further pollution abatement equipment, should it be required later. This is particularly applicable in the case of new works where available environmental abatement technology does not satisfactorily deal with the environmental problem and it is foreseen that additional improved equipment will have to be installed later.

305. Finally, consideration should be given to the necessary ancillary and other facilities and their environmental impact. These include

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(1) Land Nordrhein-Westfalen, "Abstande Zwischen Industrie-bzw. Gewerbegieten und Wohngebieten im Rahmen der Bauleitplanung", Rd. Erl. D MAGS, III BI - 8804-v 25.7.1974.

transportation facilities, which are required not only for the operation of the plant, but also its construction; power requirements, which are about 350 to 400 Kwh per ton of steel; 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 of housing, transportation system, shopping centres, social services 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 infractructure and facilities, but these aspects should be foreseen by the responsible authorities.

SECTION VII - ENVIRONMENTAL MANAGEMENT

306. The combined action of governmental authorities and industry through effective environmental management is required to ensure environmentally sound and appropriate development in each country with regards to the iron and steel industry. The main objectives of environmental management are to :

(i) protect the health and welfare of the general population ;

(ii) protect the health and safety of those at work ;

(iii) avoid unnecessary degredation of the natural environment ;

(iv) reduce nuisance and loss of amenity.

307. There are three different types of policies, alluded to throughout this report, implementation of which is the function of sound environmental management. Corrective policies are aimed at direct clean up of pollution (e.g. land restoration), control of effluents, emissions and noise by add-on type of equipment (e.g. dust arrestment equipment, scrubbers, water treatment plants, silencers) and mitigating the potential effects of pollution by protective measures (e.g. accoustic and heat screens, protective clothing for workers). Preventive policies are directed towards equipment, process and plant design so as to minimise the formation of pollutants and noise (e.g. low waste technologies, water recirculation, quiet machinery, technologies intrinsically less polluting such as formed coke and possibly direct reduction, enclosed systems such as the modern blast furnace). Resource conserving policies aim at wise management of resources, including raw materials, water and energy and involve recycling of residues and scrap.

308. The foregoing sections have shown that these three different types of approaches towards environmental protection are not independent. In the iron and steel industry, either for technical or economic reasons, there are no processes, however well designed, which do not give rise to either some emissions, effluents or noise; so that new technology usually also requires add-on pollution control equipment such as scrubbers and waste water treatment. There is an advantage, however, of designing the pollution control equipment with the plant. Whilst many resource conserving measures may support environmental protection, they have their own environmental impacts e.g. residue and scrap recycling save energy but may give rise to toxic substances which must themselves be controlled. Again some environmental protection measures are orthogonal to resource conservation, particularly with regards to energy (1). Consequently, there must be no artificial separation of different types of measures in sound environmental management, which attempts to implement the most cost-effective and overall cost-beneficial combination of approaches in support of the environmental protection objectives listed above. Furthermore, an inbuilt flexibile approach may be essential if the most advantageous environmental protection is to be achieved in any given local situation.

309. Industry and governmental authorities each have their several responsibilities which should be mutually consistent, in achieving sound environmental management. Industry's responsibilities are mainly concerned with the plant operated and the workers employed. Governmental responsibilities include both the local, regional and national conditions, as well as certain international aspects. These responsibilities must be married in any given situation, and seen within the time frame of both the industrial installation investment itself and the social goals for the community. Both industry and government have a responsibility for making sure that personnel at all levels in the iron and steel industry are environmentally aware and act in the best interests of the environment.

(a) Governments

310. The Governmental authorities have the responsibility of establishing overall environmental protection policies which take into consideration the various influencing factors. These include : the overall environmental objectives, which may vary from region to region due to different physical and socio-economic conditions, but should be based on available scientific and technical criteria ; the rate at which progress in achieving objectives is desired in the light of other national and local priorities ; policies in relation to management of overall resources such as raw materials, energy, manpower, economic resources

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(1) For an interesting example where energy generation to run pollution control equipment gave rise to as much pollution as removed by the equipment see "Zero Visible Emission, Energy Requirements, Economics, Environmental Impact", by John E. Barker, page 65, and proceedings of Conference "Engineering Aspects of Pollution Control in the Metals Industries, Book No. 172, the Metals Society, London 1975, p. 205.

and including cost-benefit evaluation; the closely related aspect of the need to conserve natural resources; the effects on the viability of the industry; the socio-economic costs and benefits; and various international considerations. The international considerations include: need to protect the global environment from long range transport of pollutants by air or water; desirability of common approaches and harmonisation of policies; possible trade effects of different environmental control standards; promotion of internationally concerted approach to problems; exchange of experience on criteria and making available environmental protection experience to developing countries. In relation to environmental management, government plays a key role in orchestrating the interaction between industry and the community, and has the responsibility of monitoring the effectiveness of its action.

311. In establishing overall environmental objectives authorities have certain information of the effects of pollutants in the environment. Complete dose-effects relationships are unfortunately not available for all substances arising from iron and steel industry operations. Important unknowns remain in the areas of both occupational health and health effects in the community, particularly in relation to fine particulates and certain hydrocarbons e.g. benzene and polycyclic aromatic components. Information as to effects on agriculture, flora and fauna etc., of the industry operations are also incomplete. Many authorities have already made their own evaluations of available information and established criteria on which regulations controlling the industrial activities are based. Some internationally evaluated criteria are provided by WHO and ILO to help guide national authorities e.g. in relation to occupational health exposure and effects of ambient concentrations of substances such as nitrogen oxides, sulphur oxides, particulate matter, lead. WHO has recommendations as to quality of drinking water and the Workd Bank also provides guidelines in relation to specific types of industrial activities. Authorities in each country have the responsibility to establish and implement legislation to meet the objectives of environmental management outlined in paragraph 306 above.

312. There are various instruments available to national and local government bodies through which they can influence environmental management in the industry. Firstly, there are legislative regulations and these are used in one form or another in most countries. Such regulations are normally primarily aimed at controlling environmental pollution and siting of new plants. The approaches to legislative control differ in various countries and perhaps the most significant differences are whether fixed standards are set or whether the standards are designed to be varied according to local circumstances. Fixed standards have a degree of simplicity in that all works must meet the same standards wherever they are situated. On the other hand fixed standards can lead to unnecessary waste of resources since they do not make allowance for variations in the natural assimilative capacity of the local environment. There is much in favour of variable standards such that a works placed in a particularly sensitive environmental situation would be expected to meet more stringent requirements than elsewhere. The arguments against such are that it may cause distortions in the trading positions of different companies who have different standards to meet. However, there are also many other factors which affect

industry's costs, such as proximity to markets, raw materials, etc. Recent studies on this subject by the OECD would indicate that different standards at present do not give rise to significant effects on trade.

313. There are various approaches to defining emissions, effluent and noise standards. These are generally defined in terms of maximum concentration of emission or effluent or total quantity emitted over a given time period. Authorities may also give guidance in terms of standards of technological performance, which require certain specifications to be met. Industry tends to prefer the flexibility to design its own equipment and processes and not be required to implement prescribed abatement technology.

314. Governments also have available to them economic instruments and these become of particular significance in terms of resource conservation. A classic example is to control water consumption by adopting appropriate charging schemes based on quantity and use or discharge levels depending on type amount and concentration of discharge. Similarly, energy conservation can be regulated in this way. Other economic instruments such as subsidising the installation of environmental control equipment are also used. This approach has now become less acceptable since the formulation of the "polluter pays principle". Although difficult to introduce, economic instruments are particularly useful in controlling the environmental impact of industry because industry is very responsive to economic pressures and indeed generally monitors its whole business in financial terms.

315. The rate at which environmental protection objectives are achieved and the priority amongst different objectives in relation to a given industry may also be strongly influenced by governmental action. It is important for authorities to plan ahead and give a lead to industry in setting priorities. In some cases, e.g. clean up of old plant, it may be appropriate to negotiate with industry a timetable for achieving specific objectives.

(b) Industry

316. In regard to established iron and steel activities sound environmental management by industry requires the installation of control equipment and the adoption of techniques at existing plant so as to reduce the environmental impact of these activities. To be successful, this activity must be properly managed, just like a production activity, so that those working in the industry are aware of their environmental responsibilities, the proper maintenance is carried out and process and equipment are correctly operated, etc.

317. For new works, environmental management extends right back to the proper evaluation of potential environmental impact before the plant is built, the full integration of environmental requirements into the planning, building, start and up and continuing operation of the plant, the building-in of low waste and low pollution technology, the design of energy and water saving measures and similar factors. Although the environment is only one parameter amongst many to be taken into account in the siting of a new steelworks and other related activities,

4323

it is a very important one since the works must co-exist satisfactorily with its surrounding environment for at least several decades.

318. A number of factors motivate industry to establish and implement environmental protection policies. Legislative requirements; a sense of responsibility; social pressure, including those of employees, and a concern for the company image are all motivating factors. Legislation is usually the most important factor and it is essential for industry in being able to plan its investment to have clear legislative requirements, phased within an achievable time frame. It is in the interests of industry to reduce uncertainty in relation to planning investments for environmental protection. One means of doing this is to plan ahead of the legislative procedure and foresee coming needs. Another is to work cooperatively with authorities in providing data to enable requirements for pollution control to be established on as sound a scientific basis as possible, given the inevitable uncertainties. Where appropriate, it is also in the interest of industry to cooperate with authorities in effective implementation of legislation.

319. There is need for an enlightened company policy which makes environmental protection an essential requirement, equal in status with production/profit requirements. A number of instruments are available to industry in achieving environmental objectives. By integrating environmental affairs fully into the overall management philosophy, all employees will become aware of environmental responsibilities through the normal management control system. An appropriate well designed training or education scheme on environmental matters, directed at all levels within the company, according to their several responsibilities, is essential. The financial accounting systems can be designed to be responsive to and encourage rational use of resources. These possible approaches on the part of industry may require parallel action by governments, e.g. in the field of taxation and financial accounting, to make them more effective.

(c) International Institutions and Workers Organisations

320. Various international institutions can play a valuable role in providing a forum for international examination of relevant aspects. For example, scientific and technical data may be examined and evaluated and internationally accepted criteria established. Comparability of data can also be established as well as an international basis for evaluation where appropriate international conventions may be agreed.

321. Workers' organisations have a special responsibility also to participate in the environmental evaluation process as well as encourage their members to support environmental protection measures both for the internal working environment and the environmental training of workers either directly or through cooperation with governmental authorities or industrial management.

Monitoring

322. An important aspect in environmental management is that adequate monitoring of the achievements in environmental control is carried out. Monitoring is necessary to ensure that environmental quality objectives

both within and outside the plant are being met. Monitoring of emissions and effluents is vital, not only to ensure compliance with regulations but also to provide management with information for control of the process and/or to ensure that environmental control facilities are functioning correctly. These issues are discussed in section I. Both governments and industry have a role to play in providing adequate monitoring. Close cooperation may avoid waste of resources and a more rapid identification of possible problems needing resolution. Detection of emergency situations to enable implementation of pre-planned action is also an importance aspect.

SECTION VIII - CONCLUSIONS AND SUMMARY OF ISSUES

Environmental Objectives

323. It has been demonstrated that if adequate protection measures are not implemented, the iron and steel industry has the potential for creating a significant adverse environmental impact. The overall long term objective is to minimise this impact to the lowest practicable level, or in other words to ensure that iron and steelworks are environmentally acceptable.

324. It is necessary to identify a base-line "objective" concerning environmental quality degradation beyond which is not acceptable. This base-line "objective" must be the avoidance of damage to health of human life: this should be a basic requirement which is acknowledged by governments and the industry alike. There is considerable debate as to the appropriateness and medical evidence for some of the criteria at present used to assess health risks, but the whole subject of definition of criteria in this area is one of continuing evaluation where other U.N. bodies such as WHO and ILO are also actively involved. Until definitive criteria can be arrived at, the only option for governments is to use the best evidence currently available in setting their environmental protection standards, with the incorporation of appropriate risk factors.

325. Thus, whilst there may be a degree of flexibility as to the rate at which progress is made towards the objective of an environmentally acceptable iron and steel industry, there can be no flexibility in achieving the base-line requirement of preventing a hazard to health (i.e. induced illness or death or long term effects on human health) either within the working environment or in the external environment. Where this requirement of preventing hazards to health cannot be met, direct or indirect government intervention is necessary. The intervention may take the

form of subsidies to install pollution abatement equipment or in extreme cases closure of the works with suitable measures to ameliorate the effects of resulting unemployment. The instruments used will depend on the national situation.

326. Methods of pollution control are changing rapidly. The impetus comes from increasing awareness within industry of the need for improvement; and from general environmental concern in the various countries of the world, expressed in legislation. It is believed that at any one point in time appropriate methods for controlling emissions in the iron and steel industry should not differ for new plants, wherever constructed. Nor should there be any distinction, in principle, between the technologies which should be applied in new or old plants recognising in some cases that this may be physically difficult and alternative technologies may need to be considered for old plants. In practice pollution control technology should be applied to new plants at the time of initial planning, design and construction. The retrofit difficulties for applying pollution control technology to existing plants may require longer time schedules depending upon local economic and other relevant considerations. However, it is urged that retrofit of pollution control technology to existing plants be done as rapidly as conditions permit.

Present State of Environmental Control

327. The consultants' and IISI reports indicate that there are still some unsolved technological problems in environmental control in the iron and steel industry. These are highlighted in table XII. Overall much of the technology for corrective action is available and the problem areas remaining tend to be the high cost areas such as fugitive emission control. Fundamental major problems of process design coupled with technologically difficult corrective action are few, but mention must be made of one important area in this respect, namely coke ovens.

328. However, it is also evident from the reports of the consultants, IISI and national governments, that despite the corrective technology being available for many processes, actual environmental control performance may still be inadequate. In some cases this is due to the fact that corrective measures have not been applied, whereas in others the equipment has been installed but no longer operates in a satisfactory manner. This, in turn, reflects on poor operating and maintenance practices and/or inadequate original design.

329. On the economic side, there are problems with the high cost of retrofitting corrective measures at old plants. There is also a trend towards high cost and high energy consumption corrective action at new and existing plants, for example as more attention is paid to the control of fugitive emissions. There is however, insufficient data available on a comparative basis to carry out a full analysis of the impact of the environmental control costs on the industry. Nor has it been possible to obtain information on overall cost-benefits which integrate social aspects of environmental impacts.

330. A high level of resource conservation and recycling, particularly of water and residues within the industry has already been achieved in many plants around the world. Energy in terms of fuels produced is well utilised. More attention needs to be paid to the problems of recovering waste heat, but it is recognised that this will involve technological and even process changes. There is scope for an increased reclamation of ferrous scrap, but at the same time certain technological problems need to be overcome. Governments could help in overcoming some of the institutional and economic barriers to increased use of scrap, particularly in relation to collection and separation of domestic scrap. In view of the fluctuating market situation in scrap, governments might also take actions which would improve the cost-benefits of scrap recovery.

Structural Changes in the Industry and the Environmental Consequences

331. The present prolonged recession on a global level in the iron and steel industry and the resultant overcapacity in certain areas is occurring at the same time as many developing countries are reaching the stage where they wish to develop their own iron and steel industry and to rely on importing steel from the developed countries. Thus the export markets for some of the developed countries in steel products are declining and it is becoming economically and politically less acceptable to invest capital in new capacity for products intended for export. The net result appears to be that capital investment in the iron and steel industry will decline in certain developed nations but increase in some developing countries. It is interesting to note that in the United States at present an increasingly large proportion of new investment is for pollution abatement and replacement of old plant. Whilst investment in new production capacity in many developed countries is expected to remain relatively low for some time, investment for pollution abatement equipment to meet environmental protection requirements of old plant will continue to be considerable.

332. The consequences for environmental control are significant because the major opportunities for reducing the environmental impact of the industry lie in the building of modern works where the necessary corrective and preventive measures can be designed and installed as an integral part of the new works. The present trend is therefore leading to the situation where those who have the environmental control technology will be unable to utilise it in new developments (although some opportunities will arise in replacing old plant), whereas those countries with the major opportunities for improving environmental control in new works may well not have the technology to do so. For progress to be made in environmental control there will, therefore, have to be a transfer of technical knowledge from the developed steel industry to the developing steel industry.

TABLE XII

PROCESS	PRESENT 'STATE OF THE ART'	COMMENTS
Ore mining	Restoration techniques available	Possible high cost.
Coke Ovens	Severe problems. Some improved control technology developing. Longer term need for less polluting process or alternative production route for iron not using coke.	Occupational exposure problems. Possibility of formed coke, direct reduction
Raw materials handling and stocking, blending.	Basic dust control technology available but stock piles present problems. Treatment of effluents run-off from stock piles.	Possible high cost area.
Sintering/ pelletising	Technology available for particulate control.	Some problems with high basicity sinter and maintenance.
	SO_2 control technology available/ developing.	Possible high cost area. Solid waste problems. High cost area?.
	NO_x control technology developing. F, CO not at present controlled.	
Blast furnace	Cast house fume control technology developing.	High cost and energy consumption
	Slag utilisation possible.	Market dependent.
Direct reduction	No major technology problems apparent so far.	Process is developing.
Foundry cupola	Waste gas cleaning technology available.	Possible high relative costs.
Steelmaking	Primary fume control technology available.	Possible maintenance problems.
	Fugitive fume control technology developing.	High cost, high energy consumption.
	Possible heavy metal and fluoride problem. Some slag utilised. Some specific effluent problems.	
Casting and rolling	Effluent treatment technology available.	

Table XII (Continued)

PROCESS	PRESENT 'STATE OF THE ART'	COMMENTS
Finishing operations	Effluent treatments may be complex. Basic chemistry known but problems in implementation.	Especially acid pickling wastes, although acid recovery techniques are available.
Fuel combustion	Technology for desulphurising coke oven gas is available. Blast furnace and BOF gas is sulphur free. Combustion control techniques for minimising smoke and NO_x available. NO_x removal technology developing.	SO_2 emissions can be reduced by selecting lower S content fuel oil.
Noise	Numerous sources, technology of control at source not complete. Technology for reducing effects of noise generally available.	Possible high cost area.
Water usage	Technology for water recycling and re-use is available.	

333. On the question of appropriate technology for developing countries it must be borne in mind that the criteria in relation to investment in various technologies differ depending on circumstances. Development of resources may need to be undertaken to meet certain social objectives, such as employment. Foreign exchange may be severely limited for buying foreign capital intensive equipment. These factors may affect the cost-benefit calculations concerning scale and location of operation. Additionally, there may be certain types of inexpensive waste water treatment techniques applicable in warm climates e.g. bacterial oxidation, which would be less effective in colder climates. Whilst it is important to establish international co-operation in the iron and steel industry with technical exchanges on environmental control matters, it is also necessary for the less developed parts of the industry actively to adapt existing or develop new technology appropriate to local circumstances.

334. Another possible consequence is that the overall recession and the tendency towards limited capital availability, combined with the steep rise in the cost of capital equipment, may lead, in some cases, to a slow-down in the progress of implementing environmental control programmes in the industry both at existing plants and in the context of less new plant being built. If this is so, any slow-down in environmental control programmes can only be looked upon as a temporary setback in progress towards the long term objective. Even where that temporary setback is unavoidable, non-capital intensive remedial action must be sought to ameliorate the overall environmental impact.

335. Due to the high capital intensity of the iron and steel industry, the rate of fundamental technological change is anticipated to be rather slow. Direct reduction is predicted to play an increasingly significant role during the next couple of decades, but will not replace the large scale conventional production processes. Increasing use of electrical energy and possibly renewable resources of energy, such as wood charcoal, may also be anticipated. For the longer term i.e. the twenty-first century, the use of hydrogen and process heat from nuclear energy coupled with the use of low grade carbon sources may be foreseen. From an economic point of view little information is available on the cost-effectiveness of new low waste, energy saving technologies compared with that of the add-on abatement techniques.

Areas of Attention

336. The following areas are highlighted in broad terms as appropriate avenues for further investigation and attention, bearing in mind the changes that are now occurring within the industry in the short and long term.

(i) Greater attention should be paid to minimising the environmental impact from existing plant through improved management control, operation, maintenance, motivation and improvement of existing technology. This is particularly important where capital for new or replacement plant is not available for the moment and where the technology of the corrective measures is not adequate (e.g. coke ovens, fugitive emissions at BOF plants).

(ii) Every effort should be made at existing plants to conserve energy and other raw materials. This can frequently be justified on economic grounds alone. Attention is also drawn to the effect of improving efficiency in the industry on reducing the quantities of material to be converted per ton of steel and the resultant advantages in environmental terms.

(iii) Environmental impact assessment techniques should be used for major iron and steelworks developments in order to take into account all aspects of the environment at the earliest stage so that appropriate measures can be integrated into the siting and building of the development.

(iv) All new plant must be designed with the environment and resource conservation in mind. This can produce a significant lowering of the cost of corrective action (for example appropriate design of BOF plant buildings and equipment to facilitate fugitive fume collection).

(v) Research and development is necessary to develop new "low pollution" technologies to replace those where there are intractable problems (e.g. coke ovens) and to provide more economically attractive alternatives to those control measures which require high levels of capital and operating expenditures.

(vi) Much work still remains to be done to define and overcome problems in the working environment at iron and steelworks.

(vii) There remains uncertainties as to the precise levels of environmental contamination which constitute a health hazard. Criteria on the effects of specific pollutants arising from the iron and steel industry, including particulate matter, benzene, carbon monoxide, coke oven emissions, nitrogen oxides, sulphur oxides, silicon compounds, oil mist, and physical agents such as noise, vibration and heat stress, should be further examined and developed where not available. Where data on criteria are not available environmental control should in the meantime be instituted on the basis of best scientific information.

(viii) Effective management control, operation and maintenance are essential to achieving environmental protection in relation to the industry. A significant contribution may be made by industrialised countries to the less developed countries through providing training and experience.

(ix) Finally, there will be a need for proper mechanisms for the transfer of appropriate technology for environmental control and resource conservation from the developed countries to the developing countries in order to ensure that the maximum possible environmental benefit is obtained from the capital that will be invested.

ANNEX I

IRON & STEEL PROCESSES

1. The main raw materials for iron and steelmaking are iron ore, coal or wood charcoal, limestone, natural gas and a variety of other materials such as fluxes, oil, etc., and of course air and water. The main processes which transform these materials into iron and steel products are described briefly in outline below and a flow-line on steelmaking is given in figure I (1). More details of the processes are given in the background papers and in the literature (2).

a) Iron ore mining

2. Iron ore is naturally occurring and is mined from geological deposits, both at open cast sites and underground. These operations are frequently operated by the industry itself or by enterprises closely associated with the industry. The ores are treated according to type, quality and process requirements. This may include crushing, screening, benefication, and in some cases calcining and drying. High quality ore is required for direct reduction, and advanced magnetic, chemical and physical processing may be needed.

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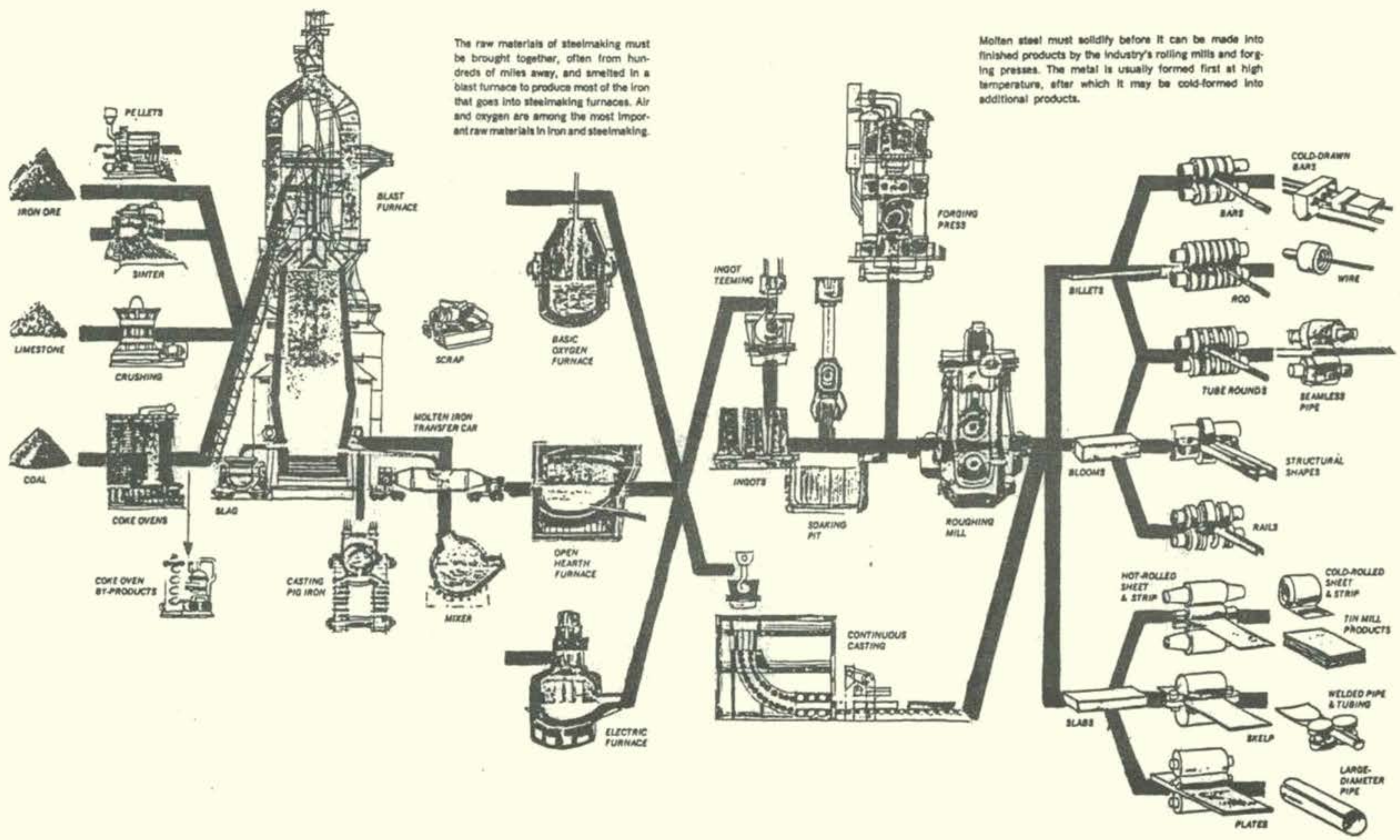
(1) From American Iron and Steel Institute.

(2) For example see the United States EPA Environmental Protection Technology Series Industrial Process Profiles for Environmental Uses, chapter 24, the Iron and Steel Industry, EPA - 600/2-77-023x, Feb. 1977.

Figure I

A FLOWLINE ON STEELMAKING



b) Fluxes

3. The main fluxing material 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.

c) Coke-making

4. The other major raw material, coal, is also mined from natural deposits, but this is normally done by the coal industry and is not considered in this study. The 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 coal (i.e. formed coke). In the latter a continuous process of coking is used with recirculation of the gas, after washing and by-product removal, for heating purposes. Dry quenching under an atmosphere of nitrogen, with recuperation of energy in the form of steam is also practised at some integrated works.

5. 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 with abundant wood resources, but no coking coal.

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.

d) Preparation of iron ore

7. Prior to charging the iron ore to the reduction process, it is generally agglomerated to give suitable size and strength of material. Sintering or pelletising are usually used in this process. In the sintering process the finely crushed iron ore is mixed with coke breeze 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 iron rich material (sinter). The sinter is broke up and screened in readiness for charging to the blast furnace, the fines being recycled within the process.

8. In pelletising 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.

9. Nodulising and briquetting are also ore preparation treatments for certain processes. In nodulising 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 roller. In hot briquetting the ore is heated to between 870° and 1040° and then briquetted in a press at loads of 45 to 55 tons.

e) Reduction of iron ore

10. 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 steelmaking 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.

11. A recent innovation is direct reduction of iron ore. Reduction of iron ore in the solid state is achieved either with gaseous (e.g. natural gas) or solid reductants (e.g. coke or coal) and various processes are in existence. In some processes 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.

12. The steelmaking processes commonly in use today which utilise molten iron as a charge material are the open hearth furnace and the basic oxygen furnace. The basic 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 65% of the western world's steel production is now by the BOF process.

13. 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 additon of oxidising agents such as ore or oxygen to oxidise the carbon and other impurities in the iron. Oxygen shortens the process time considerably.

14. 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.

15. Another commonly used steelmaking 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. 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.

16. Present day developments in bulk steelmaking 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.

f) Foundry iron

17. 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 cast direct into products after suitable treatments depending on metallurgical requirements.

g) Ferro-alloys

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

h) Hot forming of steel

19. Molten steel from the steelmaking process may be cast into ingots, continuously cast into semi-products or cast into specific products in the steel foundry business. Shaping of steel into the wide range of products is carried out in rolling mills with soaking furnaces or reheating furnaces provided, as required, to maintain appropriate temperatures in the material for rolling. Although the different products are many, 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 processes.

i) Cold rolling and finishing

20. 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 is a variety of finishing processes including galvanising, tinning, organic coating and painting. Other products than strip may also be further processed by pickling, annealing, heat treatment, etc.

RECORD OF THE WORKSHOP

Originally Issued As
UNEP/WS/IS.9 (Final)

TABLE OF CONTENTS

PAGE

RECORD OF THE WORKSHOP 127

Annex I : Report of Working Group I on Availability of Criteria 141

Annex II : Report of Working Group II on Availability of Technology 149

Annex III : Report of Working Group III on Resource Utilisation 175

Annex IV : Report of Working Group IV on Environmental Management 183

Annex V : List of Participants 189

RECORD OF THE WORKSHOP

1. A Workshop on the Environmental Aspects of the Iron and Steel Industry was held at ILO Headquarters, Geneva from 17 to 20 October, 1978. 75 experts from 27 countries (9 developing and 18 developed) and 13 international institutions took part. The Workshop was chaired by the Secretariat.

2. By way of introduction the Secretariat recalled the decisions of the UNEP Governing Council to undertake a review of the environmental problems associated with the iron and steel industry and the methodology agreed for these reviews. The purpose of the Workshop was to:

   (i) identify and define outstanding environmental problems and issues, taking note of what is known and where solutions are available;

   (ii) select those few issues or grouped problem areas which the Workshop considers feasible for subsequent examination and where there would be advantage in doing so internationally;

   (iii) plan a tentative programme to examine these selected issues or problem areas, suggesting who should do what and within what time frame.

   The Secretariat chose four main clusters of problem areas, which it was proposed would be the subject of in depth review by the Workshop, in order to better characterise and define the issues involved (see paragraph 25).

3. On the basis of the material provided by governments, industry and international institutions, the Secretariat had prepared a preliminary report (UNEP/WS/IS.2) summarising the environmental aspects of the industry and highlighting the main problems and issues. The Secretariat's report was supported by technical background documents prepared by consultants and the International Iron and Steel Institute (IISI) as follows:

(a) "The Environmental Impact of the Steel Industry in Developed Nations", by Julian SZEKELY (see UNEP/WS/IS.3);

(b) "The Environmental Impact of the Steel Industry in Developing Countries", by Hidehiro OBATA (see UNEP/WS/IS.4);

(c) "Impact on the Environment of Various New Possible Methods to Produce Iron and Steel Materials", by Jacques ASTIER (see UNEP/WS/IS.6);

(d) "Iron and Steel in Eastern Europe and Pollution Control", by Lechoslaw JARZEBSKI (see UNEP/WS/IS.7);

(e) "Environmental Control in the Iron and Steel Industry", prepared by the International Iron and Steel Institute.

The documents were presented and discussed, although not examined in detail. A draft review of the human health effects associated with the industry was also presented by WHO. Paragraphs 4 to 24 summarise the presentations and discussions. Formal statements were also presented to the Workshop during the meeting by Mr. S. MOINOV, International Labour Office (ILO), Mr. E. ALEXEYEV, Secretary, Trade Union International of Workers in the Metal Industry (WFTU) and Mr. K. CASSERINI, Assistant General Secretary, International Metal Workers Federation (IMF).

PRESENTATION AND DISCUSSION OF BACKGROUND DOCUMENTS

"The Environmental Impact of the Steel Industry in Developed Nations", by Julian SZEKELY (UNEP/WS/IS.3)

4. Professor SZEKELY presented his report highlighting two main problem areas namely the inadequate implementation of existing pollution control technology and the non availability of satisfactory technology for pollution control in certain processing applications. In the first case, although new plants were generally equipped with environmentally acceptable controls, the retro-fitting of such controls to older plants appeared to be lagging behind. In the second area, fully satisfactory technology was not available for dealing with fugitive emissions, e.g. from raw material stockpiles, coke ovens, blast furnace casthouses, nor for the treatment of certain aqueous discharges, such as coke plant waste waters.

5. The unresolved issues referred to in the report included:

(i) the need for accurate cost-benefit analysis, where lack of data on the effects of pollutants was a significant barrier to assessing levels of control required for environmental protection.

(ii) the need for improved pollution control techniques, especially in relation to fugitive emissions where present techniques are major consumers of energy. The development of new, less polluting technologies is highly desirable, especially if higher discharge standards have to be met.

4323

(iii) resource conservation, where economic factors sometimes represent a major constraint on recycling and reuse. In some instances resource conservation is in direct conflict with the desired environmental impact.

6. Three areas were suggested for international consideration:

(a) Development of a data base to establish threshold levels for pollution control, and an associated basis for developing realistic cost-benefit analysis, including the use of modern systems analysis techniques to arrive at globally optimal solutions.

(b) Organisation of technology transfer on environmental control between developed and developing countries in the iron and steel industry.

(c) Development of innovative technologies that would enable resource conservation and less adverse environmental impact to be achieved.

Discussion

7. A number of points were raised in the discussion. On the subject of discharge standards, it was considered unwise to think in terms of fixed discharge limits for all plants since local circumstances and plant configurations may, quite justifiably, warrant different standards. Whilst considerable amounts of data already existed on the effects of pollutants, it was clear from contributions from a number of delegates that there was still considerable debate on correlating emission levels to effects on either the working environment or the external environment. It was emphasised that the best available data should be used until this could be better improved upon. The view was expressed that innovation in technology was hampered by the inherently long life of a number of iron and steel production units. There was scope for more effort in applying innovation to existing technology to help overcome environmental problems.

"The Environmental Impact of the Steel Industry in Developing Countries", by Hidehiro OBATA (UNEP/WS/IS.4)

8. Mr. OBATA introduced his report drawing delegates' attention to certain corrections to the text, precise details of which were tabled at the meeting. These corrections would be incorporated in the final edited version of the report.

9. It was pointed out that great opportunities would exist in the developing countries for establishing new plants with pollution control measures built in from the beginning, and also possible new, lower pollution processes. The report covered the following areas: description of air and water pollution discharges by process with an indication of possible control methods; a discussion of pollution control techniques at existing works; preventive policies and the inclusion of pollution control provisions and energy conservation in the design stage for new plants; resource conservation policies; siting of iron and steel works and associated matters; cost-benefit relationships and the working environment.

Discussion

10. In the discussion, it was mentioned that there were some areas where data from developed and developing countries differed. This indicated not only uncertainties within the industry, but also differences between countries in process techniques and the application of environmental protection measures and their costs. The suggestion was made that UNEP might stimulate the preparation of an integrated data bank, drawing information from the background reports and other sources.

"Impact on the Environment of Various New Possible Methods to Produce Iron and Steel Materials", by Jacques ASTIER (UNEP/WS/IS.6)

11. Mr. ASTIER presented his report which explored possible future process developments and possible solutions to environmental problems arising from different routes to steel production. The report surveyed six possible scenarios:

(i) the classical route and its possible future evolution;

(ii) the direct reduction/arc furnace route, especially suited to countries rich in hydrocarbon fuels, but also requiring high grade ores;

(iii) mini-steel plants using recycled scrap;

(iv) iron and steel production using vegetable based sources of carbon, e.g. charcoal;

(v) iron and steel production based on electrical energy, including hydro-electric and nuclear power;

(vi) iron and steel production based on hydrogen.

12. In summary, the following conclusions were highlighted:

- present developments in the classical iron and steel processes will lead to environmental improvements;
- innovative technology was scientifically feasible but further work was required and its introduction may be costly as well as require long time scales;
- the trend was not towards general solutions but rather to specific regional approaches;
- in the future, steelmaking was likely to be more and more associated with other industries, especially in the energy sector.

Discussion

13. Three main points were made during the discussion of this report. Attention was called to the importance, especially with the newer technologies, to look at all aspects of environmental impact in relation to the complete system. For example, in electrical power based processes, the environmental impact of power generation must be taken into consideration, as well as that for the iron and steelmaking process itself: similarly with hydrogen or nuclear power based technologies. In charcoal based reduction processes, the environmental impact of the processes themselves, of the production of charcoal and of reafforestation

must all be evaluated.

14. While much work had already been done on the environmental impact of the classical iron and steel processes, it was noted that there is a real need to refine further developments so as to make the processes more acceptable environmentally. Data on the newer technologies are not yet available to judge whether they would be truly advantageous in environmental terms.

15. Further it was observed that there is also insufficient data to judge whether one large plant is preferable environmentally to a number of smaller plants. Whilst decisions on what technologies to adopt in the future could not be made on environmental grounds alone, environment is becoming an increasingly important factor.

"Iron and Steel in Eastern Europe and Pollution Control", by Lechoslaw JARZEBSKI (UNEP/WS/IS.7)

16. Mr. JARZEBSKI presented his report which centred on environmental control in central and eastern European countries. Parts I and II of the report were distributed to delegates at the meeting, Part III was made available after the meeting. The report gave a process by process assessment in environmental terms, highlighting the problems experienced in eastern Europe in coke making, sintering, iron making, steel making (open hearth, tandem furnaces, oxygen steel making), ferro-alloy production, rolling mills, forges and foundries. The basis of legislative requirements were included in the report and environmental monitoring procedures especially for new plants were reported. The working environment was also included (Part III), together with standards for health protection.

17. In conclusion it was stated that iron and steel was one of the most important industries from the point of view of environmental impact and that much could be achieved in the way of environmental protection for existing processes. Not all of the possibilities had yet been explored and further research work was still required.

Discussion

18. Two main points arose in the discussion:

- Quenching of coke with untreated coke oven effluent is now considered in many areas as environmentally unacceptable because of the air pollution problems arising. Treatment of coke oven effluents before discharge is therefore necessary. Attention was drawn to a report on coke quenching with various media, sponsored by the American Iron and Steel Institute.
- The problem of what standards are appropriate for old plants and whether these should be more tolerant than for new plants was discussed. It was stated that in eastern Europe, the regulations for old and new plants are the same but some degree of flexibility is exercised where there is an apparent lack of economically justifiable technology for old plants.

"Environmental Control in the Iron and Steel Industry", prepared by the International Iron and Steel Institute (IISI)

19. Mr. TUCKER, as Chairman of the IISI Committee on Environmental Affairs, presented this report. He prefaced his remarks by referring to the severe financial problems now being faced by the industry in market economy countries and the dilemma this produced in terms of trying to meet ever increasing demands (with associated high expenditures) for environmental improvement. However, the report itself restricted its considerations to the present state of the art in environmental control in the established iron and steel industry. Two corrections to the report were noted.*

20. The report detailed environmental problems and solutions for each process under the following headings: air pollution, water pollution, management of wastes, and the working environment. The aspects particularly highlighted were the following:

- Coke making presented the most serious environmental problems which may only be overcome by new processes. These were being developed.
- Proven technology was to a large extent available for pollution control.
- A high degree of recirculation of water was technically possible but conversion of older plants from once-through to recirculation systems may in some cases be economically impracticable.
- Mistakes had been made in environmental terms in countries with developed iron and steel industries which could be avoided in the developing iron and steel industry. Although some problems remained, much of the know-how to build and site properly an environmentally acceptable iron and steelworks was established and this know-how would be made available to developing countries by members of the IISI.

Discussion

21. The main items arising in the discussion were as follows:

(i) Vibration and heat stress were areas which had not been covered in the IISI report due to lack of time.

(ii) There was a general concensus of opinion amongst experts that retro-fitting of environmental control measures to existing plants was far more costly than installing such measures from the outset at new plants. This was an important message for any undertaking intending to build a new steelworks.

(iii) A number of figures were quoted for the proportion of capital expenditure on a new plant that could be attributed to environmental control. The variations in these figures could largely be explained by the absence of any internationally based definitions as to what should be accounted as environmental control.

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* Page 48, line 6: "ammonium chloride" should read "ammonium hydroxide"

Page 29, para. 3, line 3: the reasons for controlling NO_x in Japan ~~was due to health risks of NO_2 and not due to photochemical pollution~~ problems.

(iv) Emissions of hydrocarbons from sinter plant feed material were thought to be a problem in some areas.

(v) The use of automatic monitoring techniques still presented considerable problems in terms of high maintenance requirements and the need for skilled operators.

(vi) Evaporative cooling was an important aspect of water and energy conservation especially in new plants and experience was developing well in certain countries.

"A Draft Review of Human Health Effects Associated with the Iron and Steel Industry", submitted by the Division of Environmental Health, World Health Organisation

22. Dr. HASEGAWA of WHO introduced this report which reviewed health effects of various emissions from iron and steel industry operations. It was emphasised that the report was in a draft stage only. It was observed that there have been virtually no studies on the effects on health of the general population of emissions from iron and steel operations but some work has been done on occupational exposure. WHO is evaluating the toxicity of several substances emitted from the industry and also looked at various epidemiological studies.

23. Whilst information was only available on the health effects of general industrial and urban pollution, which was not necessarily specific to the steel industry, WHO expert groups had proposed exposure limits for various pollutants which were also emitted from iron and steel works. These were summarised in an attachment to the draft report.

24. Discussion was deferred for inclusion in the considerations of Working Group I (see annex I).

EXAMINATION OF THE SECRETARIAT'S REPORT

25. The primary task undertaken by the Workshop was a detailed examination of the Secretariat's Report (UNEP/WS/IS.2). Four main clusters of problem areas, chosen by the Secretariat, and dealing with various sections of the report were examined concurrently in four small specialist working groups as follows:

Group I on Availability of Criteria to Define in relation to the Iron and Steel Industry:

(i) health risk to the population,
(ii) safety and occupational health of workers,
(iii) impact on the environment (excluding human health).

Group II on Availability of Appropriate Technology to Control Discharge and Nuisance from Iron and Steel Industry Operations in relation to:

(i) new plants in developed and developing countries,
(ii) old plants.

Group III on Assessment of Resource Utilisation in the Industry and its Impact on the Environment:

(i) raw materials,
(ii) energy,
(iii) water,
(iv) residues,
(v) scrap metal.

Group IV on Evaluation of Environmental Management:

(i) environmental impact assessment and environmental criteria for siting:
(ii) approaches towards establishing acceptable levels of discharge;
(iii) environmental management at the plant level, including maintenance of pollution control equipment; training; employee awareness, motivation and responsibilities;
(iv) needs for monitoring and surveillance within and outside the plant.

The participants in the working groups are indicated in annex V.

26. The purpose of the working groups was to go beyond the examination of the report and to identify, characterise and define specific issues which might be the subject of recommendations and conclusions by the Workshop. Each specialist group participated in the plenary workshop discussions of the relevant sections of the report i.e. group I in the examination of sections II and VII; group II, section V; group III, sections III and V; group IV, sections II, VI and VII. All groups took part in the discussion of sections I and VIII.

(a) Section I: Environmental Assessment

27. The Workshop observed that the iron and steel industry operates under a wide variety of geographical, physical and socio-economic conditions and that the impact on the environment of various operations may differ from country to country both in nature and degree. Whilst the report was not exhaustive it was agreed that it should reflect the global situation and be as comprehensive as possible concerning environmental aspects. Furthermore, it was recognised that the understanding of environmental aspects of this industry were evolving and the present report, which reflects the current state of the art, would require up-dating from time to time as knowledge and experience improve. In this respect attention was drawn particularly to possible significant ecological changes which could result in the future with the expected increases of production activities in the tropical and sub-tropical regions of the world and with the installation of new technological processes.

28. In view of the different situations associated with different plants throughout the world and the variations in operating conditions as well as the lack of internationally comparable emission data, it was recognised that a global environmental assessment would need to reflect a broad range

of experience and provide data in relative rather than absolute terms. The approach taken in the IISI report of analysing environmental problems on a media by media basis was considered particularly effective and it was agreed that, in amending section I of the Secretariat's report in accordance with the observations of the Workshop, it should be redrafted to incorporate the material of the IISI report on air and water pollution, waste disposal and noise. It was considered that this restructuring of section I would allow a balanced incorporation of additional material on environmental problems and their technological solution, as provided by the meeting. Other consequent minor modifications to other sections of the report would be necessary.

(b) Section II: Working Environment

29. In relation to the working environment the Workshop recognised that the Secretariat's report could not be exhaustive, nor cover every aspect of occupational health and safety, particularly accident hazards. Note was taken of the extensive programmes of ILO and WHO in these fields *. The Secretariat reported on the joint thematic programming exercise in relation to the working environment being undertaken by UNEP with other relevant U.N. institutions, as well as on the activities on trade-union attitudes concerning the environment. The Workshop emphasised the need to involve management and workers' participation in agreeing and establishing the occupational health and safety measures required for each installation as well as in enhancing job satisfaction. Attention was also drawn to the role of abatement equipment designers in facilitating maintenance and good operation of equipment as well as to the appropriate selection and training of maintenance and operating staff.

30. The Workshop drew attention to the need in relation to protection of the working environment to take into consideration specific conditions in each region. Note was taken particularly of special problems which may arise in tropical areas and the possible need for a specific workshop on protection of the working environment in the iron and steel industry in these areas. It was stated that UNEP would examine this matter with ILO and WHO.

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* For example within the field of occupational health WHO's programme includes (i) the WHO programme of internationally health based permissible levels of exposure of toxic substances in the work environment; (ii) early detections of health impairment due to occupational exposures; (iii) health effects of combined occupational exposures; (iv) occupational (industrial) hygiene (recognition, evaluation and control of occupational hazards).

(c) Section III: Resource Conservation and Recycling

31. Whilst it was recognised that major efforts were being made to use resources efficiently in the iron and steel industry, the Workshop noted that there were certain technical as well as economic limitations. Attention was drawn to the need for more R & D in this field, since there is significant potential for improved use of resources and increased recycling. Note was taken of the difficulty of comparing the costs of recycling under different circumstances.

32. The Workshop discussed some of the technical problems involved in heat recovery, water recirculation and residue recycling and it was agreed to make certain additions to the section, particularly the incorporation of the technical aspects of waste and by-product recycling from the IISI report.

(d) Section IV: Economic Aspects

33. It was observed that the information in the industry on pollution control costs was poor and that a lack of common basis for accounting made international comparison of the economic aspects impossible. There is a need for international agreement on the definition of economic parameters in relation to pollution control costs. Note was taken of the work in this field undertaken by OECD and of the cost data developed by the European Economic Communities. Data is particularly lacking in relation to the direct reduction and other non blast furnace routes to steel making.

34. A number of delegates gave environmental protection cost data for specific conditions and legislative requirements. It was observed that certain costs are site specific and depend of the local conditions. Note was taken that environmental protection costs in developing countries may be higher than in the industrialised countries due to lack of infrastructure and higher maintenance costs. It was universally agreed that the cost of retrofitting pollution control equipment is higher than incorporating it in the initial construction, but that the difference in cost may be minimised if the possibility of retrofitting is incorporated into the original plant design. Finally, the Workshop agreed that it was important to consider within the economic aspects not only the direct pollution control costs but also the social costs and benefits and the loss of amenity of the industrial operation.

(e) Section V: New Processes and New Technology

35. There was a valuable exchange of experience amongst experts concerning new processes and technologies in steel making, including the use of fuels such as charcoal and low grade coals. It was decided to add coal gasification to this section. It was noted that concerning environmental impact assessment, it was important to consider the total route to steel making employed, including energy generation and the necessary infrastructure. Whilst the mini steel plant and the direct reduction process may give rise to less discharge per unit of output than the classical steel making approach, these former routes are usually smaller scale operations and permit a dispersion of steel making activities.

36. As regards future technologies the Workshop was not optimistic concerning the rapid development, e.g. over the next two decades, of fundamentally innovative technologies such as the use of hydrogen and process heat from nuclear energy. However, it was observed that as far as the environment as a whole is concerned the present developments in iron and steel technology would be beneficial.

(f) Section VI: Industrial Siting

37. Whilst the environmental aspects are not necessarily the determining factors in siting, assessment of the environmental impact is regarded as an important element in the planning of all new iron and steel industry developments and of major installation modifications. Experts reported on the requirements in their countries in this field. The Secretariat reported on the UNEP activity to provide guidelines on industrial environmental impact assessment and criteria on siting. The Workshop noted that it was essential to provide the necessary social infrastructure in relation to all new green field site developments.

(g) Section VII: Environmental Management

38. Discussion of section VII concentrated mainly on the question of monitoring requirements, and in particular three aspects. First, environmental mapping of the background conditions was considered important in relation to all new iron and steel developments, particularly on green field sites. It was noted that observations should be made over at least a complete period of seasonal change. Second, regular monitoring of essential parameters was required to assess the environmental impact of a plant in operation. Third, operational control of cleaning devises and some production phases as well as monitoring of emissions were also required to assess the effectiveness and the implementation of environmental protection measures.

39. Finally, the question of emergency measures to be taken under unfavourable meterological conditions and associated alert systems were discussed. Experts shared experience on the various systems in operation in their own countries as they apply to the iron and steel industry. Note was taken of the importance of developing contingency plans with the industry.

(h) Annexes

40. Some minor amendments were suggested to annexes I and II and it was decided to omit annex III in view of the poor information available on legislation. It was noted that in redrafting section I along the lines agreed in paragraph 28 above, annex II might become redundant, a matter left to the Secretariat in editing the report.

WORKING GROUPS

41. The rapporteurs of each of the four small specialist working groups (see paragraph 25) presented their reports. These groups had been convened to prepare, for the consideration by the whole Workshop, conclusions as to the environmental issues related to specific clusters

of problem areas. The group reports were examined by the meeting. These reports, amended by the rapporteurs according to the comments and discussion in the Workshop, are appended (see annex I to IV).

EXAMINATION OF SECTION VIII OF THE SECRETARIAT'S REPORT

42. The final section of the Secretariat's Report "Conclusions and Summary of Issues" was examined in the light of the reports made by the specialist working groups and the Workshop's observations on these reports (see paragraph 41). A number of amendments were agreed for incorporation in the final version of the Report.

CONCLUSIONS OF THE WORKSHOP

43. The main conclusions of the Workshop were as follows:

(i) All new iron and steel developments, wherever built, should be fully equipped from the outset with modern facilities to protect the environment. Experience in the developed steel industry showed quite clearly that retrofitting of environmental control measures at a later date is more costly than incorporating them initially.

(ii) Any major new iron and steel developments should be subject to some form of environmental impact assessment, the scope and detail of which may vary according to the circumstances of each case. Further evaluation of the factors to be considered would be appropriate, but in principle the assessments should be broad based covering both physical and socio-economic aspects.

(iii) Much of the technology for controlling pollution and conserving resources is available but in some cases it is costly and energy intensive: there are some areas, for example coke ovens, where fundamental problems of environmental control still exist. The Workshop identified areas where further study is required (see annex II).

(iv) The information on environmental control technology in the developed steel industry was available to those parts of the industry currently developing.

(v) In view of the incomplete state of current knowledge, continuing environmental assessment of the newer as well as the future iron and steel processes would be required.

(vi) Environmental pollutants arising from iron and steel operations where it is necessary to further study and develop effects criteria have been identified (see annex I).

(vii) A basis for international comparability of information on emission levels, residual emissions and costs needs to be provided.

4323

(viii) The climatic and regional factors in relation to the working environment have been identified as an area for possible joint action by ILO, WHO and UNEP.

(ix) The importance of co-operation between all employees at iron and steel works in protection of the environment was emphasised by the Workshop. Representatives of the iron and steel industry's workers' federations indicated their full support for active participation in this area. Proper environmental education and training for all the industry's employees was highlighted as a vital element in environmental management.

(x) Environmental monitoring was identified as an essential aid to achieving and maintaining satisfactory performance in environmental control and one in which further development was necessary.

TIMETABLE FOR COMPLETION OF IRON AND STEEL INDUSTRY REVIEW AND FOLLOW UP OF THE WORKSHOP

44. It was agreed that the Secretariat's Report provided an adequate basis for a UNEP overview on the environmental aspects of the iron and steel industry and that a final draft should be prepared incorporating the modifications and amendments accepted by the Workshop. This draft was distributed to participants for further comment and approval by correspondence and the final revision (see UNEP/WS/IS.2 (Final)) included in these Proceedings. Likewise, the provisional record of the Workshop was distributed to all participants for approval and this final version incorporates various comments received.

45. The Secretariat stated that a Proceedings of the Workshop would be published which included the final version of the Report, the record of the Workshop and the background documents, edited to incorporate comments made during the discussion of these documents at the Workshop. It was further stated that this material would be used by the Secretariat to prepare guidelines and an overview booklet, particularly for the use of countries new to the industry.

46. Concerning follow-up to the Workshop, the Secretariat will convene at appropriate time an Environmental Consultative Committee to oversee and give guidance and help in the task of examining the outstanding problems and issues identified at the Workshop, so that an overall report and recommendations may be brought to the attention of the UNEP Governing Council by 1982. Governments and industry from countries with major interests in the iron and steel sector as well as relevant international institutions would be invited to designate members to the Consultative Committee. The first task of the Committee would be to assign priorities for follow-up action.

ANNEX I

REPORT OF WORKING GROUP I
ON AVAILABILITY OF CRITERIA

Terms of Reference

1. The terms of reference for Group I were "To examine the availability of criteria to define in relation to the iron and steel industry (i) health risk to the population; (ii) safety and occupational health of workers; (iii) impact on the environment (excluding human health); "The Group was also asked to state what criteria are currently available: to identify those areas where further criteria are needed and to comment on criteria and standards.

Membership of the Group

2. The Group was effectively a tri-partite group including members with a background of government, industry, including management and labour, and certain international institutions. It was not, therefore, a group which could, as a whole, in any way attempt to evaluate available criteria, a task which was not undertaken.

General

3. There was agreement that problems did exist in certain areas of activity arising from the operation of iron and steel plants. In addition there are other areas with potential problems, the extent of which has not been defined. Similarly, it was recognised that as processes changed there may be additional problems not yet identified. Attention was drawn to certain aspects related to the work of the Group which are of general nature.

(a) Criteria

4. It is apparent in any discussion on this subject that there is often a misunderstanding about the use of the term criteria, and it was, therefore, agreed at an early stage that for the purposes of the Group report, the

following definition of criteria would be taken: "The best scientific information available in a collated form in the light of the knowledge current at that time when the criteria was documented". It was to be clearly distinguished from standards.

(b) Standards

5. Another area where confusion sometimes exists is the relationship between criteria and standards. It is important to recognise that standards are developed by national, and perhaps international, authorities which take account of social and economic factors which are not subjects to be dealt with by criteria.

6. Much confusion is often caused by the failure to recognise this relationship. The situation was made worse by the multiplicity of standards which exist and which, unless clearly understood, can result in quite different levels being used. Such standards include MAC values (maximum acceptable concentrations); TLVs (threshold limit values); TWAs (time weighted averages); STLs (short term exposure limits); CVs (ceiling values), etc. Obviously these differences of conception and values create difficulties of interpretation and comparison. Work to rationalise the multiplicity of these conceptual standards should be encouraged.

7. Other problems in the standard making area of activity include the need to state clearly in criteria or standard making documentation the type of equipment to be used for measurement and sampling, the methods of sampling and of sample evaluation. Different types of equipment may give significantly different readings: different methods of sampling, e.g. the use of personal or static sampling, may give rise to significant variations in results; different methods of analysing samples may also produce significantly different results. These points are particularly relevant to the use of information from data banks.

(c) Epidemiology

8. A few general comments on the use of epidemiology were also felt to be desirable. This tool is increasingly being used in attempts to define problems and particularly the nature and size of the problem. However, it should also be recognised that it is a tool which needs to be used with care if it is not to become misleading. Attention was drawn to the importance of the methodology being clearly defined if an epidemiological study was to be viable. Problems were caused by epidemiological studies where the methodology was not clearly set out and where the limitations which had to be accepted in order to carry out the study were not clearly understood and stated in the report. This led to problems in interpretation of results and could be made worse by the results of a study being used as the basis of a further study.

9. A second point to which attention was drawn is that epidemiological studies, e.g. of a mortality type, normally related to conditions which existed in a work situation many years previously. For example, studies of coke oven mortality related to the conditions which were to be found on coke oven batteries possibly some 15, 20 or 25 years previously. With the changes in techniques and methods of operation of a coke oven plant this did not necessarily truly reflect an existing situation.

(d) Other General Comments

10. Reference was also made to a number of additional general points. Firstly, many of the problems which exist in the steel industry are to be found in other industries and indeed, in many cases, the primary problem is to be found in an industry other than steel. For example, in the whole problem of general environmental pollution, the contribution of the steel industry to that pollution is only one aspect and criteria documents on general environmental pollution are unlikely except in specific cases to be directly related to the iron and steel industry. Whilst there are few epidemiological studies regarding health effects of the general public in relation to the iron and steel industry, a considerable number of studies exist which relate to common urban and industrial air pollutants such as SO_2, suspended particulate matter and nitrogen dioxide. Since these pollutants are also generated by the iron and steel industry, for the authorities who wish to establish standards related to the industry further information would be valuable on the following:

(i) direct correlation of health effects of the general population with emissions from the iron and steel industry;

(ii) possible difference in composition of emissions from the iron and steel industry and those of urban air pollution, and the health implications;

(iii) more precise estimates of the contribution of the iron and steel industry to urban and industrial air pollution loads.

11. Similarly, there are problems which, whilst they are important within the steel industry for a limited number of people who may be exposed, are a minute problem by comparison with that of industry in general. A good example of this would be asbestos. This is particularly relevant when criteria are being established, when it should be appreciated that the vast majority of criteria and the subsequent setting of standards will be based upon information from other industries or processes and not specifically in relation to iron and steel activities.

12. Secondly, reference should be made to the new technologies. In these areas pollutants in many cases may not be known and it should be a principle that work on the identification of potentially hazardous substances should go forward at the same time as the development of the new technology itself.

13. Thirdly, in reference to the use of data banks, both for the establishment of criteria and standards, it is suggested that data on substances to be found in or arising from iron and steel industry activities should be kept on existing data bank arrangements rather than build up as a separate exercise. There is no benefit to be gained from duplicating such information. Such sources of information already exist within international organisations or are being developed, for example the IRPTC (International Registry of Potentially Toxic Substances). Much work is also being done in the data collection and evaluation field by WHO and follow up work on practical problems is being developed by the ILO.

14. Fourthly, a point made at the Workshop on a number of occasions was reiterated, namely the general lack of criteria in relation to most studies which takes into consideration possible differences arising from climatic conditions, ethnic origins, etc. It is felt that the inclusion of criteria in this field would be particularly relevant in the developing countries.

Major Activity Areas

15. In identifying major areas in relation to criteria considerable use was made of the World Health Organisation draft paper, circulated to the Workshop, entitled "Draft Review on Human Health Effects Associated with the Iron and Steel Industry". However, the point which was made by the WHO delegate in presenting the document to the Workshop (see Report paragraph 22), that it is a draft was reiterated. In the opinion of the Group it contains a number of statements which WHO may wish to amend and in some cases perhaps expand. It would, therefore, be misleading in its present form if used as a reference.

16. The major activity areas arising from the iron and steel industry need to be related to the following substances, which are listed in alphabetical order rather than in any attempt to assign priority:

(i) benzene
(ii) carbon monoxide
(iii) coke oven emissions
(iv) nitrogen oxides
(v) oil mist
(vi) particulate matter
(vii) silicon compounds
(viii) sulphur oxides

The following physical agents are also of importance:

(i) noise
(ii) vibration
(iii) heat stress

In addition the thermal pollution of water is also relevant.

17. 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, naphthalene, pitch fumes and smoke, chromium, lead, nickel, cyanides, fluorides, phenols, PCBs are recognised 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.

(a) Benzene

18. Benzene may be found in the steel industry in the coke oven and by-products area. There already exists considerable criteria documentation on this subject and work is ongoing. Benzene has been linked with

aplastic anaemia and an association of leukemia with benzene exposure has been documented. (NIOSH and EPA criteria).

(b) Carbon Monoxide

19. 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. Again the criteria documentation is well established and its acute effects are well known. Work on its longer term effects are not so well documented. (NIOSH, EPA, WHO, many governments have developed criteria).

(c) Coke Oven Emissions

20. 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. (Criteria developed by NIOSH and being developed by EPA).

(d) Nitrogen Oxides

21. 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.

22. Toxicological information on nitrogen oxides is well documented and some criteria documents on the toxicity of nitrogen oxides are available.

23. 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 the nitrogen oxides atmospheric pollution.

(e) Oil Mist

24. 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 and which may give rise to some skin infection. The possible health effects of oil mist are not well documented. However, the tentative list of future criteria documents from NIOSH for 1978 mentions oil mist.

(f) Particulate Matter

25. 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.

(g) Silicon Compounds

26. 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 if silicosis. Other silicon compounds can be considered as general particulate matter.

27. 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

28. 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.

29. 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.

(i) Noise

30. The effects on the ear of continuous noise (20 to 2000 Hz) are well known and measurement as well as judgement methods are sufficiently standardised. Standardised 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, including WHO.

(j) Vibration

31. In some parts of the production processes of the iron and steel industry, for example where compressed air operated tools are used, 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 VDI and NIOSH.

(k) Heat Stress

32. 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 NIOSH, US Army, DIN and Belgium.

(l) Thermal Pollution

33. 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.

34. The Group suggests that the future work of WHO, ILO and UNEP on the establishment of criteria should take account of the general comments referred to in this report and in particular should concentrate its attention on the establishment of criteria documentation for the areas highlighted in this respect. As discussed earlier, criteria developed in temperate countries are not necessarily valid in other parts of the world.

ANNEX II

REPORT OF WORKING GROUP II
ON AVAILABILITY OF TECHNOLOGY

Terms of Reference

1. The terms of reference of Group II were "To examine the availability of appropriate technology to control emissions and nuisance from iron and steel operations in relation to (i) new plants in developed and developing countries, (ii) old plants, and to identify remaining technological problems".

2. Methods of pollution control are changing rapidly. The impetus comes from increasing awareness within industry of the need for improvement: and from general environmental concern in the various countries of the world, expressed in legislation. It is believed that at any one point in time appropriate methods for controlling emissions in the iron and steel industry should not differ for new plants, wherever constructed. Nor should there be any distinction, in principle, between the technologies which should be applied in new or old plants recognising in some cases that this may be physically difficult and alternative technologies may need to be considered for old plants. In practice pollution control technology should be applied to new plants at the time of initial planning, design and construction. The retrofit difficulties for applying pollution control technology to existing plants may require longer time schedules depending upon local economic and other relevant considerations. However, it is urged that retrofit of pollution control technology to existing plants be done as rapidly as conditions permit.

3. Current methods for reducing environmental damage are tabulated in an attachment; the consultants' reports should be used for more detailed information.

4. In the table major problem areas are signalled. These involve:

(i) Fugitive emissions at points where dusty solids are handled, or where particulate laden gases are evolved. Approaches to solving these problems have been to dampen the source solids; e.g. at ship loading points, to seek better ways of containing the gas flows e.g. enclosing solids transfer points; to police more strictly the maintenance of seals which must be broken intermittently e.g. coke oven doors; or to aspirate large volumes of air to capture the dusts as they are emitted e.g. during charging of oxygen furnaces. Large amounts of energy are required to collect, with present hood and charging systems, small quantities of particulates. The solids are recovered as fine dusts or slurries and can be difficult to handle. Specific problems are:

(a) The character and human hazards (e.g. carcinogens versus inert material) of fugitive emissions differ from process to process and consequently the technology appropriate to their treatment will also differ.

(b) Coke plants - charging, pushing, quenching, leaking doors, lids, etc., to control toxic discharge.

(c) Blast furnace emissions including cast houses and furnace tops especially as retrofit to smaller existing furnaces.

(d) Charging and tapping of steelmaking furnaces.

(ii) The presence, in large continuous gas streams (of mass several times that of the solids treated) from stacks, of CO and small proportions of hydrocarbons, H_2S, SO_x, NO_x, F^-, Cl^- etc. Energetically realistic solutions to the removal of these pollutants are lacking. Processes which contact the gas streams with reactive solids expend energy and produce by-products for which there is generally little demand or which themselves constitute a solids disposal problem. The sinter plant is a prime problem and less costly treatment methods are needed. To reduce the load on the plant, consideration should be given to developing improved methods for de-oiling recycled charge material such as mill scale.

(iii) Enormous volumes (of the order of 100 times the weight of solids processed) of water are used. Thermal discharge to the environment has to be considered in relation to water used for indirect cooling purposes, waters used for direct cooling or for the cleaning of gas streams are contaminated by low or high levels of cyanides, sulphates, sulphides, fluorides and particulates. Certain water streams are contaminated by oils or with coke oven residues.

Water recirculation systems help to minimise water usage. Separation of the different water flows, biological and physico-chemical treatment of waste waters, evaporative cooling, and the separation and burning of oily wastes have controlled many of the nuisances, but sludges and slurries from the treatment plants, emissions from flare towers, odours from settling ponds etc. can themselves be obnoxious. Surges and abnormal conditions in water systems are difficult to handle. Toxic and hazardous discharges from coke ovens and blast furnaces need better control. Deposition and fouling and the removal of dissolved salts remain problems in recycle systems.

(iv) Some liquids used in lesser quantity for the treatment of steel, e.g. waste acids and rinse waters from pickling and metal cleaning, can be difficult to treat. Regeneration is desirable for acids.

Other wastes can contain cyanides and heavy metals e.g. plating solutions, which must be safely segregated and treated. No universally accepted technology is available to treat these water streams.

(v) Solid wastes from all these streams and those stemming from the raw materials processed e.g. coal washery residues; slags, dusts, refractories, and slurries must be dumped, or outlets found for their disposal. Dumps are ugly, require some years and careful management to be restored to a pleasant appearance and then should not be used for other than industrial or intermittent recreational purposes. Work to improve the recovery of these potential resources, which can include valuable metals from alloy steel plants, is needed.

(vi) Noise is a nuisance which is difficult to control, mainly because each problem requires individual solutions. The large electric arc furnace, hot and cold saws in rolling mills and operations in scrap yards are prime offenders.

(vii) The ferro-alloy industry should develop economic methods for recycling wastes or find useful outlets for them since the disposal of fine fume is a problem.

(viii) Greater flexibility of design is required for pollution control equipment to allow an installation's efficiency to be increased, so pollution control requirements become more stringent, thereby making it unnecessary to remove existing equipment and replace it with new.

5. Research is in progress which seeks to evolve new solutions to many of these problems. Interesting approaches use the simultaneous application of two physical principles to achieve capture of gases and particulates, or the simultaneous chemical and physical treatment of water borne pollutants. Examples include: grounded or charged conductive bag house filters (ferro-alloy fume); magnetic recovery of chemically flocculated solids (rolling mill waste waters); electrostatic charging of droplets in venturi scrubbing systems (iron oxides in gas streams); magnetic agglomeration of particles in cyclones (steel plant waste gases).

6. It was considered that the development of solutions to the problems which have been defined, could be left to the market and planned economies in response to perceived need. A valuable role for UNEP would be to monitor on a continuing basis the state of environmental protection technology, for the information of governments. The holding from time to time of workshops involving appropriate experts would be a suitable approach.

7. It was observed that at present in the market economies progress was not rapid in the development of revolutionary or innovative technologies which might improve the impact on the environment of steel production. Taking as an example the research now being funded internationally, into new processes for coal utilisation and conversion, it was suggested that UNEP could act as a catalyst to promote the development of those new approaches to process technology, e.g. formed cokes, which have reached a sufficient stage of research to merit evaluation and assistance, as well as to promote their use.

8. Finally, the expressed intention of UNEP to form a computer accessed data base on pollution control costs and methods was commended. Such a base, subjected to expert review at intervals and set up on an INPUT - OUTPUT basis related to unit mass of steel products processed, could be a valuable contribution since it should be sufficiently flexible to permit unbiased evaluations of new process possibilities and of the proportional contributions to total plant emissions of the problem areas identified in the attached table.

A. MINING IRON AND OTHER ORES, LIMESTONE ETC...

SOURCE	EMISSION	CONTROLS	COMMENTS
Ore winning	Air - fugitive dusts from: blasting; scraping or loading transport; entrainment by wind from heaps; primary and secondary crushers.	In remote locations minor. To protect workers. e.g. Respirators; air conditioned filtered cabins; watered roadways and heaps. Near habitations more extensive provisions needed. e.g. earth screens, green belts; permanent water spray installations automatically controlled.	
Water	Suspended solids Inorganic metallic ions Other	Leached salts may need to be precipitated or absorbed. Algal growths in holding ponds may need treatment.	Problems: Dusts in run off. Staining of steams can require extensive settling ponds, floculation, etc.
Solid Wastes	Mining tips can be aesthetically damaging, control and siting should be planned in advance. Top installations of underground mines should be removed on completion of mining.		Usually open cut; problem: restoration, revegetation difficulties. Filling may prevent subsequent recovery of lean ore. Filling costly or impracticable in deep mines or hill quarries.

SOURCE	EMISSION	CONTROLS	COMMENTS
Noise	Blasting; machinery and recovery of blasted ore; crushers.	Screens; sound deadening sheets on equipment.	
Ore beneficiation	Stockage		See other sections
	Conveyor		" " "
	Concentration grinding plant	Insulated buildings	needed in inhabited regions.
	- noise		
	- fugitive dusts if dry grinding used	Hoods over points of transfer	
	- waste waters from used grinding	Thickeners and tailing dams	Management of tailing dams and restoration are problems.
B. COAL			
Coal winning	condition similar to ore mining except:		
	subsidence	purchase of properties in advance of mining;	
		adequate depth under bodies of water ;	
		props maintained over large areas and lowered slowly.	
	combustible materials in dumps.		Colliery shale tip fires once started are difficult to control. Careful management required.

SOURCE	EMISSION	CONTROLS	COMMENTS
	Slippage in coal waste dumps	Correct stocking plan.	
Coal concentration	Water borne particulates	Sedimentation	Methods to treat black waters are in development.
	Solids-tailings	Dumping and/or ponding	Clays and slurried materials difficult to handle.
	Noise	Green belt, screens.	
C. CHARCOAL MANUFACTURE			
Logging	Transport over large areas creates problems.	Attempts are being made to develop movable charring units.	Low density product implies transport costs to steelplant.
Charring	Majority of present plants do not recover by-products. If methanol recovery practiced, similar to coke ovens.	As with coke ovens.	
D. LIME KILNS			
Rotary or vertical kilns.	Fine dusts	Bag house	Problems: Uses for fine dust recovered. Mixtures of limestone and lime. Fugitive fine dusts are irritant and corrosive.
Transfer points	" "	" "	
Hydrator	" "	Wet scrubbers	Water recycled no effluent or steam.
Storage	" "	Bag House	

SOURCE	EMISSIONS	CONTROLS	COMMENTS
E. PELLET PLANTS			
Ore grinding (dry)	Air - Point emission of dusts. Fugitive dusts at transfer points.	Slight dumping	
Mixing (hydrated lime bentonite etc.)	Air - Dusts	To bag house from hoods.	
Pelletizing Discs	- dusts	Multicyclo[illegible]s wet scrub[illegible]s	
Screens	- screening	Powders r[illegible]cled	
Induration	Air - point emission dusts	cyclones [illegible] wet scrubbers scrubber water recirculated via agitator thickener cooling tower used as process water. no effluent. solids recycled to pelletizer.	Problems: if natural gas not used SO_2, SO_3 in off gas give visible emissions.
F. FERRO-ALLOY PRODUCTION			
Ferro-alloy furnace	Air Particulates, NO_x (in some cases SO_2). heavy metals	Generally by means of bag filters; examples of application of electrostatic precipators and rarely of wet scrubbers. Some problems related to tapping emissions for rotating furnaces.	In the case of bag filters problems arising from temperatures; problems from pyrophoric particles. Pre-cleaning might be required. Problems with particles with electric charges.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
	Water Suspended solids and acidity (in the case of wet dedusting)	Settling and neutralization	Difficulty in finding appropriate coagulation agents in the case of particles with low specific gravity.
	Noise	see Electric Arc Furnace (EAF)	Problem generally less important than for EAF.
	Solid wastes coming from the dedusting system	Pelletizing to reduce volumes and wind losses	Research to improve economic recycling would have to be developed.
	Heat	See EAF	Problem generally less important than for EAF.
G. FOUNDRY OPERATIONS			
Cupolas	Air - Particulates, NO_x, CO	Depending upon to size: fabric filters, scrubbers and mechanical collectors. For EA and induction furnaces fabric filters preferred.	Expensive control especially for small plants, with intermittent operation. High temperatures in certain phases of the production cycle. Possibility of changing in cleaning technology due to developments in the cupola technology.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Molding preparation	Air - particulates, silica, odorous and toxic compounds.	Wet scrubbers, fabric filters Wet collectors with chemical treatment.	Low threshold limit values are advocated for worker protection.
Pouring	Air - Particulates CO	Fabric filters	
Finishing	Air - Particulates, Silica	Fabric filters	see "molding prep"
			Necessity of having local exhausting systems. New technologies being developed.
	Noise	Isolation, enclosures	
	Solid wastes	Partial recycling for molding sands.	Research to be developed in order to find out possible ways of reuse.
	Heat	Personal protection, enclosures.	

COKEMAKING

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Coal Pile	Air - Fugitive	Wetting, covers	Troublesome in arid and windy regions and freezing conditions.
	Water-surface runoff, leaching percolation.	Sewers, drains, settling basin, neutralization, clarification.	Intermittent nature of rains may complicate control.
Crushing, blending, conveyors, transfer points.	Air - Fugitive, coal cust.	Bag house, scrubbers, covered conveyors and evacuated transfer points.	Relatively large size of dust simplifies removal from air stream.
Charging	Particulate coal dust, hydrocarbons, SO_2, H_2S, reduced sulphur compounds, carcinogens.	Stage or sequential charging with over evacuation. Collection and control dust collection.	
		Pipeline charging with pre-treated coal.	Has potential for further improvement of charger emission control, but remains to be perfected.
Pushing	Particulate, coke dust, hydrocarbons, SO_2, Carcinogens	Ensure complete coking	Minimize "green" push
		Moveable closed quench car and scrubber.	Provides high potential for control; may be overwhelmed by green push; requires good management and operation and high maintenance, remains to

SOURCE	EMISSIONS	CONTROLS	COMMENTS
			be perfected.
		Moveable hood with evacuation.	Does not provide complete capture; quench car uncontrolled while moving to quench.
		Fixed hood on coke side (shed)	Large structure on coke side question of worker exposure.
Quenching	Particulate	Baffles Clean water quench	Reduces emission of fine particulate.
		Dry quenohing	Recovers latent heat from hot coke; is claimed to improve blast furnace performance of coke; capital costs are high; difficulties may be experienced in retrofit to existing batteries.
			Requires increased control of dust from coke.
Door and lid leakage	Particulate, hydrocarbons, SO_2, H_2S, carcinogens	Good management, work practice, luting of seals with slurry.	Some emission still occur. Requires intensive application of manpower in severe coke oven environment.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Coke by-product plant	Water - Ammonia, hydrogen cyanide, complex cyanides, phenols, carcinogens.	Ammonia removal, pH adjustment biological treatment, settling basins, clarifiers.	Not perfected, does not yet achieve high removal efficiencies needed in some areas, suffers from upset conditions. Sludge becomes solid wastes.
	Solid waste - sludge from biological treatment system.	Dewater and incinerate or use as landfill.	Imperfect solution may lead to new environmental problem.
Combustion stack	Particulate, smoke	Maintain burners and oven-wall refractory.	Exposes workers to severe coke oven environment.
	SO_2	Coke oven gas desulphurization to remove H_2S prior to combustion.	Technology available, however costly. Difficulty with need for greater H_2S removal.
	CO	Assure maximum combustion of fuel gas.	No available solution exists except for expensive - energy intensive incineration.

SINTERING

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Exterior storage of charge materials.	Air - Fugitive emissions.	Wetting, covers	Technology is generally unsatisfactory especially in arid and windy regions and freezing climates.
	Water - surface runoff leaching percolation.	Liners and drains to water treatment system.	Technically feasible but intermittent rains may complicate control.
Material handling	Air - Fugitive emissions	Cover conveyors, enclose and evacuate transfer points to air cleaning device such as bag house.	Technically feasible.
Windbox	Air - Particulate	E.S.P, Bag House, Scrubber	E.S.P. may perform poorly if dust has high resistivity baghouse may blind from hydrocarbons; high energy scrubbers needed for many sinter plants are very energy intensive. Severe corrosion problems.
	SO_x	Wet scrubber using high pH scrubbing liquid. May simultaneously remove particulates.	High cost, potential, for scaling, fouling, and need for waste disposal.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
	Fluorides		
	NO_x	NO_x removal system.	Costly.
	CO	None available except incineration.	Incineration is costly and requires fuel.
	Water - when wet gas cleaning is used, suspended solids, dissolved solids, oils.	Clarifiers, filters chemical treatment for precipitation and pH adjustment.	Technically feasible, costly and troublesome to treat.
	Solid wastes result from wet gas cleaning, SO_2 and fluoride scrubbing may be contaminated with hydrocarbons.	Recycle back to charge material when not contaminated. Use clean calcium sulphate as marketable gypsum.	
		If unable to recycle or reuse dispose of to landfill.	Suitable landfill sites may not be available.
	Noise from fan	Adequate design and construction.	Huge fans needed especially for wet scrubbers make noise control difficult.
Discharge, cooling, sizing and screening.	Air - Particulate	E.S.P. baghouse scrubbers.	Technically feasible.
	Water - If scrubbers are used.	Same as for windbox.	Less troublesome than for treatment of windbox scrubber wastewater.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Exterior storage of sinter.	Air - Fugitive Water - surface runoff, leaching percolation.	Adequately screen and minimize working to prevent dusting, otherwise same as for storage of charge materials.	Agglomerated state of sinter makes problem less critical than for the exterior storage of charge material.

BLAST FURNACE

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Exterior storage of charge materials.	Air - Fugitive emissions, iron oxides, coke and limestone dust.	Wetting, covers.	Technology is generally unsatisfactory especially in arid and windy regions and under sub-freezing conditions.
	Water - surface runoff, leaching, percolation.	Fines which drain to water treatment system.	Technically feasible but intermittent rain complicates control.
Materials handling and stockhouse.	Air - Fugitive emissions.	Enclose conveyors and evacuate transfer points.	Technically feasible.
Furnace top	Air - Particulates, CO, phenols, ammonia, cyanides.	Good management, operation and maintenance.	The extent of this potential problem has not been adequately assessed.
	Noise	None available	Intermittent.
Cast house	Air - Particulates	Enclose runners with evacuation, air curtains, cast house building evacuation with air cleaning.	Technically feasible for new blast furnaces at time of construction. More difficult to retrofit to existing furnaces, costly.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Top gas scrubber.	Water - suspended and dissolved solids, phenols, cyanides, ammonia.	Settling tanks, filters, chemical treatment for coagulation, clarifiers, chlorination carbon adsorption.	Low concentration of organics makes biological treatment unfeasible. Chlorination to achieve low level of pollutant control makes carbon adsorption necessary. Requires additional development.
Slag granulation	Air - H_2S Odour	Use oxidant in water	Not perfect solution.
Storage and handling	Air - Particulate	Same as for coarse charge material.	
	H_2S Odour	None available	Has been researched for considerable time.
Air cooling and disposal.	Solid wastes.	Landfill; Recycle for use in concrete, railroad ballast, etc.	Causes H_2S Odours, potential for leaching, suitable disposal site may not be available.
Slips	Particulate of crude top gas through pressure relief valves	Good burden preparation, management and operation.	Infrequent occurence, and of short duration few times each month in well operated blast furnaces

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Septum valve	Noise continuous	Silencer after septum valve.	Potentially suitable for older furnaces having low top gas pressure.
		Extension turbine with generator	Recovers energy, more suitable for large, new furnaces having high top gas pressure.

CASTING, ROLLING AND FINISHING

PROCESS	EMISSIONS	CONTROL	COMMENTS
Ingot casting	Heat radiation W.E. dust (FeO) W.E. (SiO_2)(Bricklayers) W.E.	Protective clothing, ventilation	Increasing use of continuouse casting decrease need for ingot casting.
Continuous casting	Water, solids (scale) oil	Recycling incl. filtering	Emulsified oil in bleed off.
	Air dust (FeO) Heat radiation	Ventilation and bag filters protective cloth	
Hot rolling	Water Solids Oil	Recycling incl. filtration cooling and evaporative cooling	Oils in mill scales may cause problems in recovery emulsified oil in bleed off.
	Air SO_2 NO_x	Low sulphur fuel	Costly
	Working environment: Heat radiation	Sound-proof control rooms with air condition.	
	Hot micro-climate	Shielding	
	SO_2	Hoods - ventilation	
	NO_x		
	Noise vibration	Primary noise insulation	Noise abatement.

PROCESS	EMISSIONS	CONTROL	COMMENTS
Cold rolling	Air : Oil (also in W.E.)	Oil filters	
	Water : emulsified oil		Oil emulsion
	Noise : W.E.	Primary noise insulation Sound-proof control rooms	
Pickling	Water : acids	Regeneration of spent liquor.	
	solids	Recycling	
	metallic ions	Neutralization and filtering of the bleed off	
	Working environment		
	acids in air	Hoods - ventilation	
	noise	Primary noise insulation	
		Sound - proof control rooms	
	Air : Acids	Scrubbers	
Zinc-coating	Air : trichlorethylene		
Plastic coating	Air : solvents odours	Burning of the waste gases.	
	W.E. Solvents odours noise	Ventilation Prim. noise isolation sound-proof control rooms	

STEELMAKING

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Oxygen blow plants	Air - point emission particulates (esp. iron oxides), CO, NO_x, fluorine compounds (in dry dedusting systems)	Generally by means of high energy wet scrubbers; sometimes by means of dry-type electrostatic precipitators; rarely by bag filters.	No particular technological problems, some problem from the economical point of view, especially as far as operation costs are concerned. Possibility of CO gas recovery.
	Air - Fugitive Particulates kish Soda ashes	Generally and preferably by means of bag filters; sometimes by means of wet scrubbers (for instance in combination with dedusting)	No problem as far as dedusting is concerned Large amount of energy is needed. Some problem as for capturing with local hoods in old shops.
	Water pollution Suspended solids (for wet dedusting systems) Acidity	Neutralization	Dissolved salts are troublesome to remove.
	Noise with exhausters stack burners	Silencers, enclosures, appropriate design for burners	
	Solid wastes Zn, Pb, Alkaline compounds as far as sludges or dust from dust collectors are concerned	Recycling of iron bearing dusts to the sinter plant, if their composition (Pb, Zn and alkaline compounds concentration) is acceptable for blast furnace.	Further research is desirable in order to solve in an economical way the problem of separation and recovery of Zn and Pb compounds.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
	Sulphur and fluorine compounds in slags.	Possibility of selling of converter slags for agricultural purposes, road construction, cement production.	
	Heat	Appropriate enclosures, thermally insulated pulpits, personal protection, ambient ventilators.	
Electric arc furnace	Air Particulates (iron oxides, zinc and lead compounds), fluorine compounds.	Present tendency towards treating together both primary and secondary fumes by means of bag filters.	Changes in the fume capturing and cleaning could be determined by the evolution of the EAF technology due to technical or economical considerations. Main problems related to capturing fumes coming from charging and tapping. Importance of scrap quality and oil content.
	Water pollution Suspended solids and acidity (for wet dedusting systems)	Settling Neutralization	Dissolved salts are difficult to remove.

SOURCE	EMISSIONS	CONTROLS	COMMENTS
	Noise during the melting of solid charge	Acoustic insulated pulpits and rooms, personal protection; silencers in aerators; completely closed and insulated shops.	Future developments could reduce noise emissions, e.g. scrap preheating, use of prereduced pellets, new electrodes. Enclosures of furnaces could contribute to solving noise and atmospheri pollution problems.
	Solid wastes Zinc, lead, alkaline compounds as far as sludges or dust from dust collectors are concerned.	Recycling of iron bearing dusts to the EAF themselves after a proper treatment (process not yet completely improved)	Desirable research in order to improve recycling process.
	Sulphur and fluorine compounds in slags.	Some possibility of using slags; generally dumping of slags.	
	Heat	Appropriate enclosures, thermally insulated pulpits, personal protection, ambient ventilation.	

12-3

SOURCE	EMISSIONS	CONTROLS	COMMENTS
Open hearth and tandem furnaces	Air pollution - point sources Particulates (iron oxides, zinc, and lead compounds) SO_2 (in the case of use of oil as a fuel). NO_x fluorine compounds	Usually adopted electrostatic precipitators, rarely venturi scrubbers.	No particular) The problems.)importance of the kind of process of steel production is decreasing and the at present available cleaning technologies are adequate to the extent of the problems.
	Water pollution Suspended solids and acidity (for wet dedusting systems)	Settling Neutralization	Dissolved salts are difficult to remove.
	Noise From fans and burners	Silencers, enclosures, appropriate design for burners.	
	Solid wastes Zinc, lead, alkaline compounds as far as sludges or dust from dust collectors are concerned.	Recycling of iron bearing dusts to the sinter plant if their composition is acceptable for blast furnace operation.	Similar to comments on solid wastes from oxygen-blown furnaces and EAF plants.
	Sulphur and fluorine compounds in slags.	The same problems expressed for EAF slags.	
	Heat	Appropriate enclosures, thermally insulated pulpits, personal protection, ambient ventilation.	

ANNEX III

REPORT OF WORKING GROUP III

ON RESOURCE UTILISATION

Terms of Reference

1. The terms of reference for Group III were "To examine resource utilisation in the iron and steel industry and its impact on the environment, identifying the technological, economic or other factors which limit improved resource utilisation in the industry, particularly in relation to : (i) raw materials, (ii) energy, (iii) water , (iv) residues and (v) scrap metal".

Raw Materials: Iron Ore

2. In general there is fairly good utilisation of iron ores in all the processes considered. Losses of iron units tend to be small and are, in practice, limited to:

- losses in dusts in ore preparation, sintering, blast furnaces, and oxygen steelmaking or, in the direct reduction route, reduction furnaces and electric arc steelmaking; the quantity of dust is relatively small and part of it is recycled;

- losses in slags especially from steelmaking operation; it is noted that use of medium grade ores instead of high grade ores in the direct reduction route leads to a high slag volume in the arc furnace and can, thus, increase the loss of iron units.

3. There is a worldwide trend towards the use of lower grade ores. For example, in countries like USA, Canada and USSR they are now concentrating more and more low grade ores and this will progressively become the case all over the world. However, two remarks have to be made:

a) direct use of a local low grade iron ore, especially when it is difficult to concentrate it, can be beneficial and economic calculations have to be made in each case:

b) on the other hand, when concentration is possible, it is generally more economic to beneficiate the ore before shipping it to the plant; it could, even, be considered worthwhile to superconcentrate it in order to leave as much gangue as possible at the mine site.

4. It is considered, in general, that the environmental problems at the plant site could often be substantially reduced by concentration or even superconcentration of ores at mine sites. Environmental problems are, indeed, easier to solve at the mine site and there is usually relatively little air pollution, and not too many difficulties in using tailings and various other residues such as overburden, in restoring the ground. Water pollution or specific problems with contaminants may sometimes occur but they can usually be solved by classical processes.

Energy

a) General Energy Requirements

5. It must be emphasized at the outset that with iron ore as the starting point, the overall energy requirements are about the same, whether the traditional blast furnace - BOF route or direct reduction processes followed by melting in an electric furnace are used. Notwithstanding this similarity in overall energy consumption, there are major differences between these two routes to finished steel products. These are summarised in the following:

(i) The two processes use different kinds of energy. The energy consumed in the traditional blast furnace-BOF route is mainly based on coal (say 60 - 80%). In contrast the direct reduction processes tend to rely on natural gas or oil.

(ii) In contrast the classical route involves a complex integrated operation, with a broad range of by-products, such as coke oven gas, blast furnace gas, tars, coal chemicals and the like. Whether proper use is made of the by-products (e.g. partial flaring of blast furnace gas) plays a major role in determining the overall thermal efficiency of the system. The other route, the direct reduction processes, does not provide a broad range of by-products.

6. In recent years major advances have been made regarding the implementation of energy conservation measures in the steel industry which have resulted in a substantial reduction in the overall energy consumption (reductions as much as 30% have been achieved in certain instances).

Some of these measures are summarised in the following:

- improved burden preparation for blast furnaces

- better operation and control of the blast furnace

- improved metallurgical operations of direct reduction, especially of shaft furnaces.

1323

For both routes, mention should also be made of:

- expansion and improvement of continuous casting

- direct rolling of hot semi-products

7. In other words, it is difficult to compare energy consumptions to two plants, if they are not of the same age or of the same generation regarding metallurgical design and operation.

- There can be increased energy consumption when using lower grade ores directly, but this could prove economical in certain locations where the use of an inexpensive local low grade ore could justify it.

- Although progress will continue for all processes, a large decrease in overall energy requirements cannot be anticipated at least if liquid steel is to be processed.

- The only existing method which shows substantial lower energy requirements is the use of scrap which, of course, eliminates the energy needed for reducing iron ores to the metallic state. However scrap supply could be limited as indicated in paragraph 20.

b) Coal

8. The main point is that the classical route can, through improvements in the coking technique (and also with the newer processes of formed coke currently being developed) enlarge the variety of coals which can be used to produce a suitable material for the modern blast furnaces. Both the improvement of coke ovens and the development of formed coke process, could contribute substantially to solving environmental problems. Furthermore, there is some hope in the development of coal injection in blast furnaces. It must be noted that use of coal in direct reduction of iron ores also raises some environmental problems, which would entail additional expenses.

c) Charcoal

9. The use of charcoal as a reducing agent raises interesting possibilities, especially in some tropical countries which do not have other fossil fuel resources, provided that proper environmental management of forests is practised. Charcoal based steel production could be attractive from the economic standpoint because a renewable resource is used as the energy source. It is suggested that a great deal of useful research could be done in this general area, concerning:

(i) optimal plant location to minimise the transportation costs,

(ii) the development of an environmentally sound, energetically efficient charcoal manufacturing process,

(iii) the development of iron or steelmaking technology that is optimally suited for charcoal utilisation (there may be routes other than the low shaft furnace).

d) Oil and Gas

10. In the classical route, oil and gas are injected into the blast furnace; oil and gas are also used for heating purposes; in direct reduction, natural gas is often the main energy source for the reducing gas. The future supply of oil and gas is, however, problematical at least for a large part of the world and raises the question of finite limits to the possible development of the direct reduction process.

e) Electrical Energy

11. It is clear that more and more electrical energy will be used in the iron and steel industry. In this respect, it must be pointed out that this leads to some transfer of pollution to another industry. It should also be noted that some environmental problems are created in power stations which generate electricity for controlling pollution problems in the Iron and Steel Industry. Some recent IISI studies indicate a consumption as high as 170 KWh/t of steel for pollution control in modern integrated iron and steel plants. Another important point, especially for developing areas, is the possibility of problems in the electrical network, particularly flicker (from voltage fluctuations), when large electric furnaces are connected to the network. This is a subject for research and economic consideration.

Other Raw Materials

12. In this section the following are considered:

- fluxing agents such as limestone, dolomite, etc.

- refractories,

- carbon electrodes,

- ferro-alloys

13. The principal remarks are summarized as follows:

(i) There has been a clear trend regarding the reduced use of these materials per ton of finished products. This trend is attributable to improved raw materials preparation and to improvements in the overall processes, such as automation, better process control and the like.

(ii) It is thought, however, that no major improvements may be anticipated because refractory consumption and the use of fluxes is inherently associated with steel processing.

(iii) It is expected that efforts will continue in order to replace environmentally objectionable additives, such as fluorspar with suitable alternatives e.g. colemanite or bauxite.

Water

14. Water is by far the largest quantity of raw materials used by industry. Recycling and reuse of water is possible and often practiced. This can reduce the intake from about 150 down to 1,5 - 2 m^3 per tonne of crude steel, (excluding drinking and sanitary water) a level that corresponds to the unavoidable losses due to evaporation. The appropriate technology for this is available and well proven and should be applied at new works in areas where conservation of water is necessary. For existing plants difficulties due to high cost, available space and other constraints may arise in attempting to change from once through water usage to recycling systems.

15. At the present time, a 100% level of water recycling is not practically possible due to very difficult problems of corrosion and of outstanding residues in the water. Therefore, a certain volume of waste water has to be rejected. This effluent must be considered as an unavoidable purge of the water system of the plant and is characterised by relatively high concentrations of dissolved solids, depending on the level of recycling.

16. As for the energy requirements for water systems with high recycling levels and for systems with once-through water usage there is no significant difference between them.

Scrap Metal

17. Steel industry is consuming scrap intensively: BOF and similar processes can use up to 300 kg of scrap per ton of steel. Electric arc furnaces remelt 1040 kg of scrap to produce 1 ton of crude steel.

18. Casting and rolling of 1 ton of steel provide an internal recovery around 225 kg of scrap when ingots are used and 100 kg when steel is continuously cast.

19. The difference between consumption and recovery is found in the scrap business. This market is very important: statistically one third of the finished steel products come back as "commercial scrap" after 17 years.

20. Although recovery processes exist in special cases, the difference is lost as rust or as wasted steel due to economics (cost of transport or treatment), technical problems (scrapping of motor car bodies, mixing of different metals, coated products - tinplate, galvanized sheet, etc. - and tramp elements coming mainly from alloy steels). These items should be research subjects for the future.

21. Due to the structure of the scrap market, the prices of the different scrap grades fluctuate widely with the demand (which is correlated with the steel market). This is very important for the electric arc furnace route which uses only scrap.

22. As there are quite a few administrative barriers for the scrap trade, it might be hoped that the price of prereduced products may have a stabilizing effect on the price of the steel scrap.

By-Products and Residues

23. As mentioned previously, almost all the gaseous by-products are reused in an integrated steel works as energy resources for furnace heating or generation of electricity.

24. In some countries, coking by-products like benzol, phenol, tar and ammonia, which are normally used as raw materials for the chemical industry, may have a very low economic value and have to be destroyed by complex and expensive processes. The reliability of these processes is not yet well established. Other uses for these products can be found, such as tar injection in blast furnaces instead of fuel oil.

25. Blast furnace and steel making slags are used for civil engineering, cement making or as fertilizer when the CaO or P_2O_5 content is high enough. Sometimes steelmaking slags can be recycled for iron making. It is sometimes possible to avoid residues by process substitutions: steel coil pickling by hydrochloric acid instead of sulphuric acid alleviates the problem of dumping iron sulphate when it cannot all be utilised.

26. Some problems have yet to be solved, and require research, for example:

(i) reuse of the fine iron oxide bearing dust due to the size of particles and to other mixed materials such as Zn, Pb, etc.

(ii) Disposal of blast furnace gas cleaning sludge due to its cyanide content.

Human Resources

27. The manufacture of steel products is a major user of human resources. It is estimated that, depending of process route, location, degree of automation, etc., it may take from very few man hours (in minimills for example) to a high level of man hours to produce 1 ton of finished products (up to 80 man hours for 1 ton of very elaborate products). In developed nations, there are major incentives for increasing the total productivity through process control, because the cost of labour may be up to 35% of the total cost of production. In certain countries where skilled labour is scarce, other incentives exist for high labour productivity. In yet other situations in developing countries, steel production may provide welcome job opportunities, so that this factor will have to be balanced against economic attractiveness of improved labour productivity.

Siting

28. The steel industry seems to offer a good potential for employment for the people in both developed as well as developing countries. However, the construction of a steel works requires a large capital outlay and

thus the cost per job is high. Given this need for labour, steel works are normally situated in populated areas. Hence it is necessary when designing a new steel plant, to take this into consideration and provide the best equipment to avoid air, water and noise pollution when the plant is commissioned.

ANNEX IV

REPORT OF WORKING GROUP IV ON ENVIRONMENTAL MANAGEMENT

Terms of Reference

1. The terms of reference for Group IV were "To examine the environmental management approaches which may be adopted to protect the environment in relation to the iron and steel industry's operations, particular consideration being given to:

   (i) environmental impact assessment and environmental criteria for siting;

   (ii) approaches towards establishing acceptable levels of discharge;

   (iii) environmental management at the plant level, including maintenance of pollution control equipment; training; employee awareness, motivation and responsibilities;

   (iv) need for monitoring and surveillance within and outside the plant.

(i) Environmental Impact Assessment and Siting

2. Plant siting is not primarily an environmental matter, but a decision based on economic and political factors (raw materials availability, transportation, market considerations, regional development plans, etc.). However, once a site has been tentatively selected, then the environmental impact analysis becomes an absolutely essential tool for the planning of the installation.

3. The programme in the U.S.A., under the National Environmental Policy Act, has resulted in the development of a very complex formal process for preparation of environmental impact statements. Other countries, such as Brazil, have similar systems with more or less formality. A report giving the Executive Summary of the environmental impact assessment for a proposed new "greenfield" steel plant in the United States was

examined. While the formality of the process is perhaps too great, this report outlines those factors that must be considered in evaluating the environmental impact of a new facility. Once the plant site has been tentatively selected, a basic outline of the plant facilities, capacities, allowable effluents and emissions, and discharge points is developed. These are then utilised in an analysis which includes:

1. Regional economic impact *
2. Social environmental impact *
3. Infrastructure impacts *
4. Land use impact *
5. Atmospheric characterisation
   (a) Atmospheric impacts during construction
   (b) Atmospheric impact of operation
   (c) Secondary atmospheric impacts (community and infrastructure)
6. Hydrologic aspects
   (a) Surface water
   (b) Ground water
   (c) Water use - plant and community
   (d) Water quality impact of operation
   (e) Secondary water quality impact
7. Biotic environment
   (a) Terrestrial
   (b) Aquatic

4. It was agreed that such an impact analysis should be done in the initial planning phase of any plant development. The analysis is primarily a scientific study. It should then be used in determining the environmental acceptability of the facility, and in some cases, for establishing special or additional environmental requirements for that facility.

5. It was agreed that the government should be responsible for the guidance and development of the assessment, and that the cost of the required scientific work, which may be high, must ultimately be borne by the industrial facility. The government planning process should be organised to facilitate analysis and debate so that the compromise which may have to be made can reflect the total environment - social, political and economic as well as physical.

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* These factors will have been studied and documented in the initial siting decision, but must be considered in the environmental analysis, particularly with respect to secondary effects.

(ii) Approaches Toward Establishing Acceptable Levels of Discharges

6. It was agreed that those aspects of ambient standards which are based on health effects criteria should be essentially uniform in all regions of all countries. Standards for the worker environment, which are health-based, should also be essentially uniform in all regions, taking into consideration appropriate ethnic or climatic factors.

7. There was no initial consensus on the setting of specific emission standards for all facilities of existing and new plants. There was some thought that consideration should be given to the assimilative capacity of the environment, and to providing some flexibility in emission and effluent standards based on regional consideration and case-by-case cost/benefit analysis. One thought was that specific emissions standards should be set on an individual basis, relating them flexibly to assimilative capacity of the environment. Another position was that standards should be technology-based, and thus uniform for plants in all areas.

8. It was generally agreed that, for existing plants in areas where the infrastructure is well established, there should be flexibility in standards, recognizing cost/benefit analyses and the law of diminishing returns.

9. Relative to new plants, particularly in areas where there is little urban development, there was some question whether the adoption of best control technology is justified at the time of installation. The assimilative capacity of the environment in such locations at those times may be significant. There was some thought that perhaps standards less stringent than the best technology could be applied initially to these plants. Special consideration must be given to the increased unit cost of pollution controls for smaller plants. Recognizing that greenfield steel plants tend rapidly to become urbanized centres, that development follows development, it would be inevitable that the environment in those areas would deteriorate. Therefore, such plants would, of necessity, make provisions in space and structures for future installation of better controls. An opposing position was that all new facilities be equipped with best pollution control equipment immediately, providing maximum protection for the environment from the start, and not waiting until environmental insult becomes severe. This question was resolved in Plenary Session with the consensus that all new facilities, regardless of location, should be equipped with the best pollution control equipment immediately.

10. Concerning formal exchange of information between governments on legislation and standards, it was agreed that differences between governmental systems and policies and enforcement mechanisms are so great that such formal comparisons would not have sufficient value to justify the effort required. It was considered, however, that informal exchange and comparison of information on environmental standards is desirable and useful.

(iii) Plant Level Environmental Management

11. It was agreed that environmental control policy must be a concern of all levels of management, from top plant management through workers in operation and maintenance. Direction of environmental control activities must be made an integral part of plant management, and must be considered equal in importance to production activities. There is, in both developed and developing countries, a tendency to make operation and maintenance of environmental control facilities secondary to production activities. Only top level commitment and education at all levels can overcome this tendency.

12. In discussion of training of personnel, it was agreed that simple training in equipment operation and procedures is inadequate; that training of employees at all levels in understanding the environment and ecology is essential.

13. Organisation to achieve environmental responsibility was discussed in the framework of an organisation demonstrated to be effective in one plant:

(i) A high level committee incorporating the plant manager and heads of production, maintenance, engineering and labour staff must actively provide direction in environmental policies.

(ii) Specialists in environmental control and ecology should serve as advisers to the top level committee as well as develop technical procedures for pollution control and environmental educational programmes for employees at all levels.

(iii) A monitoring and measurement staff must be responsible for regular surveillance of the operation of environmental facilities and the quality of plant effluents. It is essential that this monitoring group be independent of, not subservient to, personnel responsible for equipment operation.

(iv) Plant operation and maintenance personnel must be adequately trained in the importance, as well as the mechanism, of environmental control facilities, and must be responsible to the top environmental committee.

(v) Engineers responsible for plant modification must incorporate environmental consideration in all their work, and must work closely with operation and maintenance to provide equipment for environmental responsiblity.

All of these groups must be adequately trained in ecology and the environment, and must continue to work cooperatively with environmental quality as a major objective.

14. Several suggestions were made to improve employee awareness and interest in environmentally sound plant operation. One was that there be rotation of personnel among positions in operation, maintenance, and environmental monitoring, so that each group would be made aware of the problems of all.

Another was that there be economic incentives for environmental considerations, in addition to those for productivity and quality. The specifics would, of course, depend on the financial system of the country and plant involved.

15. One major summary point of full agreement was that sound environmental policy must be developed by top management, and that this policy must be made clear to personnel at all levels in both words and action.

(iv) Environmental Monitoring

16. It was agreed that there are at least four classifications of environmental monitoring required for the iron and steel industry, and that the requirements and responsibilities for each are different. It is essential that the equipment, procedures, and methodology for each function be properly defined in terms of the appropriate use of the data.

(a) Performance and efficiency of control equipment must be monitored to permit corrective action to assure continual operation. This may involve monitoring of equipment parameters not directly related to effluent characteristics or pollutant concentrations, e.g., voltage in a precipitator or water pressure on a scrubber. This sort of monitoring is completely the responsibility of the industry and the plant operators.

(b) Residual pollutants in effluents must be monitored to assure that performance of the plant is in compliance with plant specifications and with legal requirements. This type of monitoring requires more sophisticated measurements to establish directly the amount and character of pollutants discharged. The frequency of monitoring, however, can be considerably lower than that for operating parameters. This type of monitoring is the responsibility of both the industry to assure that it is accomplishing its objectives and the government to assure that legal requirements are being met.

(c) Ambient environmental measurements must be taken to determine the quality of the air in the region around the plant and the water in the streams. This type of monitoring should be the responsibility of the government to protect the health and welfare of the people. It would be used, for example, for determining the need for action to prevent serious pollution episodes and to determine when or if environmental quality has deteriorated to the extent that additional pollution control equipment may be required for the plant.

(d) Worker environment should be monitored routinely for known hazards to provide adequate and continuous protection for workers. This must be accepted as an industry responsibility, in cooperation with governments and worker representatives.

(e) There are also needs for additional monitoring for use in research and development and related activities, but these requirements can be determined only on a case-by-case basis.

17. It must be stressed, however, that monitoring itself has no value unless the data will be used effectively. Programmes should be simple, effective, and confined to useful data. Regular routine monitoring by extremely simple techniques can be supplemented by more complex measurements on a periodic basis.

18. Ambient monitoring systems should be tailored to the specific needs on a case-by-case basis, considering such factors as topography, climate, degree of urbanization, and development.

ANNEX V

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4323

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