UNEP— INDUSTRY & ENVIRONMENT TECHNICAL REVIEW SERIES

ENVIRONMENTAL ASPECTS OF IRON AND STEEL PRODUCTION

A Technical Review

UNITED NATIONS ENVIRONMENT PROGRAMME

UNEP - Industry & Environment Technical Review Series

Environmental Aspects of Iron and Steel Production

A Technical Review

First edition 1986

ISBN 92 807 1079 6

The designation employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the United Nations Environment Programme concerning the legal status of any country, territory, city or area or of its authorities, or concerning delimitation of its frontiers or boundaries. Moreover, the views expressed do not necessarily represent the decision or the stated policy of the United Nations Environment Programme, nor does citing of trade names or commercial processes constitute endorsement.

Environmental Aspects
of Iron and Steel Production

A Technical Review

Industry & Environment Office
UNITED NATIONS ENVIRONMENT PROGRAMME

FOREWORD

Within the context of UNEP's ongoing review of the environmental aspects of specific industries a workshop was held in Geneva in October 1978 on the environmental aspects of the iron and steel industry. The proceedings of this workshop have been published (1).

With a view to making more widely known the environmentally related issues associated with steel making, and drawing on the material gathered in association with the workshop along with information subsequently made available, the UNEP secretariat has prepared two publications, namely an overview and a technical review. The overview, directed towards the environmental policy makers in governments and industry, is meant to summarize the decision and policy aspects regarding the environmental impact of the iron and steel industry. The overview was published in March 1985 (2).

The technical review, prepared to support and supplement the overview, deals with the technical aspects of environmental management in steel making. It covers primarily the air and water pollution, solid waste and noise problems associated with new integrated steel works based on the classical production route. It does not cover retrofitting of old plants and environmental aspects of ore mining and transportation, nor does it deal in detail with the direct reduction route to steel making, which is the subject of another publication (3).

This technical review does not cover the very important issue of occupational hygiene. Readers are advised to refer to ILO and WHO publications, (4) and (5), and also soon to UNEP Environmental Management Guidelines for Iron and Steel Works which are now under preparation.

The first draft of the present document was developed in February 1983. Therefore, it may not include some recent developments. However, on the basis of the peer review, UNEP decided to publish it as it was without waiting for any further modifications.

---

(1) See UNEP Industry and Environment Workshop Proceedings Series, Volume 1: Environmental Aspects of the Iron and Steel Industry (1980)

(2) UNEP Environmental Aspects of Iron and Steel Production - An Overview (1984)

(3) UNEP Environmental Aspects of the Direct Reduction Route to Steel Making - A Technical Review (1983)

(4) Occupational Safety and Health in the Iron and Steel Industry, ILO, Geneva (1983)

(5) Occupational Health Control Technology in the Iron and Steel Industry, WHO, Geneva (1986)

ACKNOWLEDGEMENTS

The secretariat gratefully acknowledges the assistance of the UNEP consultant, Mr. Jean Raguin, President of the Laboratoire d'Etude et de Contrôle de l'Environnement Sidérurgique, LECES, France.

The secretariat further acknowledges the valuable suggestions and comments on the text provided by:

Dr. B. H. Dieterich (WHO)

Mr. S. Das Gupta (M. N. Dastur & Company Ltd., India)

Mr. M. Hanafusa (Kawasaki Steel Corporation, Japan)

Dr. Y. Hasegawa (WHO)

Mr. S. Gagliardi (Italimpianti, Italy)

Mr. P. Gény (former Environment Consultant to the French Iron and Steel Federation)

Mr. T. Matsuda (International Iron and Steel Institute (IISI))

Mr. Obata (Brazil)

Mr. G. G. Carinci (Midrex Corporation, USA)

Mr. E. F. Young, Jr. (American Iron and Steel Institute)

Mr. A. Sacchini (Italimpianti, Italy)

Mr. Tsoting Wen (Beijing Central Engineering and Research Incorporation of the Iron and Steel Industry, People's Republic of China)

Mr. Wenlong Shu (Research Institute of Environmental Protection, Ministry of Metallurgical Industry, People's Republic of China)

Mr. D. Larré (UNEP Industry and Environment Office)

Mr. C. A. Cochrane (UNEP Consultant)

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

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SECTION 1

THE WORLD STEEL INDUSTRY

1.1 The Geography of Steel

Whilst at present world steel production is preponderantly in the industrialized countries, there is a trend for the steel industry to develop in all countries with sufficient land area and population. Table 1 summarizes steel consumption for different geographical areas of the world (reference years 1978-1984). Figure 1 illustrates the divergence which still exists between developed and developing countries. The difference is clearer still if, rather than production achieved (table 2), steel consumption figures are considered. Comparison of tables 1 and 2 shows that at present, a very substantial part of the steel consumption of the developing countries is still supplied by imports from the developed countries.

1.2 Steel Production Techniques

1.2.1 Processes

The steel industry draws on two main iron-based raw materials:

- iron ore;

- iron and steel scrap.

For these two main sources, there are two corresponding categories of steelworks:

- integrated works, working from iron ore (figure 2);

- mini-mills, recovering scrap (figure 3).

Such a breakdown is excessively crude, since integrated works also remelt scrap and certain mini-mills include installations up-stream from their steelshop for pre-reduction of iron ore (figure 4).

1.2.2 Integrated works layout.

Figure 2 shows the main sectors of an integrated works, namely:

- STOCKING and HANDLING the basic raw materials (coal, ore, fluxes).

- COKING, where, by controlled heating of coal, the metallurgical coke for producing pig iron in the blast furnace is made, the high-energy coke-oven gas being recovered.

- SINTERING, where the crushed and ground ore is brought to high temperature by combustion of coal fines or coke breeze and turned into a product (called sinter) with suitable mechanical strength and porosity for high-performance modern blast furnaces.

Another technique with the same end is pelletizing. This consists of hardening moist pellets of fine ore in a rotary furnace at high temperature.

- BLAST FURNACE, which is charged with sinter or pellets and coke and from the base of which liquid pig iron and slag are removed by tapping, gas being recovered in the air-tight circuits at the "throat".

- OXYGEN CONVERTER, in which the liquid pig iron is refined into liquid steel by oxidation of its C, Si, P and Mn components. In some countries there are also open-hearth furnaces which are particularly flexible as regards charging with pig iron or scrap.

- CASTING to solidify the liquid steel in the form of ingots (traditional casting) or longer products such as billets or slabs (continuous casting).

- ROLLING MILLS, for hot forming solid steel and even also for cold working thinner products at the end of the cycle.

- REHEATING FURNACES, used to bring the products to the desired temperature between rolling passes.

- FURTHER PROCESSING POINTS, such as ingot scarfing, acid pickling, tinning, galvanizing and lead coating.

1.2.3 Mini-mill layout

In a mini-mill, (figure 3), some of the processing is the same: casting, reheating and rolling. The conversion shop processing liquid pig iron is, however, replaced by the steelshop in which electric arc furnaces remelt scrap. In certain rare cases, instead of an electric arc furnace, an open-hearth furnace heated by burners can be found.

1.2.4 Direct reduction process

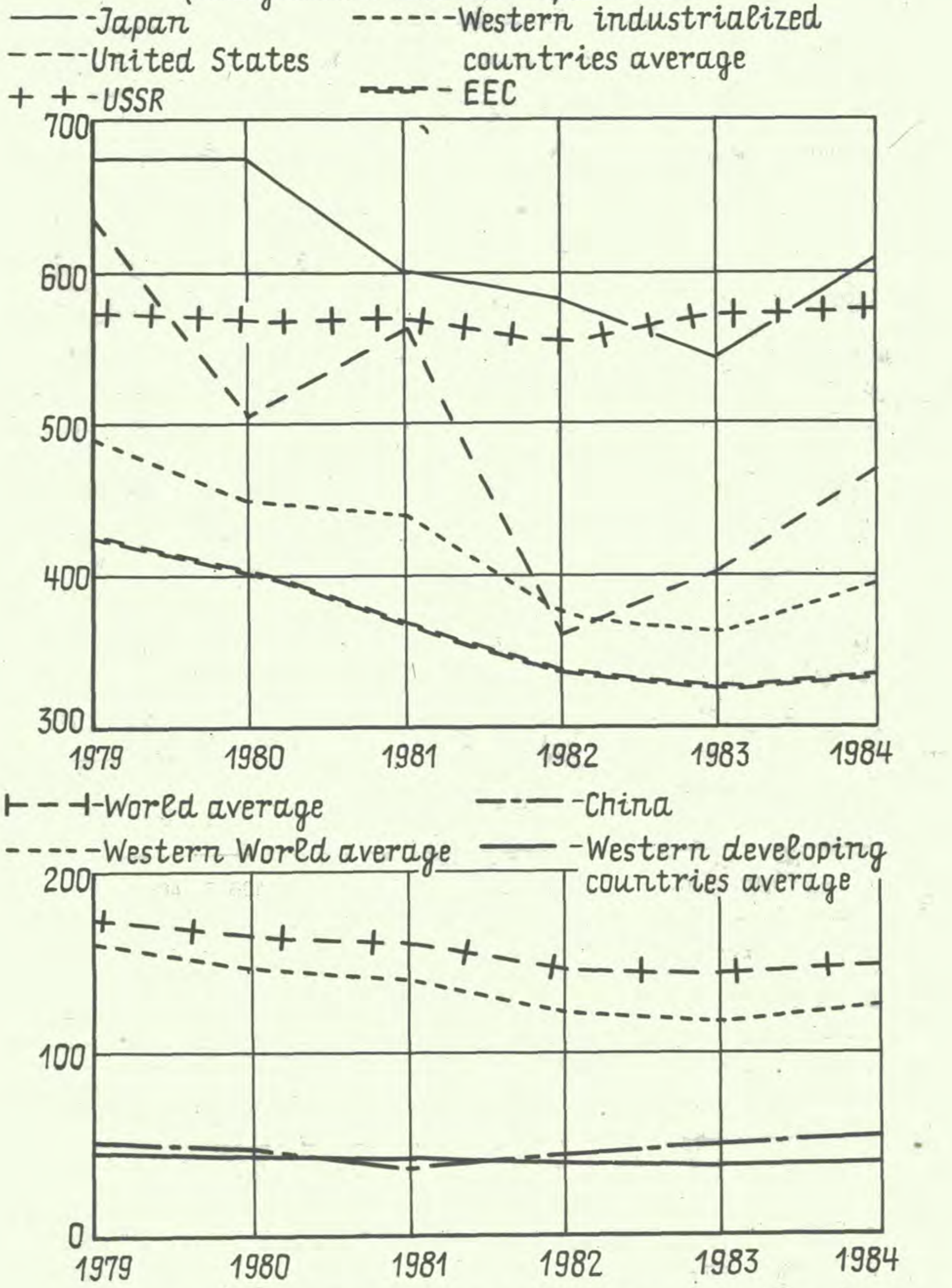
Direct reduction of iron ores is a solid-state process. The idea is to avoid the series of operations of integrated works: reduction itself and super-reduction (i.e. reduction not only of the iron oxides but also of a number of non-ferrous oxides) and carburation of the metal in the blast furnace followed by oxidation in the steelmaking shop. For a long time a more direct route from ore to steel has been sought (see figure 4).

In the last thirty years, various processes have been developed throughout the world (1). There are two main groups:

---

(1) For a detailed report on the direct reduction route to steel making see UNEP Report on the Environmental Aspects of the Direct Reduction Route to Steel Making

Figure 1
Apparent Steel Consumption per Capita
1979 to 1984
(kilograms crude steel equivalent)



Source: IISI (International Iron and Steel Institute)

Table 1
Apparent world steel consumption
(1979 to 1984)

	1979	1980	1981	1982	1983	1984
Japan	78.5	78.8	72.3	70.0	66.3	73.8
EEC	113.9	108.2	99.1	91.4	90.0	94.1
Other Western Europe	30.9	32.1	31.4	30.5	29.6	30.0
United States	142.6	118.4	128.2	92.1	96.0	114.3
Canada	14.9	13.8	14.4	10.5	11.3	13.1
South Africa	5.5	6.4	6.6	5.8	5.3	5.6
Oceania	7.3	7.2	7.4	6.8	5.8	6.9
TOTAL Industrialized Countries	393.6	364.9	359.4	307.1	304.3	337.8
Latin America	32.5	36.8	34.3	29.3	23.3	28.1
Africa, except South Africa	9.4	10.7	11.1	11.1	12.2	12.3
Middle East	16.7	15.9	16.3	16.9	18.7	17.9
Asia, except Japan, China and DPR Korea	38.1	40.4	43.1	44.4	45.5	47.5
TOTAL Developing Countries	96.7	103.8	104.8	101.6	99.7	105.8
TOTAL Western World	490.3	468.7	464.2	408.7	404.0	443.6
USSR and Eastern Europe	211.3	209.6	205.9	204.6	211.0	215.0
China and DPR Korea	50.9	49.5	45.3	48.1	57.0	61.5
TOTAL Centrally Planned Economies	262.3	259.1	251.3	252.7	268.0	276.5
TOTAL WORLD	752.6	727.8	715.5	661.4	672.0	720.1
Unallocated	- 6.1	-11.8	- 7.9	-16.4	- 8.8	-10.2
WORLD CRUDE STEEL PRODUCTION	746.5	716.0	707.6	645.0	663.2	709.9

Source: IISI (International Iron and Steel Institute)

Table 2

The major steel-producing countries and areas, 1983 and 1984

(million metric tons crude steel production)

	1984		1983	
	Rank	Tonnage	Rank	Tonnage
USSR	1	154.3	1	152.5
Japan	2	105.6	2	97.2
United States	3	83.9	3	76.8
China	4	43.4	4	40.0
FR Germany	5	39.4	5	35.7
Italy	6	24.0	6	21.8
France	7	19.0	7	17.6
Brazil	8	18.4	11	14.7
Poland	9	16.6	8	16.2
United Kingdom	10	15.1	10	15.0
Czechoslovakia	11	15.0	9	15.0
Canada	12	14.7	13	12.8
Romania	13	14.3	12	12.6
Spain	14	13.5	14	13.0
Republic of Korea	15	13.0	15	11.9
Belgium	16	11.3	17	10.2
India	17	10.5	16	10.2
South Africa	18	7.7	19	7.0
German DR	19	7.5	18	7.2
Mexico	20	7.5	20	6.9
DPR Korea	21	6.5	21	6.1
Australia	22	6.2	22	5.6
Netherlands	23	5.7	24	4.5
Taiwan	24	5.0	23	5.0
Austria	25	4.9	25	4.4
Sweden	26	4.7	26	4.2
Turkey	27	4.3	28	3.8
Yugoslavia	28	4.2	27	4.1
Luxemburg	29	4.0	30	3.3
Hungary	30	3.8	29	3.6
Bulgaria	31	2.8	32	2.8
Venezuela	32	2.7	34	2.3
Finland	33	2.6	33	2.4
Argentina	34	2.6	31	2.9
Others		15.1		13.6
WORLD TOTAL		709.9		663.2

This table lists all countries producing more than two million metric tons of crude steel in 1984

Source: IISI - International Iron and Steel Institute - 1984

Figure 2
Plan of a large integrated works

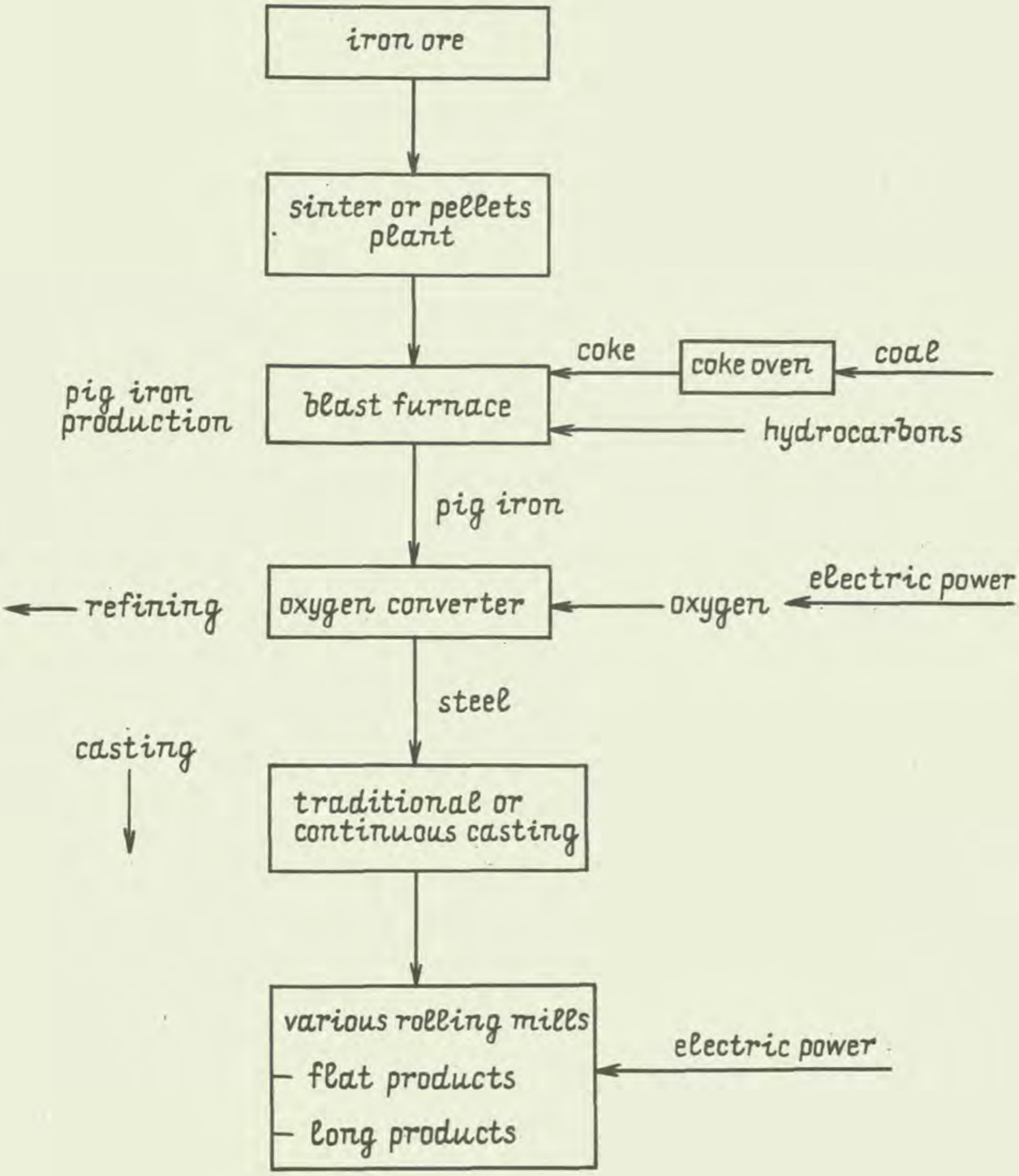


Figure 3
Plan of a mill based on scrap melting

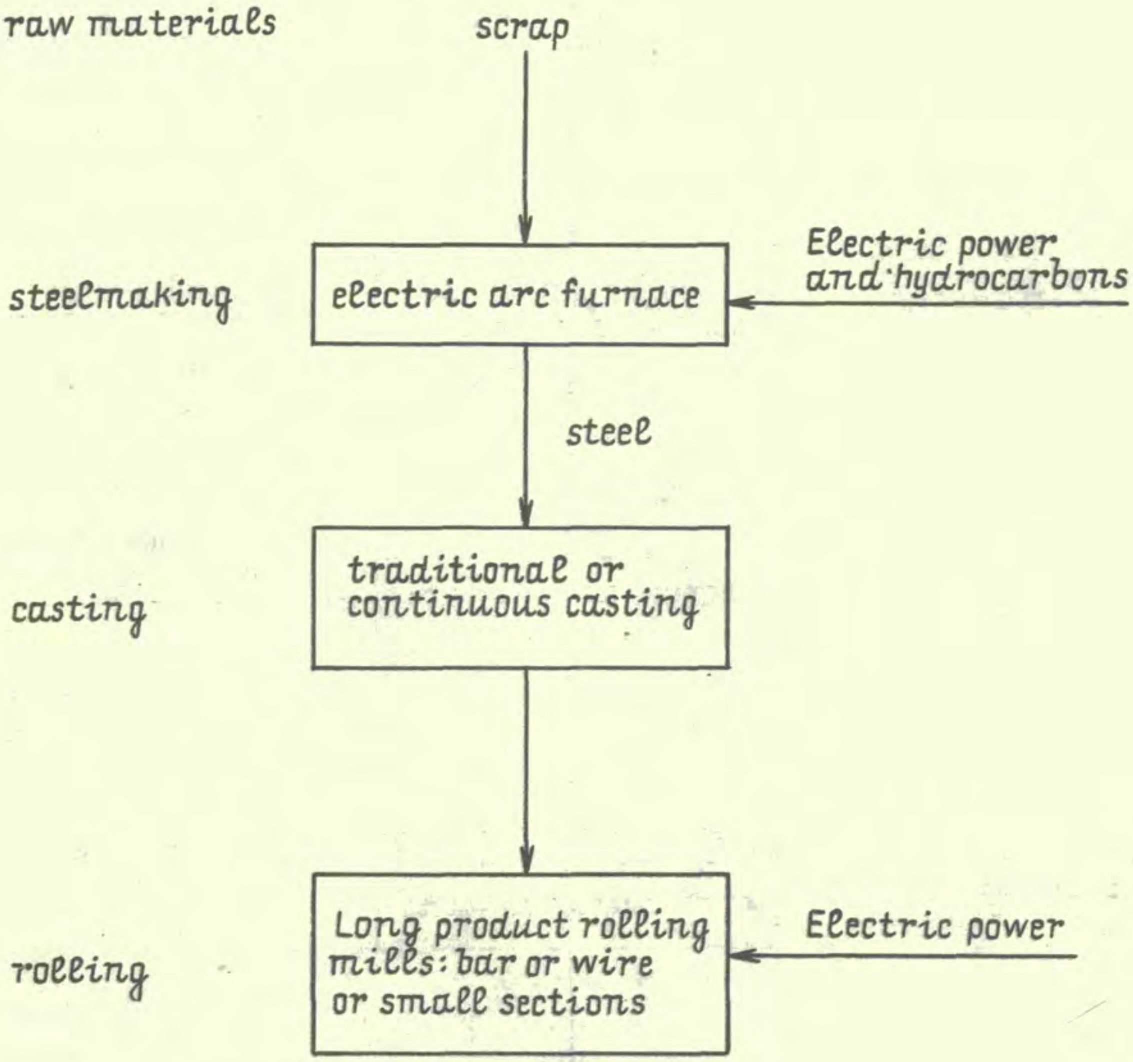
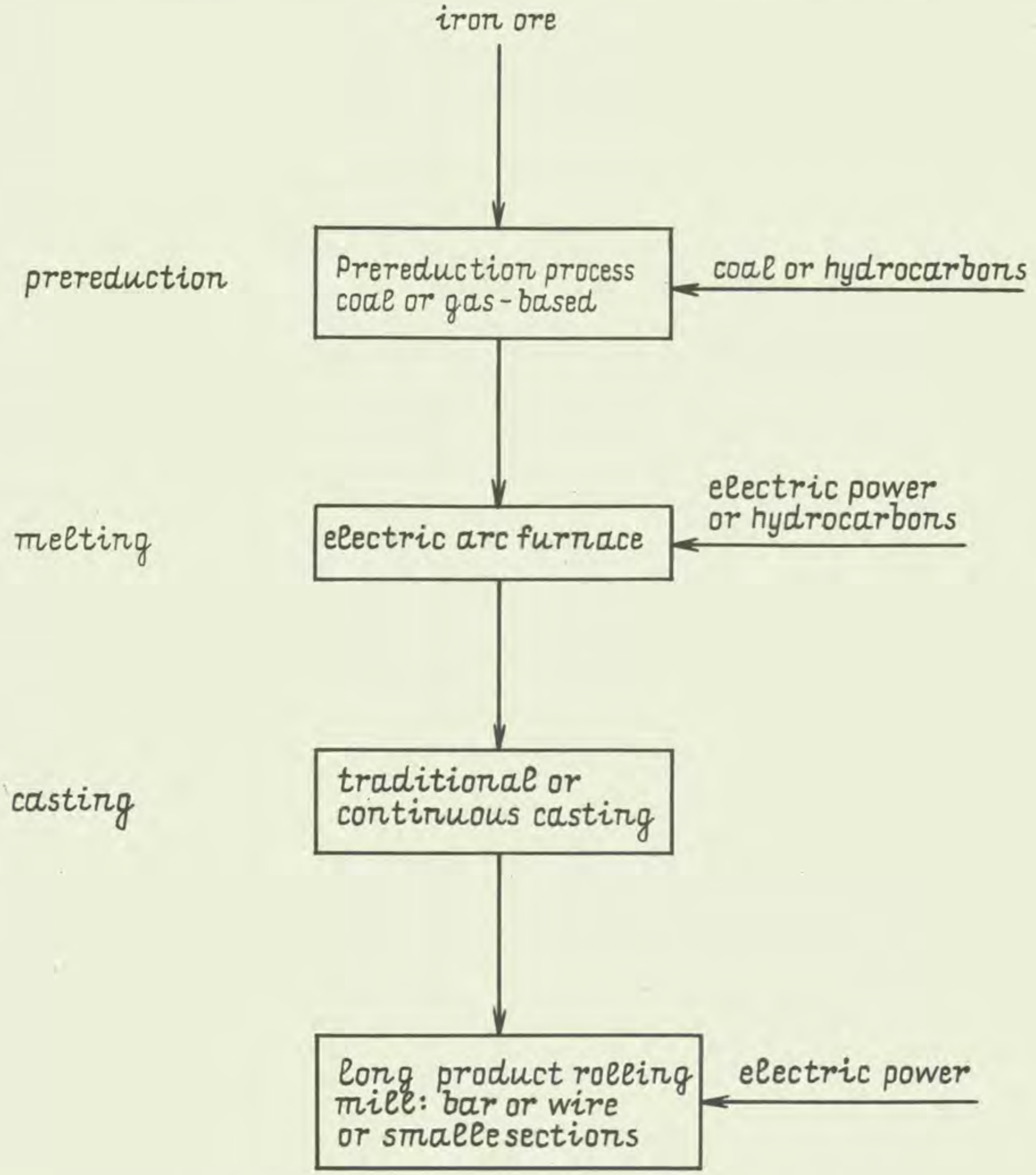


Figure 4

Plan of mini-mill based on direct reduction process



- processes based on reducing gases (CO, H_2), whether these are implemented in shaft furnaces (the HyL, Midrex, Purofer, Armco processes) or in a fluidized bed (HIB, Fior processes);

- processes based on coal (SL/RN, Krupp processes).

Tables 3 and 4 give a precise break-down of direct reduction capacities by country, on the one hand, and by process, on the other. The impact of direct reduction will remain small, even if the data quoted in table 4 suggest a relatively quick expansion.

1.3 The Cost of Steel

Table 5 gives in 1978 French Francs an analysis of the price of rolled steel for the two main categories of rolled steel for the two main categories of steelworks:

- integrated works producing sheet and plate,
- mini-mills making bar.

The dominant importance of investment costs is illustrated in figure 5.

Energy is also a major influence in the cost of steel: 25% for integrated works; in which some 7,000 therms must be used per tonne of steel to convert it from ore to rolled product. This is illustrated in table 6, which gives three examples of integrated works. The effect of maintenance expenses should not be underestimated, either.

Table 3

Worldwide direct reduction capacity (million tpy)

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Argentina							0.33	0.33	0.75	0.75	0.75	0.75	0.75	0.93	0.93	0.93
Brazil				0.07	0.32	0.32	0.32	0.67	0.67	0.67	0.67	0.32	0.32	0.32	0.32	0.32
Burma												0.02	0.02	0.02	0.04	0.04
Canada				0.44	0.44	0.79	1.03	1.63	1.63	1.63	1.63	1.63	1.63	1.35	1.00	1.00
Egypt																
India											0.03	0.03	0.03	0.18	0.21	0.21
Indonesia									0.58	0.58	1.15	1.15	2.30	2.30	2.30	2.30
Iran								0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	1.53
Iraq										0.49	0.49	0.49	0.49	0.49	0.49	0.49
Italy				0.01	0.01	0.01	0.05	0.05	0.05	0.05	0.05	0.05	0.01			
Japan								0.05	0.15	0.15	0.15	0.15	0.15			
Libya																
Malaysia															0.85	1.25
Mexico	0.92	0.92	0.92	0.92	1.39	1.39	1.39	2.02	2.02	2.00	2.00	2.00	2.00	2.03	2.03	3.03
New Zealand	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Nigeria													1.02	1.02	1.02	1.02
Peru											0.10	0.10	0.10	0.10	0.10	0.10
Qatar									0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
South Africa				0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.23	0.83	1.11
Saudi Arabia													0.40	0.80	0.80	0.80
Sweden												0.07	0.07	0.07	0.07	0.07
Trinidad											0.42	0.42	0.84	0.84	0.84	0.84
UK										0.80	0.80	0.80	0.80	0.80	0.80	0.80
USA	0.30	0.70	1.03	1.03	1.03	1.03	1.03	1.03	1.09	1.09	1.09	1.09	1.09	1.03	0.70	0.40
USSR														0.42	0.42	0.83
Venezuela							0.76	1.12	1.12	2.39	3.80	4.50	4.50	4.50	4.50	4.50
F.R. Germany	0.15	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	1.43	1.28	1.28	1.28	1.28
Total	1.49	2.29	2.82	3.29	4.01	4.36	5.73	8.15	9.66	12.20	14.73	16.06	18.86	19.61	20.23	28.42

Source : MIDREX CORPORATION

Table 4

Worldwide direct reduction capacity by process (million tpy)

Process	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Midrex	30	1.10	1.10	1.50	1.50	1.50	1.83	2.79	3.61	5.66	6.10	6.98	8.82	9.82	10.47	11.78
HyL I	.92	.92	.92	.92	1.64	1.64	2.00	2.63	3.21	3.43	5.41	6.11	7.26	6.79	6.79	6.79
HyL III										.25	.25	.25	.25	.75	.75	1.75
NSC								.15	.15	.15	.15	.15	.15	.00	.00	.60
Purofer	.15	.15	.15	.15	.15	.15	.15	.83	.83	.83	.83	.48	.33	.33	.33	.33
Armco			.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.33	.00	.00
Fior							.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
Plasmared												.07	.07	.07	.07	.07
USCO																.25
KM				.01	.01	.01	.05	.05	.05	.05	.05	.07	.03	.02	.04	.04
SL/RN	.12	.12	.12	.19	.19	54	.54	.54	.59	.59	.72	.72	.72	.72	1.00	1.00
ORC									.06	.06	.06	.06	.06	.08	.08	.08
CODIR				.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15
ACCAR				.04	.04	.04	.28	.28	.28	.28	.28	.28	.28	.15	.15	.15
DAV																.03
Total	1.49	2.29	2.62	3.29	4.01	4.36	5.73	8.15	9.66	12.20	14.73	16.05	18.85	19.61	20.23	23.42
Gas Based	1.37	2.17	2.50	2.90	3.62	3.62	4.71	7.13	8.53	11.07	13.47	14.77	17.61	18.49	18.81	21.97
Coal Based	.12	.12	.12	.39	.39	.74	1.02	1.02	1.13	1.13	1.28	1.28	1.24	1.12	1.42	1.45

Source: MIDREX CORPORATION

Table 5

Extremely simplified structure of the price of a tonne of rolled steel

(1978 study)
In 1978 French Francs

based	Traditional integrated		Mini bar mill	
	flat products works (blast furnace and		on scrap melting with electric	
arc	oxygen converter)		furnace	
	F/t	per cent	F/t	per cent
Iron ores (0.8 t iron at 1.2 F/iron points)	96	14.4	-	-
Scrap	60	14.4	350	36.0
Power (coal, hydrocarbons, electricity, etc.)				
(700 kg coking coal at 335 F/t and 1000 th at 0.04 F)	275	25.4	-	-
(600 kWh at 0.12 F per kWh and 600 th at 0,04 F)	-	-	96	9.9
Miscellaneous supplies	150	13.9	130	13.4
Manpower (at 40 F/hr)	200	18.5	160	16.5
SUB TOTAL	781	72.2	736	75.8
Depreciation, interest on loans etc.	300	27.8	235	24.2
GRAND TOTAL	1081	100	971	100

Table 6

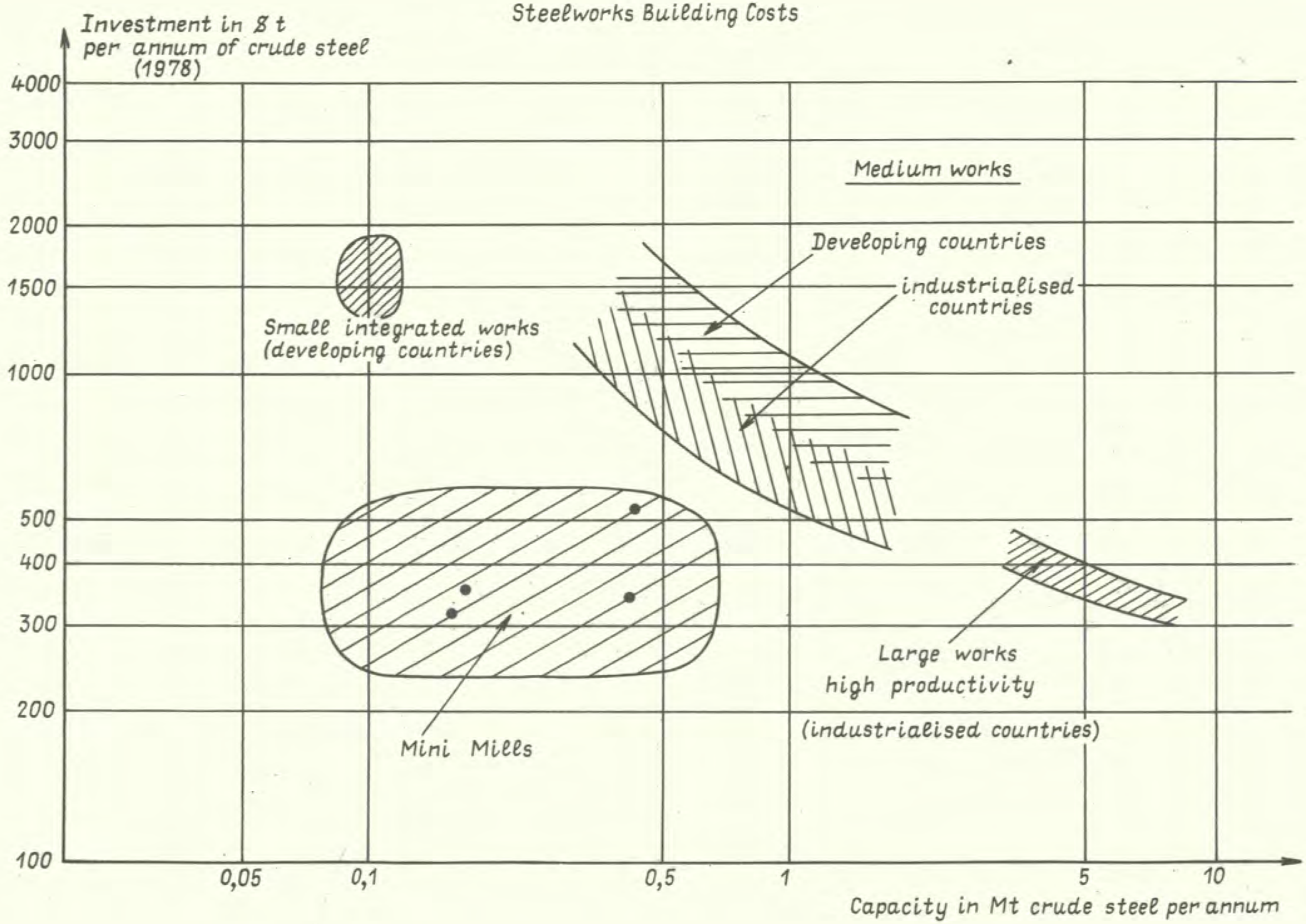
Gross energy consumption in an integrated works

(G cal/t liquid steel)

Solid fuel	Coke	Hydrocarbons	Electricity	Total
0.56	2.08	0.85	0.4	3.89
0.56	1.51	1.49	0.4	3.96
0.56	1.12	2.24	0.4	4.32

Figure 5

Steelworks Building Costs



BIBlIOGRAPHY FOR SECTION 1

1.1 The Geography of Steel

- Development of steel industry in the world until 1985, Nippon Steel News, July 1980, 123, p. 1-2

- Hiebler, M., Future perspectives in the steel industry in the 1980s (original: Portuguese), B.H.M. March 1980, 125, No. 3, p. 151-159

- OECD Symposium on the steel industry in the 1980s (27-28 February 1980, Paris)

- Schauwinhold, D., Evaluacion del consumo del acero, XXth ILAFA meeting, Santiago de Chili, Oct. 1979, p. 13-24

- World steel in figures 1980, 21 pages, International Iron and Steel Institute

1.2 Steel Production Techniques

- Astier, J., and Ch. Roederer, La préréduction des minerais de fer comme nouvelle filière d'élaboration de métal primaire en sidérurgie, Rapport de l'Institut de Recherches de Sidérurgie Française, RFP 258, Nov. 1978

- Darnell, H., Project management for raw material preparation plant introducing the life cycle concept, SEASI Conference on Raw Materials, Feed and Energy Sources for the Iron and Steel Industry, Philippines, Oct. 1978

- Guide to iron and steel manufacture (Gemeinfassliche Darstellung des Eisenhuettenwesens) Verein Deutscher Eisenhüttenleute, 1971

- Instituto Latinoamericano del Fierro y el Acero (ILAFA), Reduccion directa 80, Santiago de Chile, 1980, in-4°, 243 p.

- Leonidov N.K. and P.P.Arsentiev, Sciences and Techniques, Iron and Steel, No. 11, Ed. Moskow, 1979, 230 p.

- Meyers, S., A system analysis study of the integrated iron and steel industry, ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE. 71-15251

- Rose, S., The sponge iron in steel's future, Fortune, Jan. 1977, 45, No. 1, p. 106-119

- Szekely, J., The role of innovative steelmaking technologies, Iron and Steelmaker, December 1979

1.3 The Cost of Steel

- Astier J., H. Della Casa and P. Emery, L'utilisation de l'énergie et ses perspectives dans les diverses filières d'élaboration de l'acier, Rapport extérieur de l'Institut de Recherches de la Sidérurgie Française (IRSID), RE 196, June 1974, 23 p.

- Bambrick S., Developments in the world steel industry, SEASI Conference on Market Factors and their Effect on Steel Industry Development and Location, Newcastle, March 1980

- Brunner J.H.K., The economics of location in the iron and steel industry, SEASI Conference on Market Factors and their Effect on Steel Industry Development and Location, Newcastle, March 1980

- Kuhl R.J., Capital investment and steel industry growth in developing countries, SEASI Conference on Prospects for Mini-Steel Mills, Indonesia, April 1979

- Kuhl R.J., Some characteristics of the steel markets in developing countries and their implication, SEASI Conference on Market Factors and their Effect on Steel Industry Development and Location, Newcastle, March 1980

SECTION 2

POLLUTANT DISCHARGES IN THE STEEL INDUSTRY

2.1 Air Pollution

Among the public at large, the steel industry is reputed to be a dirty industry. While this opinion was accurate for many years, it now needs to be completely revised on account of the technical advances of the past twenty years and the installation of numerous pollution control units. The latest installations, be they coke-ovens, sintering plants, blast furnaces, steelmaking shops or rolling mills, are typical examples of works which may now be said to be "dust free", provided they are properly operated and maintained.

2.1.1 Main pollutants

In its production processes, a steelworks produces particulate pollutants (i.e. dust) and gaseous pollutants. As the case may be, these are captured or discharged into the atmosphere.

With dust, a distinction is drawn between:

- dust of a relatively bulky grain size found deposited on the ground in the vicinity of works and classed as grit or "course dust", and

- submicronic or micronic particles liable to be carried over great distances, constituting what is called "suspended dust". The most typical example in the past was the red fumes from a basic Bessemer converter.

As gaseous pollutants, the following can be cited:

- sulphur dioxide (and to a lesser degree, sulphuric acid aerosol) from the sulphur present in the fuels or ore;

- nitrogen oxides, which the steel industry discharges like any industry using combustion processes;

- in certain works, emissions of carbon monoxide;

- in certain cases, gaseous combinations of HF or HCl, the quantities of which depend on the composition of the ores used in sintering or on the amount of fluorspar charged in the steelmaking shops.

2.1.2 Emission

The steel industry uses raw materials of a fine grain size and requires very high temperature processes. If no special precautions were taken, they would, therefore, be a source of considerable air pollution, as attested by some descriptions of steelmaking areas at the time of the Industrial Revolution, when dust and gas discharges per tonne of steel produced were considerable.

Advances in processes have, in fact, practically always been accompanied by a notable reduction in air pollution, with frequent inclusion of installations for capturing and cleaning dust and fumes. A typical example is provided by the blast furnace: top gas recovery, developed primarily for energy economy, has almost completely suppressed discharge to the atmosphere.

The fact remains, however, that iron and steelworks are still relative sources of air pollution, as illustrated in table 7 (particulate emission) and table 8 (gaseous emissions).

These data call for some comments:

- A notable pollutant in weight is carbon monoxide (CO), basically discharged in the fumes from sintering. These may, for example, contain 1 per cent CO in a discharge of 2,500 Nm^3 per tonne of sinter.

- The pollutants ranked second in importance in table 8 (although this is not always so), are sulphur oxides (SO_2 and sulphuric acid aerosol). As with carbon monoxide, the main source of emission is the sintering plant.

On dust, table 7 seems particularly severe where ore sintering is concerned. In fact, great progress has been made in the past ten years and cleaning performance brings about dust discharge figures well below those given here.

Nitrogen oxides (NO and NO_2) appear in all operations in which solid fuels (coke in the blast furnace, coke breeze or coal fines in sintering), liquid fuels (fuel oil in the blast furnace) or gaseous fuels (natural or recycled gas injection) are used.

- Hydrofluoric acid is a particular case linked to the ore supply.

2.2 Water pollution

As explained in section 3 below, the assessment of all possible ecological effects of water pollution is not really possible. Technically this assessment has to be in terms of chosen parameters on which there is consensus with regard to their significance and the methods of their measurement. Even so the interpretation of the data obtained requires careful evaluation.

2.2.1 Concept of pollution potential

The most rational appreciation of the pollution potential of a plant would be the assessment of the environmental effect of operating the processes in open circuit, i.e. no recycling or treatment of discharges.

Table 7

Particulate emission factors for iron and steel plants

1. Iron and steel process

Source	Units	Emissions	Emission Factor Rating
Blast furnace			
Slips	kg(lb)/slip	39.5 (87)	D
Uncontrolled cast house emissions	kg/Mg (tonne) hot metal		
Monitor		0.3 (0.6)	B
Tap hole and trough (not runners)		0.15 (0.3)	B
Sintering			
Windbox emissions	kg/Mg (lb/tonne) finished sinter		
Uncontrolled			
Leaving grate		5.56 (11.1)	B
After coarse particulate removal		4.35 (8.7)	A
Controlled by dry ESP		0.8 (1.6)	B
Controlled by wet ESP		0.085 (0.17)	B
Controlled by scrubber		0.235 (0.47)	B
Controlled by cyclone		0.5 (1)	B
Sinter discharge (breaker and hot screens)	kg/Mg (lb/tonne) finished sinter		
Uncontrolled		3.6 (6.8)	B
Controlled by baghouse		0.05 (0.1)	B
Controlled by orifice scrubber		0.295 (0.59)	A
Windbox and discharge	kg/Mg (lb/tonne) finished sinter		
Controlled by baghouse		0.15 (0.3)	A
Basic oxygen furnaces			
Top blown furnace melting and refining	kg/Mg (lb/tonne) steel		
Uncontrolled		14.25 (28.5)	B
Controlled by open hood vented to:			
ESP		0.065 (0.13)	A
Scrubber		0.045 (0.09)	B
Controlled by closed hood vented to:			
Scrubber		0.0034 (0.0068)	A
QBOP melting and refining	kg/Mg (lb/tonne) steel		
Controlled by scrubber		0.28 (0.036)	A

Table 7 (cont...)

Source	Units	Emissions		Emission Factor Rating
Charging	kg/Mg (lb/tonne) hot metal			
At source		0.3	(0.6)	A
At building monitor		0.071	(0.142)	B
Tapping	kg/Mg (lb/tonne) steel			
At source		0.46	(0.92)	A
At building monitor		0.145	(0.29)	B
Hot metal transfer	kg/Mg (lb/tonne) hot metal			
At source		0.095	(0.19)	A
At building monitor		0.028	(0.056)	B
BOF monitor (all sources)	kg/Mg (lb/tonne) steel	0.25	(0.5)	B
Electric Arc Furnaces				
Melting and refining	kg/Mg (lb/tonne) steel			
Uncontrolled				
Carbon steel		19	(38)	C
Charging, tapping and slagging	kg/Mg (lb/tonne) steel			
Uncontrolled emissions escaping monitor		0.7	(1.4)	C
Melting, refining, charging tapping and slagging	kg/Mg (lb/tonne) steel			
Uncontrolled				
Alloy steel		5.65	(11.3)	A
Carbon steel		25	(30)	C
Controlled by:				
Configuration 1 (building evacuation to baghouse for alloy steel)		0.15	(0.3)	A
Configuration 2 (DSE plus charging hood vented to common baghouse for carbon steel)		0.0215	(0.043)	C
Open hearth furnace				
Melting and refining	kg/Mg (lb/tonne) steel			
Uncontrolled		10.5	(21.1)	A
Controlled by ESP		0.14	(0.28)	A
Roof monitor emissions		0.084	(0.168)	C

Table 7 (cont...)

Source	Units	Emissions		Emission Factor Rating
Teeming				
Leaded steel	kg/Mg (lb/tonne) steel			
Uncontrolled (as measured at the source)		0.405	(0.81	A
Controlled by side draft hood vented to baghouse		0.0019	(0.0038)	A
Unleaded steel				
Uncontrolled (as measured at the source)		0.035	(0.07)	A
Controlled by side draft hood vented to baghouse		0.0008	(0.0016)	A
Machine scarfing				
Uncontrolled	kg/Mg (lb/tonne) metal through scarfer	0.05	(0.1)	B
Controlled by ESP		0.0115	(0.023)	A
Miscellaneous combustion sources 1/				
Boilers, soaking pits and slab reheat furnaces	kg/10^6 J (lb.10^6 BIU)			
Blast furnace gas		0.015	(0.035)	D
Coke oven gas		0.0052	(0.012)	D

1/ For fuels such as coal, fuel oil and natural gas, use the emission factors presented in section 1 of this document. The factor rating for these fuels in boilers is A, and in soaking pits and slab reheat furnaces, D.

Note

a) ESP = electrostatic precipitator. DSE = direct shell evacuation

b) Definition of Emission Factor Rating (see Supplement No. 10: For Compilation of Air Pollutant Emission Factors, Third Edition, AP-42, US EPA 1980 (PB 80-199045).

A - Excellent	B - Above average	
C - Average	D - Below average	E - Poor

Table 7 (continued)

2. Open dust sources

Operation	Emissions by particle size range (aerodynamic diameter)					Units[b]	Emission Factor Rating
	<30 μm	<15 μm	<10 μm	<5 μm	<2.5 μm		
Continuous drop							
Conveyor transfer sites	13	9.0	6.5	4.2	2.3	g/Mg	D
Sinter[c]	0.026	0.018	0.013	0.0086	0.0046	lb/T	D
Pile formation - stacker							
Pellet ore[c]	1.2	0.75	0.55	0.32	0.17	g/Mg	B
	0.0024	0.0015	0.0011	0.00064	0.00034	lb/T	B
Lump ore[c]	0.15	0.095	0.075	0.040	0.022	g/Mg	C
	0.00030	0.00019	0.00015	0.000081	0.000043	lb/T	C
Coal[d]	0.055	0.034	0.026	0.014	0.0075	g/Mg	E
	0.00011	0.000069	0.000052	0.000029	0.000015	lb/T	E
Batch drop							
Front and loader track[c]							
High silt slag	13	8.5	6.5	4.0	2.3	g/Mg	C
	0.026	0.017	0.013	0.0080	0.0046	lb/T	C
	4.4	2.9	2.2	1.4	0.80	g/Mg	C
Low silt slag	0.0088	0.0058	0.0043	0.0028	0.0016	lb/T	
Vehicle travel on unpaved roads							
Light duty vehicle[d]	0.51	0.37	0.28	0.18	0.10	kg/VKT	C
	1.8	1.3	1.0	0.66	0.37	lb/VMT	C
Medium duty vehicle[d]	2.1	1.5	1.2	0.70	0.42	kg/VKT	C
	7.3	5.2	4.1	2.5	1.5	lb/VMT	C
Heavy duty vehicle[b]	3.9	2.7	2.1	1.4	0.76	kg/VKT	B
	14	9.7	7.6	4.8	2.7	lb/VMT	B
Vehicle travel on paved roads							
Light/Heavy vehicle mix[c]	0.22	0.16	0.12	0.079	0.042	kg/VKT	C
	0.78	0.56	0.44	0.28	0.15	lb/VMT	C

b) Units/unit of material transferred. Units/unit of distances travelled
c) Interpolation to other particle sizes will be approximate
d) Interpolation to other particle sizes will be approximate
Source: The Compilation of Air Pollutant Emission Factors - third edition, supplement Nº 14, EPA, May 1983 PB83-250720 (tables 7.5.1 and 7.5.2)

Table 8

OECD Proposed Standard Emission Factors:

Gaseous Pollutants

	Unit	CO	SO_2	NO_2
Sinter plant	kg/t sinter	30	2	0.3
Coke oven	kg/t coke	1	0.5-2	0.65
Hot metal production	kg/t pig iron	10	0.2	0.5
Steel Production Converter	kg/t steel	15	-	0.3
Electric arc furnace		10	-	-
Rolling mills	kg/t product	-	-	1.1

Source: Emission inventory requirements and the use of standard emission factors in OECD Europe, OECD Environment Committee, Air Management Policy Group, September 1983, 8 p.

The values thus obtained can only be orders of magnitude because all works of the same type differ in some respects. Also there can be no practical check of accuracy of the assessment because open works with no waste treatment no longer exist and variations between forecasts and reality are always found on commissioning a plant.

2.2.2 Traditional parameters

There is a vast range of parameters from which to choose. Close attention must be given to a limited number of key parameters to which all the others are linked. These should be, in so far as possible, representative of physico-chemical reality and, if possible, traditional.

Those usually chosen are:

COD	Chemical oxygen demand
BOD	Biochemical oxygen demand after 5 days
SS	Suspended solids
Hydrocarbons	Hydrocarbon content
Conductivity	Linked to salinity
Toxic substances	Content in products potentially harmful to life in the aqueous medium and to the users of the water. There are many of these, depending on the works. Appendix 1 gives a list of toxic wastewater pollutants based on an American study.

2.2.3 Methods of measurement and analysis

The values obtained depend on the methods of measurement, sometimes to a very great extent. All results ought to be accompanied by an indication of the method used.

Since this entails serious disadvantages an international organization, ISO, is attempting to standardize methods throughout the world. This can only be a slow process, since sudden application of a new method immediately renders all experience acquired with the earlier methods obsolete.

Ways of sampling and conserving samples obviously form part of the concept of a method of analysis.

2.2.4 Examples of results from an ISO assessment

Table 9 gives some orders of magnitude of potential pollution devised by methods established by ISO, when such exist; otherwise, the analysis is by the most widely used method.

Such results must be interpreted on the basis of precise physico-chemical laws, on correct mathematical systems (statistics and probability) and finally on sure technical bases confirmed by experience.

Table 9

Extent of water pollution potential from the steel industry

Area	COD kg/t*	BOD5 kg/t*	Hydrocarbons kg/t*	Conductivity mRO/cm^{3}xm^{3}t	Toxic substances mg/1	SS kg/t*	
All cooling circuits				Increase by concentration and treatment products	Products	scant (coolant)	
Sintering Pelletizing	= 0	= 0	= 0	= 0	Ore impurity Zn,As,F,S,Cu,	0.01 0.140	dry dust cleaning wet dust cleaning
Coke oven plants	1 to 3	inhibited by toxics			NH_4 + 0.4/2.5 Phenol 0.4/0.8 CN^- 5.10^{-5} Cl^- 1.5	0.32	
Blast furnace	0.6				Cn 0/2	1.2 to 6	
Oxygen converters	= 0.06		0.1			3 to 40	

Note: * kg/tonne of steel

Source: personal previous experience

Table 9

(continued)

Area	COD kg/t	BOD_5 kg/t	Hydrocarbons kg/t	Conductivity mRO/cm^3xm^3t	Toxic substances	SS kg/t	
Continuous casting Hot rolling mills	0.05 to 0.1	= 0	0.1 to 0.4	0.005	= 0	0 to 30	according type
Pickling	0.5	20			H^+ 2/3 mols/t various	7 to 9	
Cold rolling mills	0.1 to 0.2	0.1 to 0.15	0.1 to 1			0.2 to 0.4	
Surface treatments	0.05	inhibited by toxics			Zn H^+ Cl Sn Cu etc.	0.1 to 0.15	

2.2.5 Leaching effluent from waste dumps

Particular reference must be made to waste dumps in which leaching of the dumped products occurs. As this process may be slow, it can continue over a long period. Pollution may reach watercourses, and the water table. It can also be mentioned that vegetables are able to assimilate most kinds of metals.

Particular mention should be made of the sulphur compounds formed from slag, soluble salts and also hydrocarbons from rolling mill waste. On the other hand, there seems little fear of pollution by heavy metals - Cd, Cr, Ni, Pb, Zn ... and various ions provided that:

- the deposits have a pH value near 7-8
- they contain calcium carbonate.

Approaching this pH value, in fact, wastes likely to be discharged by the steel industry are insoluble (solubility 10^{-6}mols/l) except Zn and Pb, the carbonates of which are insoluble. Complexes, however, and organic complexes in particular, must be considered, since they can render products with an insoluble base soluble.

2.2.6 Sampling

It should be noted that pollution of water is a function of two variables: emitted quantities of pollutants and assimilation capacity of these pollutants by the environment. Also the concept of pollution potential of a works is inexact. Its main merit is in giving an order of magnitude of what the result would be in the natural environment if the effluents from a works were not treated. The values quoted here are an example only and cannot be used as a basis for setting up water treatment projects. A specific study is required on each occasion, with visits to operating units with features resembling those planned.

2.3 Waste Pollution

2.3.1 Main waste

At all stages in its production cycle, the steel industry generates solid or liquid waste:

- Slag, which collects gangue compounds in the blast furnace and the steelmaking shop.

- Dust and sludge, recovered after screening the raw materials, dust cleaning of gaseous effluents, liquid waste treatment or works cleaning.

- Used refractories

- Oil and grease residues .

- By-products, from coking or from re-cycling treatments.

- The waste from human activity.

2.3.2 Waste generated

The extent of this waste depends on the production processes. A great amount is generated, especially if the original ores are low-grade and contain a large content of gangue, giving rise to blast-furnace slag. In mini-mills, little waste is generated. By way of example, figure 6 shows the distribution of wastes in a German plant. These emerge in tonnages close to those of liquid steel, because of the considerable quantity of slag produced by blast furnaces processing the low-grade ores of Lorraine.

2.3.3 Dumped waste

Most of the waste is utilized: blast furnace slag, converter slag are used as by-products, other wastes are recycled in the works. Finally a small proportion of waste is sent to the dump. Figure 7 shows the extent of these discharged wastes: in the order of 5 per cent of solid waste for the example already given in figure 6.

2.4 Harmful Effects of Noise and Vibration

2.4.1 Noise levels

The increase in the production capacity of steel plant, with the corresponding spread of mechanical installations (blowers, fans, motors) of handling facilities and transport apparatus are at the origin of the noise problems faced at present in certain large works.

The sound levels measured in the immediate vicinity of works can in fact be in excess of the danger point of 90 dB (A) for employees. Thus, at source in certain works, 120-130 dB (A) can be recorded in the area of a blast-furnace snort valve, 150-160 dB (A) with decompression on charging the top of a blast furnace, 110-120 dB (A) beside a UHP electric arc furnace, 100-110 dB (A) inside a finishing bay or near a shears. Similarly, the noise around a works may be hard to bear for those living nearby.

Figure 6

Breakdown of wastes generated in the steel industry of the Federal Republic of Germany

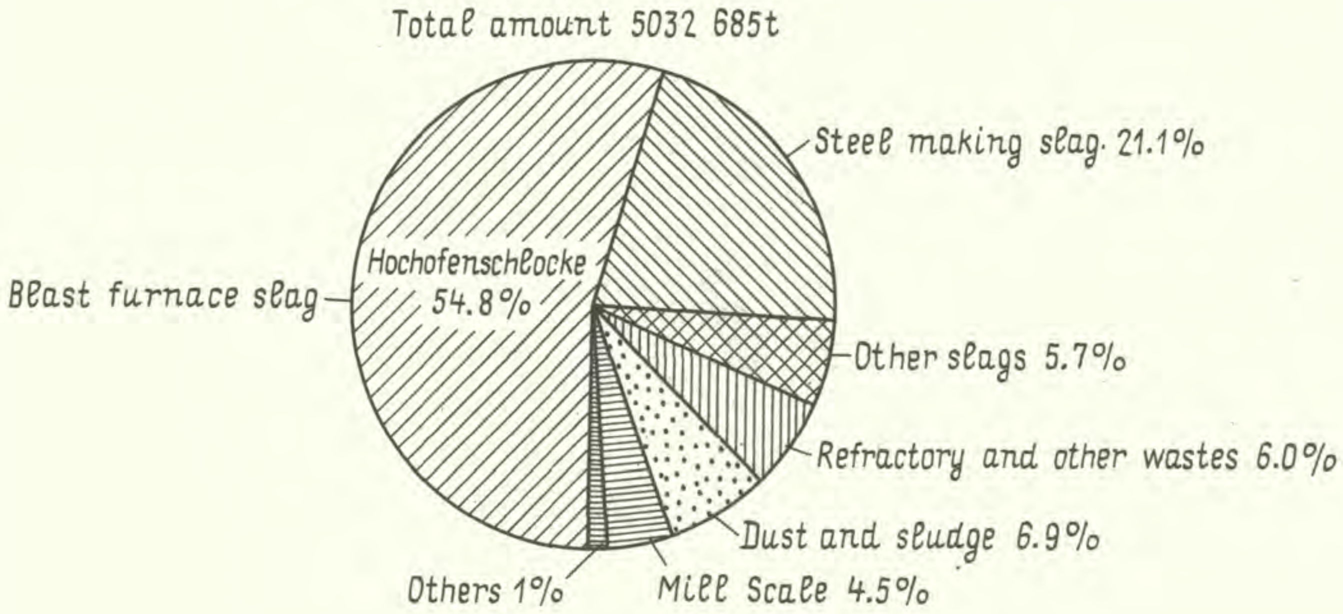
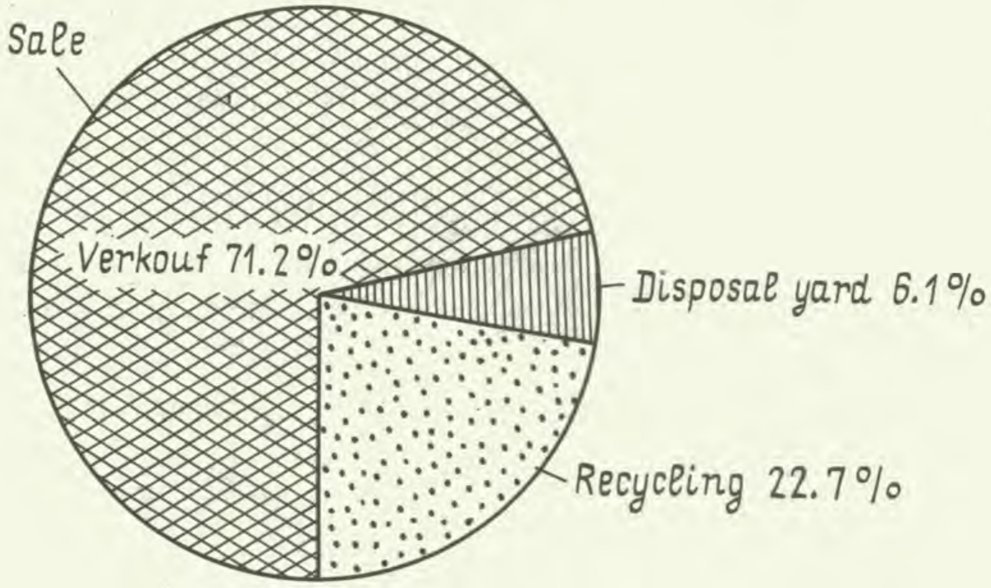


Figure 7

Utilization of wastes in the steel industry of the Federal Republic of Germany



Increasingly specific regulations are bringing steelworks to make a considerable effort to control noise. As a result of research, new techniques have been developed which reduce noise levels as measured both within and around the perimeter of works.

2.4.2 Origins of noise

In the steel industry, noise is distinguished in three broad categories:

- noise which is mechanical in origin, from rolling mills, forges or arising from handling or transport;

- noise of aerodynamic origin, from fans, compressors or valves;

- noise of electrical origin, particularly due to electric arc furnaces.

2.4.3 Vibration

In certain works, vibrations are observed. These have various causes, the following being designated in particular:

- mechanical vibrations (fans)

- vibration from combustion (cowpers)

- aerodynamic vibrations (gas ducts).

BIBLIOGRAPHY FOR SECTION 2

- Astier, J. et al., Sidérurgie et environnement, Journées des Ingénieurs Civils de France, Lyons, Jan. 1975 (in French)

- Darnell, H., The iron and steel industry and the environment, Metals and Materials, Jan. 1974, p. 48-52

- Gibrat, R., Ph. Vesseron, Steel industry and environment (Sidérurgie et Environnement), Annales des Mines, June 1976, p. 37-44

- Jarzebski, L. S., Iron and steel industry in Eastern Europe and pollution control, UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry, Geneva, Oct. 1978, UNEP Report UNEP/WS/IS.7

- Katari, V. S., and R. W. Gerstle, Industrial process profiles for environmental use, XXIV - The Iron and Steel Industry, EPA Report 600/2-77-023X, Feb. 1977, 213 p.

- Michau, A., and J. Raguin, Industry and environment: The best French iron and steel Works, French Ministry of Environment, Department for Industrial Environment, July 1981, 131 p.

- Obata, H., The environmental impact of the steel industry in developing countries, UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry, Geneva, Oct. 1978, UNEP Report UNEP/WS/IS.3

- Obata, H., Iron and steel industry in Brazil and environment control, UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry, Geneva, Oct. 1978, UNEP Report UNEP/WS/IS.5

- Pivont, J., State of the art of pollution control technology in the steel industry, SECS 12, Chicago, June 1979, SEC 2/C/O

- Ryszka, E., Atmospheric Protection against Polluting Emissions from the Steel Industry, Ed. Metallurgija, Moscow, 1979, 239 p.

- Szekely, J., The environmental impact of the steel industry in developed nations, UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry, Geneva, Oct. 1978, UNEP Report UNEP/WS/IS.4

- The First Annual Meeting on Pollution Control in Metallurgical Works, Iron and Steel (China), No. 6, Sept. 1980, p. 82

2.1 Air Pollution

- Andon'ev S.M., O. U. Filip'ev Gaseous and Dust Pollutants Emitted by Steelworks, Ed. Metallurgija, Moscow, 1979, 192 p.

- Compilation of air pollutant emission factors, third edition, supplement No. 14, US Environmental Protection Agency, Research Triangle Park, NC, May 1983, Report PB 83 - 250720

- Control of air emissions from coke plants: an APCA technical conference, Journal of the Air Pollution Control Association, Sept. 1979, 29, No. 9, p. 907-26

- Davies, G. D., Mesure et analyse des émissions véhiculées par l'air provenant des fours à coke compte tenu surtout de l'exposition du personnel, Exposé à la 6ème table ronde CECA "Recherches sur les cokeries et le coke", Luxemburg, Oct. 1980, No. 7.1

- Détrie, J. P., Atmospheric Pollution (La pollution atmosphérique), Ed. Dunod, Paris, 1969, 597 p.

- Eisenhut, W., and E. Langer, Résultats des études menées en vue de la construction d'une halle permettant le relevé de toutes les émissions liées au fonctionnement des fours à coke, Exposé à la 6ème table ronde CECA "Recherches sur les cokeries et le coke",Luxemburg, Oct. 1980, No. 72

- Johnson, D., Conference Report: The Industry and the Environment: Public Demand, Legislation and Cost of Pollution Control, Iron and Steel, Dec. 1971, 44, No. 6, p. 449-452

- Klein, F., and F. Teyssier, Theoretical and experimental study of the dispersion of sulphur dioxide emitted by a battery of soaking pits, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/2/103

- Le Vaguerese, P., M. P. Heap, and T. M. Lowest, Reduction of pollutants emissions in the flames with fossil fuel (La réduction des émissions de polluants dans les flammes de combustibles fossiles), Revue générale de thermique, Oct. 1974, XII, No. 154, p. 72-74

2.2 Water Pollution

- Development document for effluent limitations guidelines and standards for the iron and steel manufacturing - Point Source Category, US Environmental Protection Agency, Effluent Guidelines Division WH 552, Washington DC 20460, Report EPA 440/1-82/024, May 1982

- French Ministry of Environment, Water, Research, Environment (L'eau, la recherche, l'environnement), Les Journées de Montpellier, Oct. 1977

- International Union of Pure and Applied Chemistry, Industrial Waste Water, International Congress, Stockholm, 1970, Ed. Butterworths, London

- Tockmam, H. M., et al., Review of western European and Japanese iron and steel industry exemplary water pollution control technology, EPA Report 600/2-79-002, Jan. 1979

2.3 Solid Wastes

- Gény, P., et al., The co-products of French iron and steel works - Quantities produced and evaluated in 1974 - Outlook for the future (Les coproduits de la sidérurgie française: Quantités produites et valorisées en 1974 - Perspectives d'avenir), Revue de Métallurgie 76, Feb. 1979, No. 2, p. 99-112

- Görgen, R., and W. Theobald, Recycling in the steel industry of the Federal Republic of Germany (Recycling in der Stahlindustrie der Bundesrepublik Deutschland), Stahl und Eisen, 1977, 97, 14, p. 657-664

2.4 Noise and Vibration

- Briffa, F. E. J., et al., Combustion Noise, Journal of the Institute of Fuel, 46, No. 386, May 1973, p. 207-216

- Fragg, S. L., Combustion noise, Journal of the Institute of Fuel, Jan. 1963, p. 12-16

- Lesueur, C., Propagation and attenuation of waves in fluids (Propagation et atténuation des ondes dans les fluides), Revue générale de Thermique, Aug-Sept. 1976, KXV, No. 176-177, p. 651-661

- McQueen, D., Noise reduction in electric arc furnaces, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC 2/1/104

- Minister für Arbeit, Gesundheit und Soziales des Landes Nordrhein-Westfalen, Noise reduction in electric steelworks (Lärmschutz und Elektrostahlwerken), Bonner Universitätsbuchdruckerei, April 1980, 56 p.

- Toothman, E. H., Evaluation and control of certain environmental noise problems caused by steelmaking processes, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC 2/1/103

SECTION 3

ENVIRONMENTAL EFFECTS

Introduction

Environmental aspects cover two fields, that of pollution, which gives rise to adverse effects on the physical environment, and that of deterioration in the social aspects of the environment. Two types of effects on the environment may be described, namely those which are decidedly harmful and those which, while unpleasant, annoying or causing a nuisance, do not have direct harmful effects. The perception of unpleasantness or annoyance is highly subjective with different individuals or groups reacting differently, and it is also strongly influenced by vogues and preconceptions deriving from habits, traditions, ideologies and information media. Furthermore, unpleasantness or annoyance have comparative aspects in relation to the importance of associated advantages. History shows that what was and is considered to be unacceptably unpleasant to groups with a high standard of living, has been and is still quite acceptable to other, less-favoured groups because it represents an activity which is directly linked with improvements in their standard of living. Despite these variations in acceptability the fact remains that pollution and its harmful effects should be dealt with.

Here consideration will only be given to changes in the natural environment which can be brought about by steelmaking activity. It is difficult to categorize environmental problems in detail. While it is possible to discern overall effects, it is, in practice, often impossible to specify in detail the effects on the many components of the ecosystem. Another problem in assessing changes in the environment is the complexity of the normal fluctuations within ecosystems of which relatively few parameters are fully understood.

Any physico-chemical modification of an environment will entail the consequent modification of the living conditions of a whole series of organisms, to the advantage of some at the expense of others, and even fundamentally modifying some of them by mutation. A consequence of change is that the relationship between components of ecosystems may be damaged, not only as a direct result of the physico-chemical modifications, but also by modification of the environment itself. At the present time there is insufficient knowledge to predict most of these modifications or even reliably to detect them when they have happened. It is therefore possible only to give a general idea of the potential environmental effects of steelmaking. Problems of the social environment are not covered.

In recent years much attention has been directed to the possible harmful effects on human health of environmental pollutants particularly those in the atmosphere. This has resulted in constant advances in epidemiology, clinical research and experimental toxicology, each of which tend to modify previously held conclusions on acceptable levels of environmental pollutants for human populations. Thus in steelmaking, as in other industries, there should be a constant awareness of public health needs, of any relevant regulations and of the likelihood that as knowledge increases acceptable levels will be modified.

3.1 Principal Air Pollutants

As has already been emphasized, the steel industry has progressed considerably since the Industrial Revolution. All the technical progress which has been made during the last hundred years and above all, after the Second World War, has involved a considerable reduction in pollution and nuisance levels, as may be seen from tables 7 and 8 under paragraph 2.1.2. These tables show the order of magnitude of the quantities of pollutants discharged into the atmosphere by a relatively recent integrated steelworks (1970), with reference to the following pollutants: dust, carbon monoxide (CO), sulphur oxides (SO_2 and SO_3), nitrogen oxides (mainly NO AND NO_2) and fluoride compounds. In general, none of these pollutants present serious intractable problems to the environment in the vicinity of steelworks. However, some synergistic effects of certain pollutants (for instance, dust and SO_2) are possible and must be studied.

3.1.1 Dust

The steel industry has long been known for the visible fumes and clouds of dust produced. The main problem with these emissions is the dirt they cause rather than their specific toxicity, in contrast, for example, with lead-containing dusts. In practice, steelworks emit their own types of pollutant, which fall into two categories:

(i) Dusts made up of relatively coarse particles (diameter 10-100 µm) produced in the course of mechanical operations such as the storing, transfer, crushing, screening and charging of raw materials, which settle fairly rapidly, depending on size.

(ii) Particulates, produced in the course of high-temperature metallurgical processes (e.g. blast furnaces, steelmaking, oxygen scarfing). These mainly measure less than one micron in diameter and remain in suspension in the atmosphere for a long time.

In humans there are physiological mechanisms for dealing with inhaled particles. Larger particles are arrested by the mucous membranes of the nose and upper respiratory tract and conveyed to the throat. Smaller particles, measuring less than a few microns, can traverse the smaller airways and reach the lung alveoli. There, very small particles, less than 0.5 µm diameter, are readily expelled but others are retained and can be absorbed into the body by any route. Particles cleared by normal mechanisms from the respiratory tract are swallowed and can then be absorbed via the gastro-intestinal tract.

3.1.2 Carbon monoxide (CO)

Carbon monoxide gas is well absorbed through the lungs, enters the blood stream and binds to the haemoglobin of the red corpuscles to form carboxyhaemoglobin. Carbon monoxide competes for the same binding sites as oxygen and so reduces the oxygen carrying capacity of the blood. The reduction in the availability of oxygen for tissues leads to asphyxiation; some tissues are more sensitive than others e.g. nervous tissue. The effects of carbon monoxide are related to the level of carboxyhaemoglobin. This is linked not only to the concentration of carbon monoxide in the air but also to the duration of exposure, the volume of air passing through the lungs and the blood volume circulating. Effects on vision and mental function are detectable at carboxyhaemoglobin levels of 5 per cent. In individuals with certain forms of heart disease, levels of 2.5 per cent can be harmful. Individuals with some forms of lung disease are also at increased risk. To protect a general (non-smoking) population against carboxyhaemoglobin levels exceeding 2.5 per cent, the average atmospheric carbon monoxide levels should not exceed 11.5 $\mu g/m^3$. It is important to differentiate smokers because cigarette smoke can contain 460-575 mg/m^3 of carbon monoxide and heavy smokers may have carboxyhaemoglobin levels of 15-17 per cent. While the health risks presented by environments with high levels of carbon monoxide are serious there appears, in general, to be no risk of acute toxic effects in the vicinity of steelworks because of the dilution and resultant low levels of carbon monoxide.

In the environment there are some plants which can take up carbon monoxide and this affects growth hormones and thus their development.

3.1.3 Sulphur dioxide (SO_2)

Sulphur dioxide gas is a respiratory irritant. In humans it has been found that at atmospheric concentrations

- from 1 to 3 mg/m^3, it is noticeable as a taste rather than a smell,
- at 2.1 mg/m^3, early reduction of pulmonary function occurs,
- at 2.9 mg/m^3 there may be a suffocating sensation,
- at 10 mg/m^3, the pungent odour becomes easily identifiable,

- from 17 to 35 mg/m^3, irritation of the nose and throat occurs,

- at 58 mg/m^3 it causes irritation of the eyes.

At high concentrations inhaled SO_2 causes swelling (oedema) of the larynx, respiratory passages and lungs and impairs lung function. Sulphur dioxide may cause respiratory disease particularly in elderly people and very young children. For short and long-term exposures consistent with the protection of public health SO_2 levels should be low and of the order of 0.1-0.15 mg/m^3 24 hour mean values with approximately 50 per cent of these values for annual mean exposure.

The effects on flora are typically seen in the form of cankers. It also attacks building materials in a number of ways, corroding roofing and stone.

3.1.4 Sulphur trioxide (SO_3)

This anhydride is usually converted in the atmosphere to sulphuric acid mist or sulphate aerosols. A number of pollution accidents have resulted from chemical reactions between such sulphates and dusts. SO_3 is highly corrosive to living tissue as well as other material. It is more toxic than sulphur dioxide and, for example, affects respiratory function at levels of 0.35 mg/m^3.

It should be noted that combinations of oxides of sulphur and combinations with particulates are more harmful than exposure to the individual components.

3.1.5 Nitrogen oxides (NO and NO_2)

Nitric oxide (NO) gas is readily oxidized in the atmosphere to the dioxide (NO_2) and consequently the effects of NO_2 are more important. In the case of NO_2 for man:

- at approximately 0.2 mg/m^3 the pungent odour is detectable,

- at 1.3-3.8 mg/m^3 there are effects on respiratory function,

- short-term exposure (1 hour) to 47-140 mg/m^3 can cause bronchitis and pneumonia,

- at 560-940 mg/m^3 fatal pulmonary oedema can occur.

NO_2 can have acute and chronic respiratory effects following exposure to levels of 47 mg/m^3 or more. To protect public health, exposure, even short-term, should be kept low with guideline values in the region of 0.19-0.32 mg/m^3.

3.1.6 Fluorine compounds

The effects of fluorides on bone (including teeth) are known as fluorosis; basically it is an increase in bone density. In man a daily intake of around 0.1 mg of fluoride per kg of body weight produces mild fluorosis of the teeth. Skeletal fluorosis usually occurs only after several years of regular ingestion at a daily rate exceeding 8 mg of fluoride per kg of body weight.

In the case of animals, fluorosis has been noted in the vicinity of industrial installations, mainly due to the repeated ingestion of grass and fodder containing or contaminated on the surface with fluorides and to drinking fluoridated water. The most characteristic signs are the changes in the teeth and skeleton.

In the case of plants, fluorine poisoning produces a number of characteristic effects such as canker of the needles of fir trees, spruces, Norway pines and larch trees, deformation of the leaves of cherry trees, peach trees and almond trees, withering of cherries, and burn or blight in tulips and gladioli.

3.2 Principal Water Pollutants

3.2.1 Suspended particulate matter

This can reduce the light transmission properties of water and hence the ability of organisms living in it to photosynthesize. These organisms become deposited on the sides and bed of the body of water, change the surface conditions and thus affect the ability of plants to attach themselves. This, in turn, affects fish and the entire ecological cycle. Soluble particulate matter can change the chemical characteristics of the aquatic environment and affect the flora and fauna.

3.2.2 Hydrocarbons

Hydrocarbons prevent or slow down the transfer of oxygen from air in water. In the most extreme case, they can transform an aerobic medium into an anaerobic medium. The effects of their deposition on banks and beds of bodies of water are very powerful. They bring about virtual sterilization, leaving only a few resistant strains alive.

3.2.3 Oxidizable substances

These bring about a more or less rapid and severe depletion of the dissolved oxygen. It is even possible for dissolved oxygen to be eliminated altogether. The environment then exhibits classical anaerobia, with all the indications of putrefaction. However, if the oxidizable substances are biologically degradable and limited in quantity, they can result in an increase in the "productivity" of water courses (with an increase in algal, micro-organism and fish populations).

3.2.4 Toxic substances

Toxic substances are capable of producing substantial changes in environmental conditions, which can even result in complete inhibition of organisms. For example:

(i) In bases (OH^-) and acids (H^+) living organisms can only survive within narrowly-defined pH limits (about 4 to 9). Within these limits, the ecological cycle is a function of the pH. A change in the pH will modify the cycles, but continual variations will have the effect of destroying them, as will overstepping the limits.

(ii) Of the metals called the "heavy metals" (zinc, nickel, chromium, cadmium, mercury, manganese, molybdenum, lead etc.) and the metalloids, which may be grouped with them (fluorine, chlorine, iodine, arsenic etc.), some are essential to life. However, a shortage or an excess of them, may be extremely toxic at all stages in an ecological cycle, depending on species susceptibility and the different effects on individual organisms.

3.2.5 List of steel industry wastewater pollutants

Appendix 1 gives a list of major pollutants which are found in the wastewater of the works and particularly of the coke plants.

It is possible to distinguish:

- classical pollutants (cf. § 3.2.1 and 3.2.3)
- metalloids
- heavy metals
- organic compounds (polynuclear aromatic-hydrocarbons, aromatic-hydrocarbons, aromatic components).

3.3 Solid Waste

The waste from steel production is re-utilized within the industry, sold as a by-product or discharged. In recycling, there is always the danger of accumulation of toxic substances, which may lead to pollution of the working or outside environment, as has recently been found to be the case with thallium in the cement industry. No incident of this type has yet been reported in the steel industry, but precautions are being taken in particular with the recycling of waste containing lead or cadmium. Similarly, in the case of by-products care must be taken with regard to their ultimate use in consideration of possible toxic substances they may contain.

When materials are dumped, due consideration must be taken of the possibility of their leaching by rainwater. Such a leaching can ultimately affect the surface and groundwater. For example, blast furnace and steel melting slags disposed of as wastes have contaminated water due to leaching action. On the other hand more and more precautions are being taken to prevent pollution of surface or ground water by any toxic substances such as lead and hexavalent chromium.

3.4 Noise

Sound is perceived through the eardrum, which is a semi-rigid circular membrane separating the outer ear from the inner ear. It should be borne in mind that:

- the human ear does not perceive all frequencies. The audible frequency band ranges from 20 to 20,000 cycles per second or Hertz. A distinction may be made between three ranges: low-pitched, medium and high-pitched (figure 8).

- there is a threshold of audibility below which we cannot hear anything; at the other end of the scale, there is a maximum pressure level (threshold of pain) beyond which the eardrum will be destroyed.

- these two thresholds may be expressed in terms of acoustic pressure levels.

- at a frequency of 1,000 Hertz, the "threshold of audibility" is equal to 2×10^{-4} Pascals, and the "threshold of pain" is in the region of 10^2 Pascals.

- the thresholds of audibility and pain vary, as may be seen from figure 9.

Sound pressure is governed by the Weber-Fechner law, i.e. its variations correspond to an arithmetic progression while sounds vary on the basis of a geometric progression. This law is important because it forms the basis of the decision to denote acoustic levels not in terms of units of pressure (Pascals) but in another unit of comparison, the bel (or better still, its sub-multiple, the decibel).

In the steel industry, noise problems arise to a much greater extent inside the building than in the environment.

Figure 8

Classification of sound frequencies

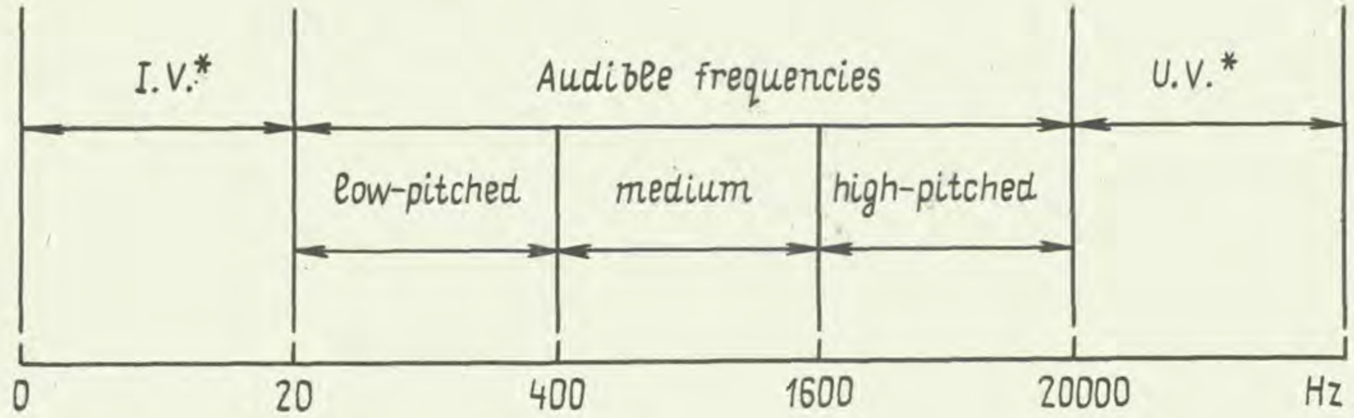
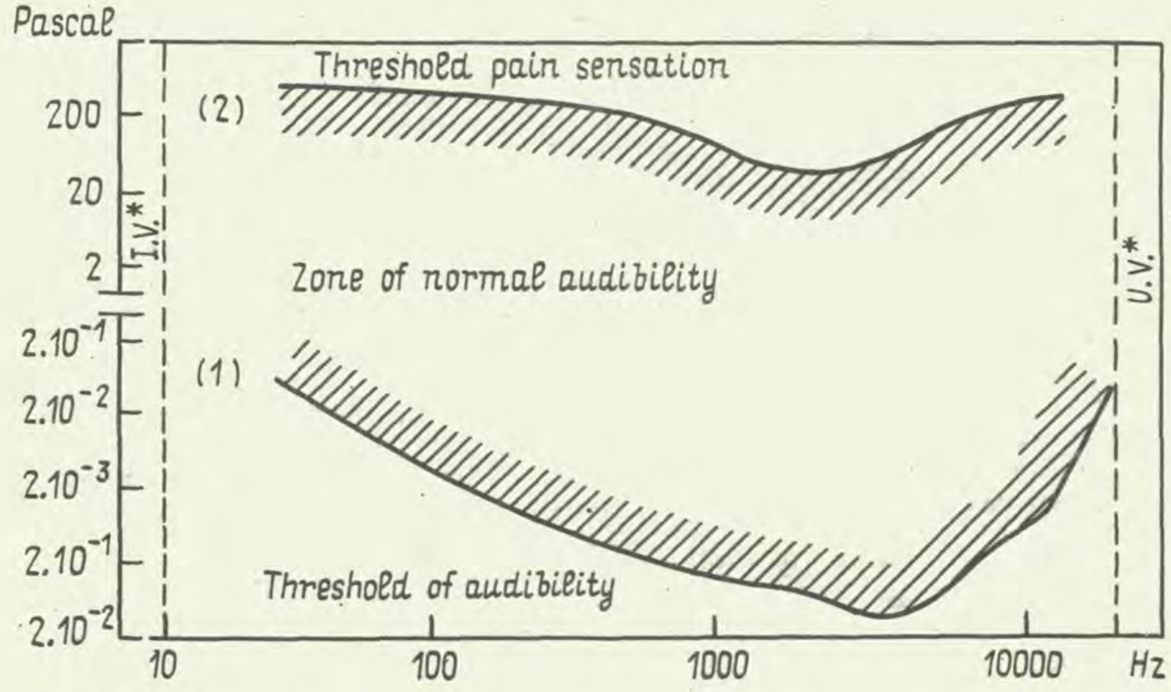


Figure 9

Threshold of audibility and pain in the human ear



*I.V.= Infrasonic vibrations.
U.V.= Ultrasonic vibrations.

3.5 Vibration

There are a number of cases where unpleasant vibration is evident, either in a workshop or in the proximity of certain installations. Vibration problems have for a long time been examined with respect to mechanical performance. At the present time, the consequences of vibration on man and the environment are also being considered. If they do in fact affect working conditions, certain frequencies emitted at very high intensities can give rise to problems and cause serious damage to the circulatory, muscular and neuro-sensory systems.

BIBLIOGRAPHY FOR SECTION 3

- Beale, J.G., The Manager and the Environment, Pergamon Press, Oxford, 1980

- Environment and Energy, Pergamon Press NY, 1979, 113 p.

- Instituto Latinoamericano del Fierro y el Acero, Pollution in Iron and Steel Industry (Contaminacion en siderurgia), Publicacion de la union de empresas y entidades siderurgicas, Madrid 1975, 513 p.

- Ramade, J., Applied Ecology (Elements d'écologie appliquée), Ed. Ediscience, 1974

- Schlipkötter, H. W., et al., Environmental load in the lands of the Federal Republic of Germany and its importance for health (Umweltbelastung in den Ländern der Bundesrepublik Deutschland und ihre gesundheitliche Bedeutung), Stahl und Eisen, 97, 1977,2,p.61-69

- Shimada, H., The development of Japanese environmental policy and basic trends in the 1980's, in current status and the problems of environmental control in the Japanese steel industry - International Iron and Steel Institute - Committee on Environmental Affairs, Tokyo, May 1980

- Weissweiler, F. J., Symposium City and Industry, Partners in Environmental Protection (Symposium Stadt und Industrie, Partner im Umweltschutz), Fachberichte Hüttenpraxis Metallweiterverarbeitung, 17, No. 7, 1979, p. 527-528

3.1 Principal Air Pollutants

- Adam, J. A., and J. H. Flux, Contamination by lead of the external and internal environment during the manufacture of steel, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC 2/6/132

- Amoudru, C., The idea of limit values in the atmosphere (La notion de concentration maximale admissible dans l'atmosphère), Industrie Minérale-Mine, 4-74, Dec. 1974, p. 262-263

- Diaconescu, Gh. I., UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-8442

- Herman, P., and F. Simon, Gaseous and odorous substances in the vicinity of cokeries, Staub, 33, 1973, p. 316

- Herman, S. W., The health costs of air pollution, a survey of studies published 1967-1977, American Lung Association, 1978, 135 p.

- Hogan, J. D., Physical and chemical characterization of refining furnace flue dusts, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/4/119

- Muhlrad, M. A., and M. J. Remilieux, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-12167

- Schimmel, H., and T. J. Murawski, SO_2-harmful pollutant or air quality indicator, Journal of the Air Pollution Control Association, July 1975, 25, No. 7, p. 739-740

- WHO (1977), Environmental Health Criteria No. 4; Oxides of Nitrogen, World Health Organization, Geneva, 79 p.

- WHO (1979), Environmental Health Criteria No. 8; Sulphur Oxides and Suspended Particulate Matter, World Health Organization, Geneva, 107 p.

- WHO (1979), Environmental Health Criteria No. 13; Carbon Monoxide; World Health Organization, Geneva, 125 p.

- WHO (1984), Environmental Health Criteria, No. 36; Fluorine and Fluorides, World Health Organization, Geneva, 135 p.

- WHO (1984), Technical Report Series No. 707; Recommended Health-based Occupational Exposure Limits for Respiratory Irritants, World Health Organization, Geneva.

3.2 Principal Water Pollutants

- Association française pour l'étude des eaux. Les micro-polluants minéraux dans les eaux superficielles continentales,
    No. 2 Al, Fe, Mn, Mo, Ti, V
    No. 3 Pb, Sn
    No. 4 Zn, Cd
    No. 5 F, Cl, Bn, I
    Documents AFEE, Paris

- Coïc, J. P., Composés organiques, Ed. Dunod, Paris, 1976, 303 p.

- S. Kiyotaki, The present and future outlook on counter-measures for anti-water pollution control in Japan, Suiyôkwai-shi, Oct. 1976, 19, No. 7, p. 359-367

- Problems of Air and Water Pollution Arising in the Iron and Steel Industry, UN/ECE Report ST/ECE/STEEL/32, 1970

- Serikov, N. V., UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-12115

- U.S. Regulations for drinking water, water and wastes engineering, Aug. 1977, 14, No. 8, p. 15

3.3 Solid Waste

- Etienne, P., Management of Slag-Heaps (La gestion des crassiers), Revue de Métallurgie, 76, Feb. 1979, No. 2, p. 135-137

- Fortescue, J. A., Environmental Geochemistry, Ed. Springer Verlag New York, 1980, 347 p.

- Lemoine, P., Research of the European Coal and Steel Community in the field of ferrous scrap treatment (Les recherches de la Communauté Européenne du Charbon et de l'Acier dans le domaine du traitement des déchets sidérurgiques), Revue de Métallurgie, 76, Feb. 1979, No. 2, p. 113-120

- Sgard, J., Landscaping of iron ore slag-heaps. Method for the rehabilitation of existing slag-heaps (La mise en végétation des crassiers de mines de fer. Méthode de réhabilitation des crassiers existants), Revue de Métallurgie, 76, Feb. 1979, No. 2, p. 138-140

- Shikimura, T., and A. Miyawaki, The creation of native forests - the path from anti-pollution to environmental creation, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/1/100

3.4 Noise and 3.5 Vibration

- Adam, J. A., and M. J. Thomas, Noise in the iron and steel industry, Journal of the Iron and Steel Industry, July 1967, p.701-713

- Arimitsu, Y., Measurement of noise fluctuation in steelworks caused by weather conditions, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, Chicago, June 1979, IISI Report SEC 2/1/100

- Mereau, P., and L. Roure, Affections des membres supérieurs dûs aux vibrations, Cahiers de notes documentaires de l'Institut National de Recherche et de Sécurité, No. 101, 4th quarter 1980, 100, No. 11, p. 575-580

- Réduire le Bruit dans les Pays de l'OCDE, Ed. OECD, Paris, 1978, 123 p.

- Specht, Origin of Noise in Steel Industry and Metallurgy (Lärmquellen der Eisen - und Metallindustrie), Berufsgenossenschaftliches Institut für Lärmbekampfung, 1973, Stahleisen-Betriebsblätter SEB 905 001-005, Verlag Stahleisen, Düsseldorf.

SECTION 4

AIR POLLUTION CONTROL

4.1 Techniques of Fume Collection and Dust Cleaning

4.1.1 Clean production processes

The best way to avoid the emission of pollutants into the air is to delete such emissions from the production processes. We observe some progress in this direction with the development of new production technologies. For instance, new burners bring about the limitation of NOx emissions from the reheating furnaces. The same result can be obtained with the development of induction heating furnaces instead of the furnaces heated by liquid or solid fuels. It is also possible to avoid the formation of pollutants by a careful selection of raw materials as in the case of SO_2 with the selection of ores and fuels.

4.1.2 Fume collection

There are five general methods of fume collection:

- directly at source: by equipping the steelmaking installation with a fume collection system. This is done in the case of the electric-arc furnace, which has three openings in its roof for the electrodes and an additional one for extracting the gases given off.

- by enclosing the steelmaking installation: this solution was originally applied to bottom-blown converters, but is now coming into general use throughout the steel making sector. It is referred to as the "doghouse" for converters or the enclosure for electric arc furnaces.

- in the immediate vicinity, by installing a local "hood": the fume is drawn towards a fixed recovery facility by creating an adequate reduced pressure. In the oxygen steelmaking shop, a secondary hood is installed against the direct-recovery hood for the purpose of sucking in, at high speed, the fumes released when the hot metal is charged.

- by hoods installed in the roof above the path of travelling cranes: this formula would appear to be essential when the last two methods are inapplicable. To be effective, the rate of extraction must be considerable (e.g. 400,000 m^3/h), as steel industry buildings are often very high.

- by closing in the building: this solution was predominantly developed in cold countries and consists of treating all the air used for ventilating the protective bays. The throughput rates are substantial (millions of m^3/h), but the air is kept clean and it is possible to twin environmental conservation with air-conditioning at work sites.

4.1.3 Dust cleaning

There are four tried-and-tested techniques which steelworks can call upon: mechanical dust catchers, electrostatic precipitators filter media and scrubbers.

4.1.3.1 Mechanical dust catchers

This equipment brings about the precipitation of the heaviest particles on the basis of the settling principle (dust catchers) or centrifugal action (cyclones). Systems such as this represent an effective means of eliminating the mechanical dust produced in the handling of raw materials, and can also be used for dry preliminary dust extraction, particularly in conjunction with blast furnaces.

4.1.3.2 Electrostatic precipitators

These devices operate on the principle of the circulation of the dust-laden waste gas at low speed between two series of electrodes which serve different functions: electron-emitting electrodes and collecting electrodes. Between these two series of electrodes, a difference in potential is created (e.g. 40,000 volts). In this way, the particles of dust are bombarded with electrons, and if they are sufficiently conductive they become negatively charged and are precipitated on to the collecting electrodes, from which (unless they drift off again) they are either knocked off (dry method) or washed off (wet method).

4.1.3.3 Filter media

Textiles represent the most widely-used filter media in the steel industry (e.g. woven materials, needle felts). In a number of cases, gravel is also used (e.g. lime-burning kilns). Filtering through these materials is an efficient way of recovering the fine dust emitted by various metallurgical processes (tapping of pig iron and the blast furnace, electric-arc steelmaking). It is also suitable for treating the diffuse gases in steelmaking. Otherwise high temperature gas cleaning by using special fabric bag filters is a possible new tendency (see para. 4.6.2.1).

4.1.3.4 High-energy scrubbers

Water is used to trap the dust on the basis of three principal mechanisms:

- trapping by collision between the water and the dust, on the basis of either a flow of water or droplets;

- trapping by condensation of water on to the dust, in the same way as fog is formed;

- trapping by diffusion, whereby very fine droplets and very fine particles are brought into contact as a result of Brownian motion.

The systems used in the steel industry are based on one or other of these mechanisms. The following examples may be quoted:

- water sprays operating predominantly on the basis of collision with the largest particles;

- the disintegrators which used to be very familiar in conjunction with blast furnaces and in which the spraying takes place using the fan as it rotates;

- venturi scrubbers exhibiting a substantial drop in pressure (e.g. 250 mbar on the waste gas), whereby the water is pulverized by the gas and the efficiency increases as the pressure drops;

- venturi scrubbers exhibiting only a small drop in pressure and which operate on the basis of the fog principle, whereby the energy for spraying the water is derived from it being placed under pressure (e.g. 15 bars).

4.2 Fumes Collection and Dust Cleaning Installations

4.2.1 Stockyards and handling areas

Unloading, storage, recovery and transfer operations are activities which are going on all the time in the case of ore, coal, coke, limestone, lime and also slag. They may involve a certain amount of air pollution as a result of dust being carried away by the wind. There are various methods available for reducing this pollution, and these are implemented locally as and when they appear necessary:

- installing hoods above conveyor belts which suck in the air and extract the dust from it;

- smoothing and compacting down the coal in the stockyard using a bull-dozer;

- spraying of the stockpiles with water, with or without surface-active agents added;

- constructing a building to prevent dust being blown away in the case of stockyards;

- building walls to serve as wind-breaks.

4.2.2 Coke ovens

Coke ovens may be a source of pollution at each individual stage of manufacture: preparing the coal, charging the coal into the oven, the coking process itself, removal of the coke from the oven, quenching it, final screening and handling. The visible emissions are made up of dirty, black dust; the proportions involved are shown in table 10. Such data are only examples from a source in the Federal Republic of Germany. Practically the dust generation in coke plants is highly variable, depending on a number of factors, like coal properties, coke ovens design, operational procedures, etc. It should be observed that figures shown in table 10 are a rough estimate, as several other reports do not agree with the proportions indicated.

Over the last few years, there has been marked progress in all areas, particularly the handling, coal-preparation, coke-quenching and screening areas. Solutions are now available to cover the operations of charging the coal into the oven and removing coke from it. To quote an example, there are three possible ways of recovering the waste gases and extracting the dust in the case of the coke pushing operations:

- completely mobile technique: mobile hood and dust cleaner coupled to the coke car;

- completely stationary technique: covered bay equipped with a stationary dust cleaner;

- combination technique: mobile hood connection up to a pipe running the length of the battery and linked to a dust-extraction system on the ground.

Another example is concerned with the quenching of the hot coke. This quenching can be wet or dry. To limit the emission of particulates from the quenching tower, it is necessary to control the quantity and the quality of the used water and to optimize the position of the baffles. Now dry quenching is developing. It allows the avoidance of the emission of particulates and gaseous pollutants into the atmosphere and the recuperation of heat from the hot coke.

A great deal of progress has been achieved in a few years, but unfortunately the solutions marketed sometimes produce disappointing results, in view of the difficult conditions under which they have to operate (formation of tar, corrosive gases, etc). Progress in pollution control clearly goes hand in hand with improving manufacturing conditions and adopting operational practices aimed at reducing the emissions.

4.2.3 Sinter plant

All workshops are fitted with dust-collection systems, e.g. electrostatic precipitator for the main waste gases and bag filters for ventilating the premises. The amounts of air involved are considerable. The flow for the main fumes from a 400 m^2 grid surface, for example, is in the region of 2 million m^3/hour, necessitating two 700-kW ventilators.

Table 10

Quantities of dust given off by a modern coke oven before and after installation of effective collection and cleaning equipment

Operations	pollution of in-house atmosphere in g/t coke	
	Before treatment	After treatment
Coal charging	150	10
Coke pushing	400	10
Coke quenching	350	5
Coke handling	1500	50
	——	—
	2400	50

4.2.4 Blast furnace

Before the Second World War the blast furnace was rightly considered to be a major source of pollution, as a result of the top gas, a highly noxious gas - with a 25 per cent CO content - which it discharged along with 40 kg of dust per tonne of hot metal. Top gas is, however, a source of energy, and it has long since been the practice to recover it and re-use it in its entirety, so that it never comes into contact with the outside world except in the event of an accident.

Waste gas is also discharged in the cast house. Effective sky-light design has to date enabled this waste gas to be drawn into the atmosphere. The trend nowadays is towards collection of the waste gas and extraction of the dust. There are some installations functioning which produce satisfactory results, but at the expense of vast amounts of power - in the region of 5,000 kW - which necessitates considerable investment. The dust is principally extracted by bag filters, but there are signs of a move towards electrostatic precipitators which use less energy.

4.2.5 Pig iron refining plants

Pig iron is an alloy of iron and oxidizable metalloids such as silicon, carbon and phosphorus. It is converted into steel by the oxidation of these metalloids. This refining operation was for a long time based:

- on the acid Bessemer process or its variant, the basic Bessemer Process involving injection of air through submerged nozzles

- on the open hearth process (see 4.2.6.1)

The Bessemer process is now no longer used and the importance of the open hearth furnace is decreasing. The pig iron is refined more and more in oxygen converters:

- the LD process and its variants, using a vertical lance above the bath;

- the OBM, Q-ROB and LWS processes, which involve injection of the oxygen through nozzles in the same way as in the Bessemer converter, with the impact of the pure oxygen on the metal being damped down by the injection of a hydrocarbon.

At the mouth of the converters, the gases produced by refining are composed of CO and to a much smaller degree CO_2. They contain substantial concentrations of fine particles of iron and iron oxides called "red fume". In the case of the LD process, there is about 150 g/Nm^3 at the point of emission. Methods are available for collecting these gases from both top and bottom converters. These gases may be handled in two environmentally acceptable ways, each of which includes dust extraction:

- recovery without combustion of the CO, providing a combustible gas which is capable of being recycled into the works' energy circuits;
- recovery involving combustion by air of all the discharged CO, whereby the energy is extracted in the form of steam. This method has the disadvantage, however, that the throughput for dust extraction has to be much greater than the rate of discharge at the converter mouth.

Dust cleaning is practised at almost all plants on the basis of the wet method, using venturi scrubbers with high or low pressure drop. The use of bag filters has not managed to establish itself. On the other hand, electrostatic precipitators which were used first, appear to offer prospects for the future, bearing in mind the excellent results already observed. In general terms, whatever the method of recovery, the purified gases have an average dust content of less than 120 mg/Nm^3, but when it is recovered for use in plant, it is usually cleared in precipitators to below 10 mg/Nm^3.

By way of comparison it should be pointed out that the cost of the investment for dust cleaning installation is in the region of 15 per cent of the cost of the steelworks itself, and that the operating costs are very high.

As a result of the progress achieved in the extraction of dust from the waste gases at the converter, the fugitive emissions are now the predominant ones in an oxygen steel making plant (as may be seen from table 11). Action is currently being taken within steel making shops to collect and clean "fugitive" emissions which arise in the course of re-ladling, charging the vessel, de-slagging and tapping operations.

The problem of fugitive emission is the collection in each particular case of the gases rather than the extraction of the dust from them, which is a standard procedure. When charging the converters in particular, the suction velocity required would need to be extremely high (e.g. 15 m/s), as would the throughput (300,000 Nm^3/h), in order to force the waste gases into a hood at the front of the converter. In the same way, the gases discharge on injection and those emitted on clearing bottom-blowing oxygen converters are recovered via a box system.

4.2.6 Scrap melting plants

Plants which produce steel by the scrap melting method use two major processes: the open-hearth process which takes its heat input from burners, and the electric-arc process which uses electricity.

Table 11

Fugitive dust emissions from
an oxygen steelmaking plant

(with fume collection restricted to the main hood
on the converter)

	Dust emission in g/t of steel
Reladling of pig iron	19
Desulphurization of pig iron	16
Converter charging	140
Converter blowing	24
Miscellaneous	8
Total	187

4.2.6.1 Open-hearth furnace

The open-hearth process is losing popularity throughout the world, but there are many open-hearth furnaces still in operation in the world, particularly in China, Eastern Europe and the USSR. If the intensity of the steelmaking process is very low, it is not necessary to install cleaning systems: the rate of emission of red fumes remains limited. However, the situation is very different if the intensity of the process is high, for instance with the use of the oxygen top blow technology. The red fume emission becomes an environmental problem and to solve it it is necessary to clean the fumes, for instance by using electrostatic precipitators like those in China.

4.2.6.2 Electric arc furnace

In the case of the electric arc furnace, on the other hand, the collection of fumes and the extraction of the dust from them are of very topical interest.

In general, it is possible to draw a distinction between two methods of fume collection:

- "direct" collection from the furnace, basically effected via a "4th hole" into the furnace roof (in addition to the three taken up by the electrodes);
- "secondary" collection by means of a canopy hood overhead in the roofing, which is designed to capture those gases in particular which are emitted on charging the furnace and tapping from it.

The throughput rates involved, in the case of 80-t furnaces, are in the region of 1,000 Nm^3:h/t for collection via the 4th hole, and 4,000 Nm^3/t or more for secondary fumes. In order to reduce these throughput rates, the electric arc furnace may be enclosed in a box with sliding doors in such a way that the waste gases remain confined within a limited space.

Dust cleaning is essentially by bag filter. Cloth has long been used for this purpose, but needle felts are now becoming more popular as a result of the various advantages they have to offer (smaller floor space required in the plant, fans down stream of filters, fumes channelled through a chimney, better maintenance conditions for staff).

High-energy scrubbers have been developed for direct collection only, but have turned out to be too expensive to be used for treating secondary fumes as well. Except in special cases, they are on the decline. As far as electrostatic precipitators are concerned, there has been a revival for obvious energy-related reasons.

4.2.7 Reheating furnaces

The liquid steel produced is conventionally cast in the liquid state into ingot moulds, where it has to solidify before it can be rolled. It then undergoes alternate reheating and rolling stages. The reheating operations are carried out in furnaces which are usually heated by a mixture of blast-furnace and coke-oven gas, natural gas or fuel oil. As these fuels do not generally constitute a particular source of particulate pollution, dust-cleaning is not practised in the case of reheating furnaces.

4.3 Techniques for Eliminating Gaseous Pollutants

4.3.1 Desulphurization

SO_2 in the presence of water produces the following acid reaction: $SO_2 + H_2O$ ---- H_2SO_3. Hence, any chemical desulphurization process requires alkaline products such as calcium, sodium, magnesium, copper or ammonium compounds, etc. It is also possible to apply physical principles (adsorption using activated carbon). Practically the most developed method, particularly in Japan, uses milk of lime as the desulphurization product. The desulphurization yield obtained is over 90 per cent.

4.3.2 Denitration

Nitrogen oxides are formed in the course of combustion processes. There are four possible ways of limiting their formation or of removing them:

- modification of the combustion procedure (lowering the temperature of the flame, reducing the air excess, cutting down the time spent in the combustion chamber, technological modifications to the chamber);

- modification of the fuel (high-temperature denitrating of the coke beforehand);

- immediate recovery of the nitrogen oxides formed (in sinter plant by addition of lime to the sinter burden);

- denitration of the waste gas (chemical reaction with a base, as in the case of desulphurization, catalytic reduction of the nitrogen oxides to molecular nitrogen, solidification in the form of dust which can then be recovered by simple dust cleaners.

4.4 Equipment for Control of Gaseous Pollutants

Steelworks used to be characterized by their "plumes" of bright-coloured smoke. This was the case with the basic Bessemer converters, which produced a characteristic red flume. Nowadays, the visible discharges of dust are much more discreet and often resemble accidental emissions or are of very short duration.

Ways of reducing particulate emission will therefore cease to be the top-priority objective they have been in the past, with a number of administrative authorities beginning to show more concern about gaseous pollution, in particular that due to sulphur and nitrogen oxides. The Japanese steel industry is already well under way in the control of gaseous emissions, in particular with the desulphurization of the main gases produced by sintering plants, and with the first installations for the purposes of denitration of the same gases, along with those from coke-oven batteries. The desulphurization of coke-oven gas is moreover becoming more widespread.

4.4.1 Desulphurization

The techniques applied for the purpose of desulphurization are of a classical nature, based on scrubbing in a tower in a calcium (milk of lime, calcium chloride solution) or ammonium based liquid. SO_2 and SO_3 are finally recovered, following oxidation, in the form of calcium and ammonium sulphate. As in the case of dust cleaning, moreover, there appears to be a trend towards linking several physical purification processes together. This will in principle make it possible to capture residual dust and SO_2 at the same time by using bag filters charged with lime.

4.4.2 Denitration

Two processes are currently being developed in Japan as methods of eliminating NO and NO_2:

4.4.2.1 Reduction of nitrogen oxides to molecular nitrogen

This reduction is brought about by ammonia in the presence of a catalyst Fe_2O_3-Al_2O_3 or V_2O_5-Al_2O_3 at a high temperature (200° to 400°C depending on the circumstances). Two industrial plants are in operation in Japan, one at Nippon Kokan Keihin and another at Kawasaki Steel Chiba (SR process) for the denitration of gases produced by sintering.

4.4.2.2 Use of an electron beam

A process studied a few years ago on a pilot basis by the Technological Research Association for Abatement and Removal of NO_x in the Steel Industry at Nippon Steel Yawata consists of adding NH_3 and of bombarding the gases by an electron beam.

4.5 Performances and Limitations

Over the last few years, there have been considerable improvements in purifying equipment, both from the point of view of technical performance and also reliability. Residual concentrations of dust which it was impossible to reach only a short time ago are now readily attainable. As an example, bag filters make it possible to reduce dust content to less than 10 mg/m^3N, although it must be stated that this requires expensive equipment, frequent maintenance and a certain level of energy consumption (e.g. 45 kWh/t).

One should not, however, underestimate the lack of flexibility offered by a dust-cleaning system when a steelmaking process has to adapt to variations in burdens and the grades of steel to be produced. By way of an example, when sintering on a modern grate, any changes in the operating conditions of the strand as against the optimal setting result in a deterioration in the standard of the dust extraction. However, a sinter strand is very often required to speed up or slow down production in response to demands of the subsequent production processes. This example highlights the need for close co-operation between manufacturers and users of dust extraction systems, to enable the equipment to adapt to variations in demand of the steelmaking processes.

Another example relates to electric arc furnaces. A dust collector which is well designed to cope with a burden of good scrap can prove to be useless when it is only possible to charge oily scrap. The steelmaker, however, is not always in a position to dictate the quality of the scrap supplied to him by the merchant.

This lack of flexibility in the case of dust collectors places a heavy restriction on the steelmaker who wishes to develop his processing techniques. A dust collector designed to cope with gases of given characteristics can prove to be useless if the changes brought about by technological progress are too radical. In electric steelmaking, for example, new techniques enable melting to be speeded up, but may prove impossible to use without changes in the dust control system.

4.6 Prospects for Further Advances in Dust Extraction Systems

The excellent results already achieved should not cause us to forget that the conditions as regards air pollution control are bound to change and evolve as a result of various factors:

-tightening of the regulations governing pollutants (both particulate matter and gases);

-need to achieve greater economies in terms of energy;

-similar need to economize on raw materials, resulting above all in better utilization of dust and sludge;

-progress in steelmaking techniques which may result in radical changes;

-new possibilities in terms of dust extraction techniques;

-the search for ways of improving working conditions;

-economic constraints.

The prospects for the future open to steelmakers vary depending on the category of dust extractor used.

4.6.1 Electrostatic precipitators

Electrostatic precipitators are already well established in the steel industry (main gases in sinter plants, de-tarring in coking plants, oxygen cutting and scarfing) and their range of applications should expand (steelmaking processes, treatment of secondary fumes) as they are very economical to use in terms of energy. The steel industry is undergoing a process of constant improvements in the classical methods along with a radical investigation into ways of achieving greater processing speeds.

4.6.1.1 Improvements in classical methods

Manufacturers are seeking to improve the method of trapping fine particles or those with high resistivity. They are also endeavouring to improve the reliability of their installations in the following ways:

- adopting higher voltages. On a very modern sinter strand at Nippon Steel, for example, a voltage of 150,000 V is being used;
- redesigning both emitting and collecting electrodes;
- minimizing the quantity of particles flying off on impact by introducing partitions into precipitators and optimizing the cycle;
- possibility of operating at a higher temperature;
- in the case of wet precipitators, improving the spraying action of the liquid, e.g. by an electrostatic device.

4.6.1.2 Increasing the through velocity

The disadvantage of electrostatic precipitators is that they are expensive to buy as a result of having to be bulky to enable the gases or fumes to circulate at slow speed between the electrodes. Research has been carried out into ways of speeding up this process, and thus reducing the amount of space taken up by the dust collection system. To quote an example, a company in the USA has just placed an order for some ring-shaped wet precipitators which operate at high speed (20 m/s) and use new materials. It is planned to install these appliances in a sintering plant with a view to perfecting an existing dust collector and trapping residual droplets of oil arising from high levels of mill-scale in the burden.

4.6.2 Bag filters

Bag filters have established themselves in the steel industry above all in electric steel plants and for the purposes of treating the diffuse gases produced by sintering, in blast furnace cast-houses and in steelmaking shops.

The current techniques using terylene cloth or felt already appear to be very reliable, but they could be developed still further depending on the technological progress made:

4.6.2.1 High-temperature dust collection

There appear to be two possibilities in terms of technology:

- fabrics woven from stainless steel fibres;

- similar material made from refractory fibres, e.g. aluminium oxide.

Work is now being started on testing these new media with a view to using them for dust collection in several industries, including the steel industry.

Where synthetic materials are used in bag filters, the temperature of the waste gases has to be severely limited (to a maximum of 130°C in the case of terylene, for example),and it is not therefore possible to recover the appreciable heat given off with any effectiveness. It would be desirable to extract the dust at a higher temperature (e.g. 600°C, or even 1000°C) in order to obtain a gaseous flux which would be both clean and hot.

4.6.2.2 Increasing the filtering speed

The technical literature on the subject refers to research into ways of substantially increasing the throughput of waste gases per unit of filtering surface. These involve taking the progress already made a stage further by moving from woven fabric to needled felts. This research is of interest to steelmakers who often have to handle throughput rates regularly running into millions of m^3/h.

4.6.2.3 Reappraisal of bag filters

A number of research centres are working on rigid ceramic "sponges" which are internationally patented. They may be adapted for use both in dust collection and water treatment.

4.6.3 High energy scrubbers

While the equipment which has been developed to date is proving satisfactory as far as steelmakers are concerned, it may undergo further development either with a view to achieving greater energy savings, or following a reappraisal of certain rules of aerodynamics, or via the use of emulsions.

4.6.3.1 Energy savings

The power necessary to enable the water to be finely sprayed into the gas for dedusting purposes may be supplied either by the gas (high energy scrubbers, for example, of the Venturi scrubber type) or by the water (scrubbers with only a small pressure drop, whereby the water is injected under heavy pressure). The first solution has currently established itself within the steel industry for operational reasons, but the trend may be reversed with the possibility of a new development in scrubbers with only a small pressure drop. An example of this is an appliance working on the basis of convergent jets, whereby a mist of very fine droplets is formed as a result of causing two jets of water under pressure to converge.

4.6.3.2 New aerodynamic designs

Scrubbers with a large pressure drop have their Venturis aerodynamically profiled. A number of researchers have, however, thought up other ways of bringing the gas or fumes into contact with the water. These include for instance:

- a multicellular reactor whereby a succession of funnel-shaped combining-diffusing nozzles are used to create water gates which the gases have to cross, thus causing a small drop in pressure;

- a scrubber investigated in the United States, in which the classical Venturi device is replaced by a bulb shaped combining nozzle without a divergent section.

4.6.6.3 Dust collection in an emulsion

Several new technologies are being investigated at the laboratory stage. They may be of interest to steelmakers once they have reached a more advanced stage in their development. One could also mention in this context an adaptation of the technique using columns with perforated plates for the purposes of dust collection. This forms the basis of a procedure applied to the sintering gases produced by Japanese sinter plants, both for dedusting and desulphurization purposes.

4.6.4 Combination of several physical processes

To date, manufacturers have sought primarily to apply only one physical dust cleaning principle at a time. Now a number of them are proposing to combine several physical principles together in the same appliance. They are coming up with new techniques which are beginning to be applied in industry, e.g. scrubbers and precipitators or bag filter and also precipitators.

BIBLIOGRAPHY FOR SECTION 4

4.1 Techniques of Fumes Collection and Dust Cleaning

- Abramovich, G. N., The theory of turbulent jets, The M.I.T. Press, 1963

- Bouilliez, L., Simulation en laboratoire des techniques industrielles de filtration de gaz par média textiles, Courrier des Etablissements NEU, Dec. 1976, 72, p. 15-22

- Dennis, R., et al., Dust dislodgement from woven fabrics versus filter performance, Journal of the Air Pollution Control Association, Jan. 1979, 28, No. 1, p. 47-52

- Eisenbarth, M., Secondary dust collection systems in electric and oxygen converter steel plants, Metallurgical Plant and Technology 5/1979, p. 1-10

- R. Guthmann, Stahl und Eisen, 1965, 85, No. 15, p. 949

- Hatch, T. F., and D. B. Oronzco, Air Flow in Free Convection Over Heated Bodies, 63rd Annual Meeting, The American Society of Heating and Air Conditioning, Chicago, 1957

- Leith, D., and M. W. First, Performance of a pulse-jet filter at high filtration velocity, Journal of the Air Pollution Control Association, 1977, 27, No. 6, p. 534-539 and No. 7, p. 636-642

- Pe Kaz, J., The Art of Electrostatic Precipitation, Precipitation Techn. Edition, 1979, 350 p.

- Raguin, J., Methods for cleaning industrial fumes in steel industry (Le dépoussiérage des effluents gazeux en sidérurgie), Journées européennes de la filtration et de la séparation, Paris, Nov. 1976

- Steiner, B. A., Air pollution control in the iron and steel industry, International Metals Reviews, Sept. 1976, 21, P. 171-192

- Sutton, O. G., The dispersion of hot gases in the atmosphere, Journal of Meteorology, 7, p. 307-312, 1950

- Watanabe, Y., A New Type of Electrostatic Precipitator, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC 2/2/106

4.2 Fumes Collection and Dust Cleaning Equipment

- Chantereau, R., et al., Efforts to counter pollution and environmental problems in the French steel industry, The Metals Society Meeting on Engineering Aspects of Pollution Control in the Metals Industry, London, Nov. 1974

4.2.1 Stockyards and handling areas

- Kahnwald, H., Dust emission from stockyards and measures for its reduction (Staubemission beim Umschlag und Lagern feinkörniger Schüttgüter und Massnahmen zu ihrer Verringerung), Stahl und Eisen, 97, 1977, No. 2, p. 79-84

4.2.2 Coke ovens

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

- Barker, J. E., The Case for dry cooling of coke, Coke Oven Managers' Yearbook, 1976, p. 206

- Bernet, H., and H. Roger, Technological evolution in coke ovens: A stage for pollution reduction (La mutation technologique des cokeries: une étape vers la diminution de la pollution), Third Clean Air Congress, Düsseldorf, 1973

- Bieschеuvel, A. A., et al., Automation on a coking plant, Iron Steelmaker, Aug. 1977, p. 20

- Breidenbach, D., and H. Eisenhut, Erste Ergebnisse neuer Vorhaben zur Verringerung von Staubemissionen bei Koksdrücken, Glüchauf, "Preliminary results of new designs for the reduction of dust emissions from coke ovens" Feb. 1973, p. 219-223

- Brough, J. R., Preheating and pipeline charging of a slot-oven coke plant, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/3/110

- Conners, A., and J. Mullen, Developments in coke-oven emission control, Iron and Steel Engineer, June 1980, p. 33-38

- Davies, R. F., Système Coaltek de chargement des fours à coke par conduite, AIME Ironmaking Proceedings, 35, p. 478-486, 1976

- W. Eisenhut, Mesures destinées à réduire les émissions dans les cokeries, Communication aux Journées d'information de la CCE - Qualité de l'environnement en sidérurgie, Luxemburg, Sept. 1974

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

- Gobiet, V., Expériences acquises avec recouvrement des voies côté extinction par une toiture, Congrès sur les techniques des cokeries, Luxemburg, May 1975

- Giunta, J. S., and R. W. Stanley, Door Emissions Control Technology, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/4/116

- Gould, W. C., et al., Carbonizing preheated coal at J and L Steel Corporation, 85th General Meeting AISI, New York, May 1977

- Graham, J. P., and B.P. Kirk, Problems of coke-oven air pollution control, The Metals Society Meeting on Engineering Aspects of Pollution Control in the Metals Industries, London, 1974

- Hoffman, O., Development and Demonstration of Concepts for Improving Coke-Oven Door Seals, PB-286, 628/3JL, Aug. 1978, 123 p.

- Hooded quench car system controls - coke pushing emissions, Iron and Steel Engineer, March 1978, p. 83-84

- Khadzioglo, A. V., et al., Coal Charging Without Fumes in Coke Ovens Batteries, Ed. Metallurgija, Moskow, 1978, 184 p.

- Kiritani, Y., Air pollution control related to coking, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/3/113

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

- Marting, D. G., and R. Marcellini, Le chargement du charbon préchauffé dans les fours à coke selon le procédé Coaltek, Revue de Métallurgie, June 1976, p. 487-493

- Masciantonio, P. X., Air pollution control related to coking operations, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/G

- Munson, J. G., et al., Charging emission control by use of stage charging, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/3/109

- Patton, J. R., Hooded coke quenching system for air quality control, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/3/111

- Phelps, R. G., Le programme AISI-EPA-BATTELLE relatif à l'amélioration des joints des fours à coke, J. Air Pollution Control Asso., Sept. 1979, 29, No. 9, 908-12

- Plaks, N., Improved processing methods to control air pollution emissions from cokeries, ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-15462

- Stage charging reduces air emissions, Envir. Sci. Tech., 8, 1062, 1974

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

- Tucker, F.E., and C.V. Decaria, Air pollution control, at a new by-product coking operation, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/3/112

4.2.3 Sinter plant

- Barascu, I., and R. Privache, Dedusting and gas cleaning equipment in sinter plants, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-8454

- Bohus, O., Epuration des gaz de haut fourneau au moyen d'appareils venturis, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-8982

- Cavalcanti, H. B., Air pollution control related to sinter plants, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/E

4.2.4 Blast furnace

- Blast furnace slips and accompanying emissions as an air pollution source, EPA Report 600/2-76-268, Oct. 1976

- May, W. P., Blast Furnace Cast House Emission Control Technology Assessment, EPA Report 600/2-77-231, Nov. 1977, 312 p.

- Petersheim, H., and M. Eisenbarth, Pollution control in blast furnace plants, Metallurgical Plant and Technology, No. 6/79, p. 3-7

- Philipp, J., and R. Eschenberg, Blast furnace cast house without dust: Contribution to environmental protection and ergonomy (Staubfreie Hochofengiesshallen - Beitrag zu Umweltschutz und Ergonomie), Handelsblatt, 28, No. 4, Technische Linie, 1975

- Yamamoto, Y., A Secondary dust emission building evacuation system in a blast furnace cast house, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/6/127

4.2.5 Oxygen converters

- Baum, J. P., Comparison of gas cleaning for BOF and OBM/Q-BOP, Second OBM/Q-BOP Licensees Conference, Bodenmais, Oct. 1975

- Brown, C. M., and R. W. Engelbert, Control of secondary emissions from basic oxygen steel making furnaces, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI, June 1979, IISI Report SEC/2/6/129

- Caine, K. R., Development of Technology for Controlling BOP Charging Emissions, Report EPA 600/2/77/218, Oct. 1977, 165 p.

- Ikeuchi, H., Build evacuation dust collecting systems in BOF steel making plants, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/6/130

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

- Pearce, J., Q-BOP steel making developments, Iron and Steel Engineer, p. 29-38, Feb. 1975

- Pilkington, S., Collection of secondary fume in BOF steel making, Proceedings of Conference-Engineering Aspects of Pollution Control in the Metals Industries, Metals Society, London, Nov. 1974, p. 25

- Reports for SECSI 2 (Second Symposium on Environmental Control in Steel Industry), Chicago, June 1979

- Smith, C. G., et al., Control of fugitive emissions in the iron and steel industry, Iron and Steel Engineer, USA, 56, No. 3, March 1979, p. 49-56

- Status of secondary fume collection in BOF shops, International Iron and Steel Institute - Committee on Environmental Affairs, Brussels 1981, 52 p.

- van Ackeren, P., The problems of dust action from converter, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/5/122

- Van der Poel, A., and G. A. C. Van der Lindern, Combatting air pollution in LD Plant 2 at Hoogovens, Ijmuiden, Operation of large BOFs, Ed. The Iron and Steel Institute, London, 1972

4.2.6 Melting furnaces

- Eisenbarth, M., Secondary dust collecting systems in electric arc furnaces, Electric Arc Steel Making for the 1980s, p. 41-48

- Flux, H. J., Containment of melting shop roof emissions in electric arc furnace practice, The Metals Society Meeting on Engineering Aspects of Pollution Control in the Metals Industries, London, Nov. 1974

- Graf, H., et al., Possibilities of efficient and low-pollution steel making in the arc furnace (Möglichkeiten einer Leistungsfähigen und Umweltfreundlichen Stahlerzeugung im Lichtbogensofen), Stahl und Eisen, 1976, 96, No. 13, p. 607-611

- Japanese Steelmakers make progress in fighting pollution, 33, Metal Producing, Feb. 1977, p. 49-51

- Leary, E. C., The modern approach to slag handling at basic oxygen steelmaking plants, Iron and Steel Engineer, Sept. 1965

- Marchand, D., Dust and gas evolution in arc furnace steel making and possible alternatives for reducing emissions with suitable collection and cleaning systems, The Metals Society Meeting on Engineering Aspects of Pollution Control in the Metals Industries, London, Nov. 1974

- Pokrovskij, L., et al., l'épuration des fumées des fours à arc à l'aide de filtres à sacs ou par voie humide, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-8995

- The electric arc furnace, International Iron and Steel Institute, Brussels, 1981

- Yamashita, Y., A counter measure for dusts at the electric furnaces, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, Feb. 1974, IISI Report SEC/5/128

4.3 Techniques for Eliminating Gaseous Pollutants

- Leblanc, B., Formation and survey of pollutants in industrial furnaces (Formation et contrôle des polluants dans les fours industriels), Groupement d'étude des fours à gaz naturel, GEFGN-Report, 1973

- Mukaida, A., Environmental control measures in the Japanese steel industry, IISI Committee on Environmental Affairs, Tokyo, May 1982, p. 13-54

- Reboux, A., Synthèse sur la formation et le contrôle des oxydes d'azote émis par les installations de combustion, LECES Publication - P.5, Nov. 1973, 27 p., 13 fig.

- Van Houte, G., 60 Procédés de désulfuration des fumées, Edition Office national de librairie, Brussels, 1973, 169 p.

4.4 Equipment for Control of Gaseous Pollutants

- Aronds, C. A., et al., Measurement and control of fluorine compounds at a sinter and pelletizing plant of Hoogovens, Ijmuiden, First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1, February 1974, Report SEC/2/107

- Minghelli, G., Elimination des vapeurs acides provenant du décapage à l'acide chlorhydrique, nitrique ou fluorhydrique, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 71-10167

- Peters, K. H., Granulation of blast furnace slag and its air pollution control, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/6/128

- Rehmus, F. H., D. P. Manka, and E. A. Upton, Control of H_2 emissions during slag quenching, J. Air Pollution Control Association, 23, p. 864, 1973

4.4.1 Desulphurization

- Ikeuchi, H., Moretana technology for flue gas desulphurization and dust removal, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/2/109

- Last-gap desulphurization for coke oven gas taking-off as states start cracking down, 33 Magazine, October 1976, p. 33-37

- Sheldrake, C. W., and O. A. Homberg, coke oven gas desulphurization - state of the art, 5th AIISI General Meeting, New York, May 1977

4.4.2 Denitration

- Hirroka, H., Equipment for removal of nitrogen oxides for No. 4 sinter plant at Chiba Works, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC/2/2/108

- Hirose, Y., and T. Kannari, Journal of the Fuel Society of Japan, September 1976, p. 765-772

- Michelfelder, S., et al., The effect of burner construction and burner parameters on the emission of NOx from natural gas, heavy fuel oil and pulverized coal flames, Chemical Engineering Congress, April 1977, Milano

- Yamamoto, I., Catalytic reduction of nitrogen oxides with ammonia from coke oven flue gas, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC/2/4/120

4.5 Performances and Limitations

- Muhlrad, W., and F. Lardit, Séparation des poussières et des vésicules liquides, Techniques de l'ingénieur, A 5700 p. 1-21 and A 5701 p. 1-24

4.6 Prospects for Further Advances in Dust Cleaning Systems

- Ewan, T. K., and J. S. Master, Fine particle scrubbing with Lone Star hydro-sonic cleaners, Second Symposium on Fine Particle Scrubbing, New Orleans, May 1977

- Joffre, R., Evolution des dépoussiéreurs électriques au cours des dix dernières années, Informations Chimie, 169, August-September 1977, p. 195-203.

- Matsumoto, K., Progress in MHI's integrated techniques for environmental protection, Technical Review of Mitsubishi Heavy Industries, 13, No. 3, October 1976, p. 173-191

- Morrison, G. F., Hot gas cleanup, IEA Coal Research (London) ICTIS/TR 03, March 1979, 54 p.

- Stark, S. B., Sur l'efficacité du dépoussiérage électrostatique des fumées chaudes (in Russian), Cern, Metall., 1975, NO. 3, p. 179-182

SECTION 5

WATER POLLUTION CONTROL

5.1 Techniques of Wastewater Treatment

Different ways of treating wastewater are currently in use in the steel industry:

- recycle systems (§ 5.2)
- settling lagoons, clarifiers and filters, for suspended solids removal (§ 5.3)
- skimming, filtration, air flotation and ultrafiltration for oil removal (§ 5.4)
- carbon adsorption and biological treatment for organic toxic pollutants removal (§ 5.6)
- advanced technologies (§ 5.7)

5.2 Recycle Systems

Recycle is used to reduce the volume of wastewater discharged and can achieve significant pollutant load reductions at relatively low cost.

At high recycle rates, two problems can be encountered. First, if the wastewater is contaminated, a build-up of dissolved solids in the recycled water can cause plugging and corrosion. This problem can be avoided by providing sufficient treatment of the wastewater prior to recycle, by adding chemicals that inhibit scaling or corrosion, and by having sufficient blowdown to limit the build-up of dissolved solids and other pollutants. The second problem that can occur is excessive heat build-up in the recycled water. If the temperature of the water to be recycled is too high for its intended purpose, it must be cooled prior to recycle. The most common method of reducing the heat load of recycled water in the steel industry is with mechanical draft cooling towers.

Most recycle systems include only simple pump stations and piping. These components require very little attention apart from routine maintenance. However, for those recycle systems associated with wet air pollution control devices, higher maintenance costs are incurred to control the recycled water chemically in order to remove suspended and dissolved constituents and to prevent fouling and scaling.

5.3 Suspended Solids Removal

Many types of suspended solids removal devices are in use in the steel industry including:

- settling lagoons,
- clarification which includes clarifiers, thickeners, and inclined plate separators and,
- filtration.

5.3.1 Settling lagoon

Settling removes solid particles from a liquid matrix by gravitational force. The operation reduces the velocity of the wastewater stream in a large volume lagoon so that gravitational settling can occur.

Long retention times (some days) are generally required, periodically or continuously. The addition of settling aids, such as alum or polymeric flocculants is also often used.

Sedimentation is often preceded by chemical precipitation and coagulation. Chemical precipitation converts dissolved pollutants to solid form, while coagulation enhances settling by gathering together suspended precipitates into larger, faster settling particles.

A properly operated sedimentation system is capable of efficiently removing suspended solids (including metal hydroxides), and other impurities from wastewaters. The performance of the lagoon depends primarily on overflow rate and a variety of other factors, including the density and particle size of the solids, the effective charge of the suspended particles, and the types of chemicals used for pre-treatment, if any.

Sufficient retention time and regular sludge removal are important factors affecting the reliability of all settling systems. The proper control of pH, chemical precipitation, and coagulation or flocculation are additional factors which affect settling efficiencies. Little maintenance is required for lagoons other than periodic sludge removal.

5.3.2 Clarifiers

Clarifiers are more effective for removing suspended solids than simple settling lagoons, require less space, and provide for centralized sludge collection. However, the cost of installing and maintaining clarifiers is greater than the costs associated with simple settling lagoons.

Conventional clarifiers consist of a circular or rectangular tank with either a mechanical sludge collecting device or with a sloping funnel-shaped bottom designed for sludge collection. In alternative clarifier designs, inclined plates or tubes may be placed in the clarifier tank to increase the effective settling area and thus increase the capacity of the clarifier.

As with settling lagoons, chemical aids are often added prior to clarification to enhance suspended solids removal.

Advanced clarifiers using slanted tubes or inclined plates may require prescreening of the wastewater in order to eliminate any materials which could potentially clog the system.

The systems used for chemical pre-treatment and sludge dragout must be maintained on a regular basis. Routine maintenance of mechanical parts is also necessary.

5.3.3 Filtration

Filtration is currently used to remove suspended solids, oil and grease, and toxic metals from steel industry wastewaters, with the following principal advantages: low initial and operating costs, modest land requirements, lower effluent solids concentration, and reduction or elimination of chemical additions which add to the discharge stream. However, the filter may require pre-treatment if the suspended solids level is over 100 mg/l. In addition, operator training is necessary due to the controls and periodic backwashing involved.

Filtration is a highly reliable method of wastewater treatment. Several types of filters and filter media are used in the industry and all work by similar mechanisms. Filters may be pressure or gravity type; single, dual or mixed media; and the media can be sand, diatomaceous earth, walnut shells or some other material.

A filter may use a single medium such as sand. However, by using dual or multiple media, higher flow rates and efficiencies can be achieved. The dual medium filter usually consists of a fine bed of sand under a coarser bed of another medium. The coarse medium removes most of the influent solids, while the fine sand performs final polishing.

A knowledge of particle density, size distribution, and chemical composition is useful when selecting a filter design rate and media.

Filter media must be selected in conjunction with the filter design rate. The size and depth of the media is a primary consideration and other important factors are the chemical composition, sphericity, and hardness of the media chosen. The presence of relatively large amounts of oil in the wastewater to be filtered also affects the selection of the appropriate media.

During the filtration process, suspended solids and oils accumulate in the bed and reduce the ability of the wastewater to flow through the media. To function properly, all filters are backwashed. The method of backwashing and the design of backwash systems is an integral part of any deep-bed filtration system. Solids penetrate deeply into the bed and must be adequately removed during the backwashing cycle or problems may develop within the filtration system. Occasionally, auxiliary means are employed to aid filter cleaning. Water jets used just below the surface of the expanded bed will aid solids and oil removals. Also, air can be used to augment the cleaning action of the backwash water to "scour" the bed free of solids and oils.

5.4 Oil Removal

The source of oils and greases is usually lubricants and preservative coatings used in the various steelmaking and finishing operations.

The most effective first step in oil removal is to prevent the oil from mixing with the large volume wastewater flows by segregating the sumps in all cellars and by appropriate maintenance of the lubrication and greasing systems.

Oils and greases which remain in water are removed from process wastewaters by three methods including oil skimming, filtration and air flotation.

5.4.1 Oil skimming

This technique may be used on any wastewater containing pollutants (free oil, grease and soaps) which float to the surface. Skimming is always used with air flotation and often with clarification to improve removal of both settling and floating materials.

The removal efficiency of a skimmer is a function of the density of the material to be floated and the retention time of the wastewater in the tank. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending upon wastewater characteristics.

Skimming as pre-treatment is effective in removing naturally floating waste material. It also improves the performance of subsequent downstream treatments.

Many pollutants, particularly dispersed or emulsified oil, will not float "naturally" but require additional treatment. Therfore, skimming alone may not remove all the pollutants capable of being removed by air flotation or other more sophisticated technologies.

5.4.2 Filtration

The discussion presented above on filtration systems applies here as well. The oils and greases, either floating or emulsified types, are directed into the filter where they are adsorbed on the filter media. Significant oil reductions can be achieved with filtration, and problems with the oils are not experienced unless high concentrations of oils are allowed to reach the filter bed. When this occurs, the bed can be "blinded" and must be backwashed immediately. If too much oil is in the filter wastewater, frequent backwashing is necessary which makes the use of the technology unworkable. Therefore, proper pre-treatment is essential for the efficient operation of filtration equipment.

5.4.3 Flotation

Flotation causes particles such as metal hydroxides or oils to float to the surface of a tank where they are concentrated and removed. Gas bubbles are released in the wastewater and attach themselves to the solid particles, which increase their buoyancy and cause them to float.

Flotation is used primarily in the treatment of wastewaters that carry finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which require abnormally long sedimentation times, may be removed by flotation.

This process may be performed in several ways, the principal difference between which being the method of generating the minute gas bubbles (usually air) needed to float the oil. Chemicals may be used to improve the efficiency of any basic methods.

The most commonly used techniques are: froth, dispersed air, dissolved air and vacuum flotation.

Froth flotation is based upon the differences in the physiochemical properties of various particles. Wettability and surface properties affect particle affinity to gas bubbles. In froth flotation, air is blown through the solution containing flotation reagents. The particles with water repellent surfaces stick to air bubbles and are brought to the surface. A mineralized froth layer, with mineral particles attached to air bubbles, is formed. Particles of other minerals which are readily wetted by water do not stick to air bubbles and remain in suspension.

In dispersed air flotation, gas bubbles are generated by introducing the air by mechanical agitation with impellers or by forcing air through porous media.

In dissolved air flotation, bubbles are produced as a result of the release of air from a supersaturated solution under relatively high pressure.

There are two types of contact between the gas bubbles and particles. The first involves the entrapment of rising gas bubbles in the flocculated particles as they increase in size. The bond between the bubble and particle is one of physical capture only. This is the predominant type of contact. The second type of contact is one of adhesion. Adhesion results from the intermolecular attraction exerted at the interface between the solid particle and gaseous bubble.

Vacuum flotation consists of saturating the wastewater with air, either directly in an aeration tank or by permitting air to enter the suction of a pump. A partial vacuum causes the dissolved air to come out of solution as minute bubbles. The bubbles attach themselves to solid particles and form a scum blanket on the surface, which is normally removed by a skimming mechanism. Grit and other heavy solids which settle to the bottom are generally raked to a central sludge pump for removal. A typical vacuum flotation unit consists of a covered cylindrical tank in which a partial vacuum is maintained. The tank is equipped with scum and sludge removal mechanisms. The floating material is continuously swept to the tank periphery, automatically discharged into a scum trough, and removed from the unit by a pump also under partial vacuum.

The advantages of such a process include the high levels of solids and oil separation which are achieved in many applications; relatively low energy requirements; and, the capability to adjust air flow to meet the varying requirements of treating different types of wastewaters. The limitations of flotation are that it often requires addition of chemicals to enhance process performance; it requires properly trained and attentive operators; and it generates large quantities of solid wastes.

The reliability of a flotation system is normally high and is governed by proper operation of the sludge collector mechanism and by the motors and pumps used for aeration.

Maintenance of the scraper blades used to remove the floated material is critical for proper operation. Routine maintenance is required on the pumps and motors. The sludge collector mechanism is subject to possible corrosion or breakage and may require periodic replacement.

5.4.4 Ultrafiltration

Ultrafiltration includes the use of pressure and semi-permeable polymeric membranes to separate emulsified or colloidal materials suspended in a liquid phase. The membrane of an ultrafiltration unit forms a molecular screen which retains molecular particles based upon their differences in size, shape, and chemical structure. The membrane permits the passage of solvents and lower molecular weight molecules. At present, ultrafiltration systems are used to remove materials with molecular weights in the range of 1,000 to 100,000 and particles of comparable or larger sizes.

In the ultrafiltration process, the wastewater is pumped through a tubular membrane unit. Water and some low molecular weight materials pass through the membrane. Emulsified oil droplets and suspended particles are retained, concentrated, and removed continuously. In contrast to ordinary filtration, retained materials are washed off the membrane filter rather than held by it.

Ultrafiltration is an attractive alternative in certain applications, namely in cold rolling operations because of lower installation and operating costs, high oil and suspended solids removal, and little pre-treatment required. It places a positive barrier between pollutants and effluent which reduces the possibility of extensive pollutant discharge due to operator error or upset in settling and skimming systems. Another possible application is recovering alkaline values from alkaline cleaning solutions.

A limitation on the use of ultrafiltration for treating wastewaters is its narrow temperature range (18 to 30 degrees C) for satisfactory operation. Membrane life is decreased with higher temperatures, but flux increases at elevated temperatures. Therefore, the surface area requirements are a function of temperature and become a trade-off between initial costs and replacement costs for the membrane. Ultrafiltration is not suitable for certain solutions. Strong oxidizing agents, solvents, and other organic compounds can dissolve the membrane. Fouling is sometimes a problem, although the high velocity of the wastewater normally creates enough turbulence to keep fouling at a minimum. Large solids particles are also sometimes capable of puncturing the membrane and must be removed by gravity settling or filtration prior to ultrafiltration.

The reliability of ultrafiltration systems is dependent upon the proper filtration, settling or other treatment of incoming wastewaters to prevent damage to the membrane.

A limited amount of regular maintenance is required for the pumping system. In addition, membranes must be periodically changed. The maintenance associated with membrane plugging can be reduced by selecting a membrane with optimum physical characteristics and providing sufficient velocity of the wastewater. It is necessary to pass a detergent solution through the system at regular intervals to remove an oil and grease film which accumulates on the membrane. With proper maintenance membrane life can be greater than twelve months.

5.5 Metals Removal

Steel industry wastewaters contain significant levels of toxic metal pollutants including chromium, copper, lead, nickel, zinc and others. These pollutants are generally removed by:

- chemical precipitation,
- filtration.

5.5.1 Chemical precipitation

Dissolved toxic metal ions and certain anions may be chemically precipitated and removed by physical means such as sedimentation, filtration, or centrifugation. Several reagents are commonly used to effect this precipitation.

- Alkaline compounds such as lime or sodium hydroxide, to precipitate many toxic metal ions as metal hydroxides. Lime may also precipitate phosphates as insoluble calcium phosphate and fluorides as calcium fluoride.

- Both soluble sulphides such as hydrogen sulphide or sodium sulphide and insoluble sulphides such as ferrous sulphide, to precipitate many heavy metal ions as insoluble metal sulphides.

- Carbonate precipitates to remove metals either by direct precipitation using a carbonate reagent such as calcium carbonate or by converting hydroxides into carbonates using carbon dioxide.

These treatment chemicals may be added to a flash mixer or rapid mix tank, a pre-settling tank, or directly to a clarifier or other settling device. Coagulation agents may be added to facilitate settling. After the solids have been removed, a final pH adjustment may be required to reduce the high pH created by the alkaline treatment chemicals.

A small amount of metal will remain dissolved in the wastewater after complete precipitation. The amount of residual dissolved metal depends on the treatment chemicals used, the solubility of the metal and co-precipitation effects.

Chemical precipitation is used extensively in the steel industry for precipitation of dissolved metals including aluminium, antimony, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, tin and zinc. The process is also applicable to any substance that can be transformed into an insoluble form such as fluorides, phosphates, soaps, sulphides, and others.

Chemical precipitation is a simple and effective technique for removing many pollutants from industrial wastewaters. It operates at ambient conditions and is well suited to automatic control. The use of chemical precipitation may be limited due to interference of chelating agents, chemical interferences from mixing wastewaters and treatment chemicals, and potentially hazardous situations involved in the storage and handling of those chemicals. Lime is usually added as a slurry when used in hydroxide precipitation. The slurry must be well mixed and the addition lines periodically checked to prevent fouling. . In addition, hydroxide precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most hydroxide sludges.

The reliability of alkaline chemical or sulphide precipitation is high, although proper monitoring and control are necessary.

The major maintenance needs involve periodic upkeep of monitoring equipment, automatic feeding equipment, mixing equipment, and other hardware. Removal of accumulated sludge is necessary.

5.5.2 Filtration

Filtration (cf. § 5.4.2) is a proven technology for the control of suspended solids, oil and grease. It can also treat the metallic elements which are present in particulate form.

5.6 Organic Removal

Different organic toxic pollutants of which a list is given in table 12 after American studies can be eliminated by two technologies:

- carbon adsorption,
- biological treatment with activated sludge.

Table 12

Toxic organic pollutants eliminable by carbon adsorption or biological oxidation

Acrylonitrile
Benzene
Hexachlorobenzene
1,1,1-Trichloroethane
2,4,6-Trichlorophenol
Parachlorometacresol
Chloroform
2-Chlorophenol
2,4-Dimethylphenol
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Ethylbenzene
Fluoranthene
Isophorone
Naphthalene
2-Nitrophenol
4,6-Dinitro-o-cresol
Pentachlorophenol
Phenol
Phthalates
Benzo(a)anthracene
Benzo(a)pyrene
Chrysene
Acenaphthylene
Anthracene
Fluorene
Pyrene
Tetrachlorethylene
Toluene
Xylene

5.6.1 Carbon adsorption

The use of activated carbon for removal of dissolved organics or many toxic metals from water and wastewater has been demonstrated and is one of the most efficient organic removal processes available. This process is reversible, thus allowing activated carbon to be regenerated and re-used by the application of heat and steam or solvent. Regeneration of carbon which has adsorbed significant metals, however, may be difficult.

The term activated carbon applies to any amorphous form of carbon that has been specially treated to give high adsorption capacities. Typical raw materials include coal, wood, coconut shells, petroleum base residues and char from sewage sludge pyrolysis. A carefully controlled process of dehydration, carbonization, and oxidation yields a product which is called activated carbon. This material has a high capacity for adsorption due primarily to the large surface area available for adsorption (500-1500 m^2/gr) which results from a large number of internal pores. Pore sizes generally range in radius from 10-100 angströms.

Activated carbon removes contaminants from water by the process of adsorption (the attraction and accumulation of one substance on the surface of another). Activated carbon preferentially adsorbs organic compounds and, because of this selectivity, is particularly effective in removing toxic organic pollutants from wastewaters.

Carbon adsorption requires pre-treatment (usually filtration) to remove excess suspended solids, oils, and greases. Suspended solids in the influent should be less than 50 mg/l to minimize backwash requirements. A downflow carbon bed can handle much higher levels (up to 2000 mg/l), but frequent backwashing is required. Backwashing more than two or three times a day is not desirable. Oil and grease should be less than about 15 mg/l. A high level of dissolved inorganic material in the influent may cause problems with thermal carbon reactivation (i.e. scaling and loss of activity) unless appropriate preventive steps are taken. Such steps might include pH control, softening, or the use of an acid wash on the carbon prior to reactivation.

Activated carbon is available in both powdered and granular form. Powdered carbon is less expensive per unit weight and may have slightly higher adsorption capacity but it is more difficult to handle and to regenerate.

Activated carbon is used in a variety of applications and some installations are in use in the steel industry for treating cokemaking wastewaters.

The major benefits of carbon treatment include applicability to a wide variety of organics, and a high removal efficiency. The system is not sensitive to fairly wide variations in concentration and flow rates. The system is compact, and recovery of adsorbed materials is sometimes practical. However, the destruction of adsorbed compounds often occurs during thermal regeneration. If carbon cannot be thermally desorbed, it must be disposed of along with any adsorbed pollutants.

The process is very reliable with proper pre-treatment and proper operation and maintenance.

5.6.2 Biological oxidation

Biological treatment is another method of reducing the concentration of ammonia-n, cyanide, phenols (4AAP) and toxic organic pollutants from process wastewaters. The activated sludge system is well demonstrated in the steel industry, although other systems including rotating biological discs have also been studied.

In the activated sludge process, wastewater is stabilized biologically in a reactor under aerobic conditions. The aerobic environment is achieved by the use of diffused or mechanical aeration. After the wastewater is treated in the reactor, the resulting biological mass is separated from the liquid in a settling tank. A portion of the settled biological solids is recycled and the remaining mass is wasted. The level at which the biological mass should be maintained in the system depends upon the desired treatment efficiency, the particular pollutants that are to be removed and other considerations related to growth kinetics.

The activated sludge system generally is sensitive to fluctuations in hydraulic and pollutant loadings, temperature and certain pollutants. Temperature not only influences the metabolic activities of the microbiological population, but also has an effect on such factors as gas transfer rates and the settling characteristics of the biological solids. Some pollutants are extremely toxic to the micro-organisms in the system, such as ammonia at high concentrations and toxic metals. Therefore, sufficient equalization and pre-treatment must be installed ahead of the biological reactor so that high levels of toxic pollutants do not enter the system and "kill" the micro-organism population. If the biological conditions in an activated sludge plant are upset, it can be a matter of days or weeks before biological activity returns to normal.

The activated sludge system achieves significant reductions of most toxic organic pollutants at significantly less capital and operating costs than for carbon adsorption. Also, consistent effluent quality can be maintained if sufficient pre-treatment is practised and shock loadings of specific pollutants are eliminated. The temperature, pH and oxygen levels in the system must be maintained within certain ranges or fluctuating removal efficiencies of some pollutants will occur.

5.7 Advanced Technologies

Two other advanced treatment technologies are possible alternative treatment systems:

- ion exchange
- osmosis.

5.8 Treatment Processes

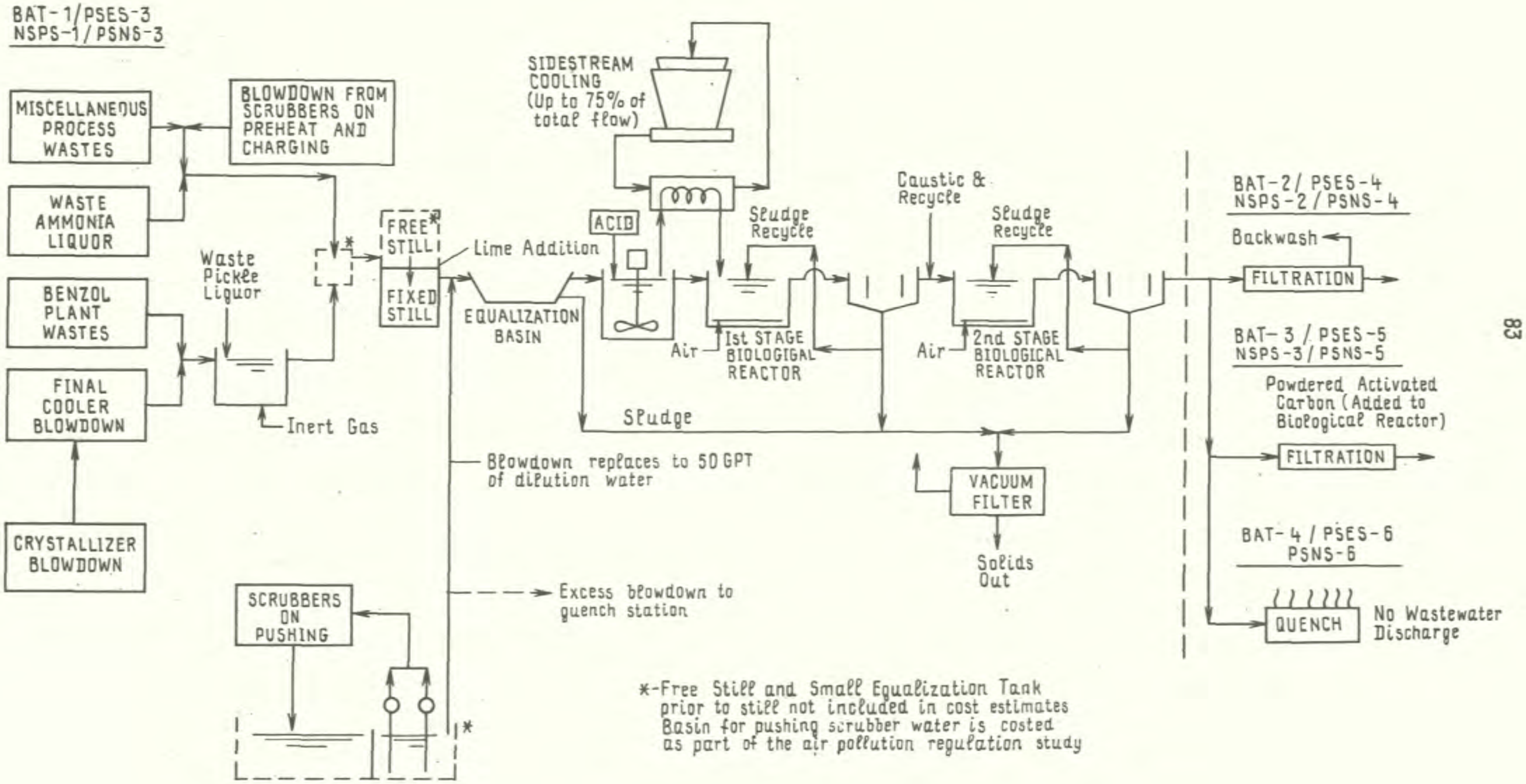
It is not possible to describe all the processes which are applied world-wide to treat different steel industry wastewater. We prefer to give some examples, from an American publication. Figures 10 to 22 present some treatment models for:

- cokemaking (figures 10 and 11)
- blast furnace (figure 12)
- basic oxygen furnace (figures 13 and 14)
- vacuum degassing (figure 15)
- continuous casting (figures 16 and 17)
- hot forming (figures 18 and 19)
- cold rolling (figure 20)
- hot coating (figures 21 and 22).

These figures agree with some American regulations:

BPT : best practicable control technology currently available
BAT : best available technology economically achievable
NSPS : new source performance standards
PSES):
PSNS): pre-treatment standards
BCT : best conventional technology.

Figure 10
By-product cokemaking
Treatment models summary

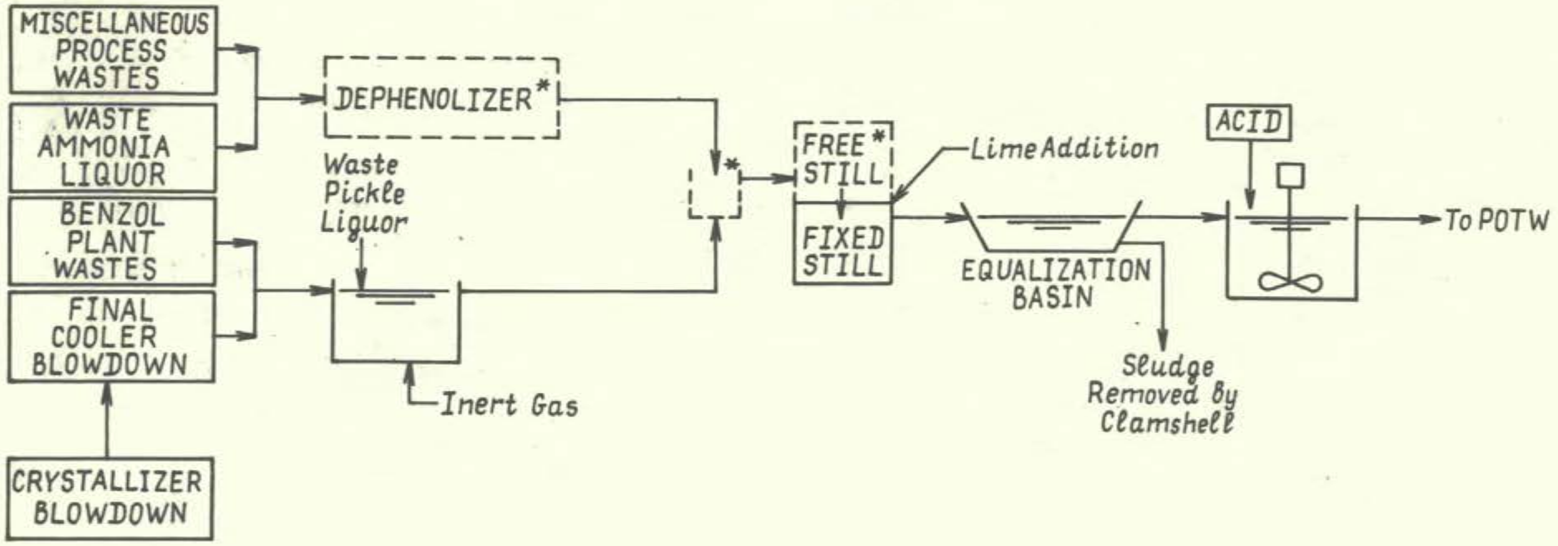


*-Free Still and Small Equalization Tank prior to still not included in cost estimates
Basin for pushing scrubber water is costed as part of the air pollution regulation study

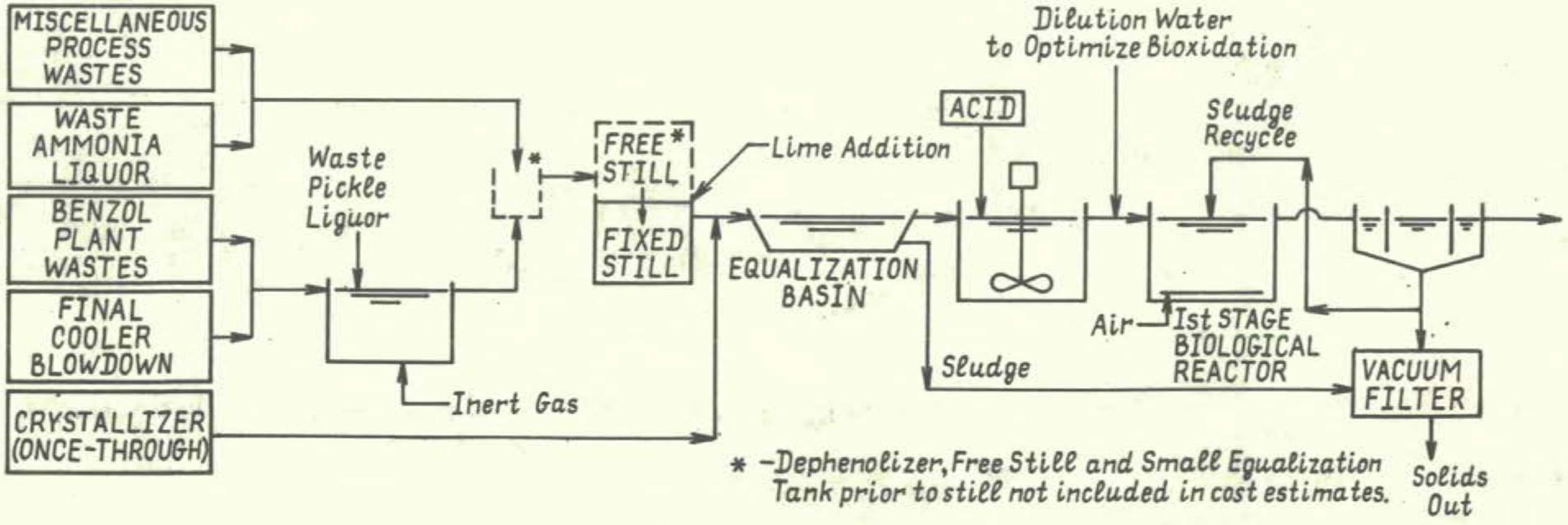
Figure 11

By-product cokemaking
Treatment models summary

PSES-1/PSNS-1

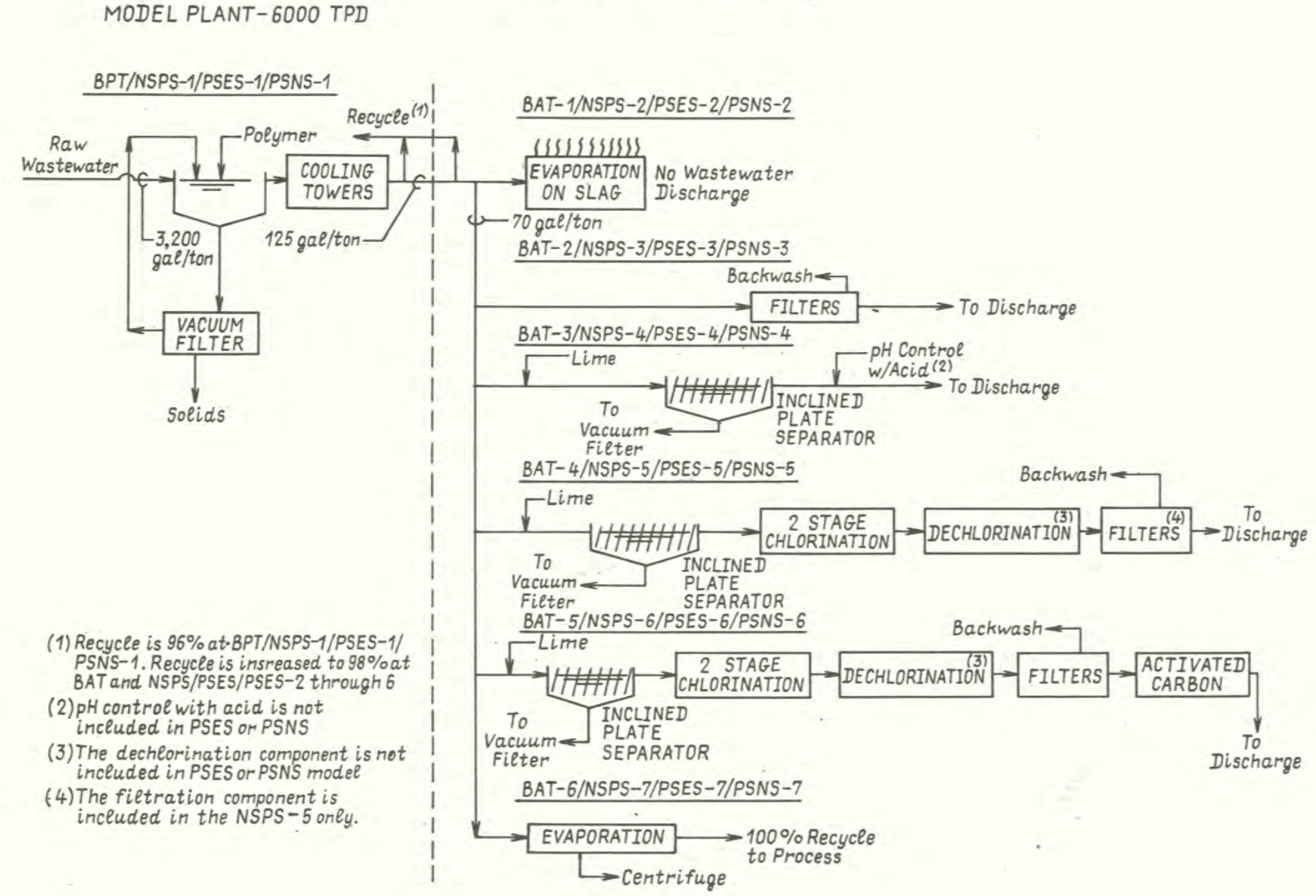


BAT/BCT/PSES-2/PSNS-2



* -Dephenolizer, Free Still and Small Equalization Tank prior to still not included in cost estimates.

Figure 12
Ironmaking
Treatment models summary



(1) Recycle is 96% at BPT/NSPS-1/PSES-1/PSNS-1. Recycle is insreased to 98% at BAT and NSPS/PSES/PSES-2 through 6

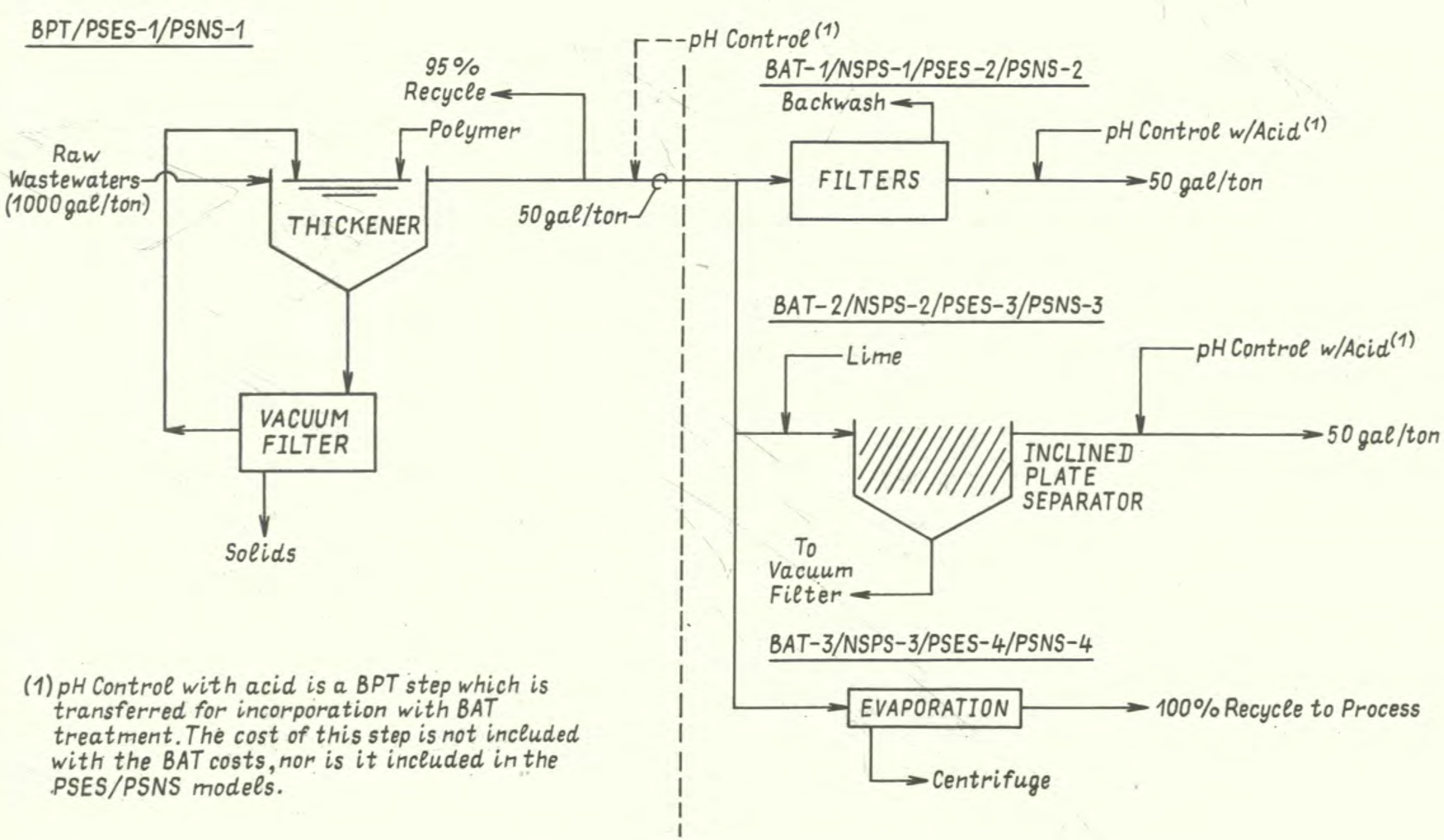
(2) pH control with acid is not included in PSES or PSNS

(3) The dechlorination component is not included in PSES or PSNS model

(4) The filtration component is included in the NSPS-5 only.

Figure 13
Basic Oxygen furnace-wet suppressed combustion
Treatment models summary

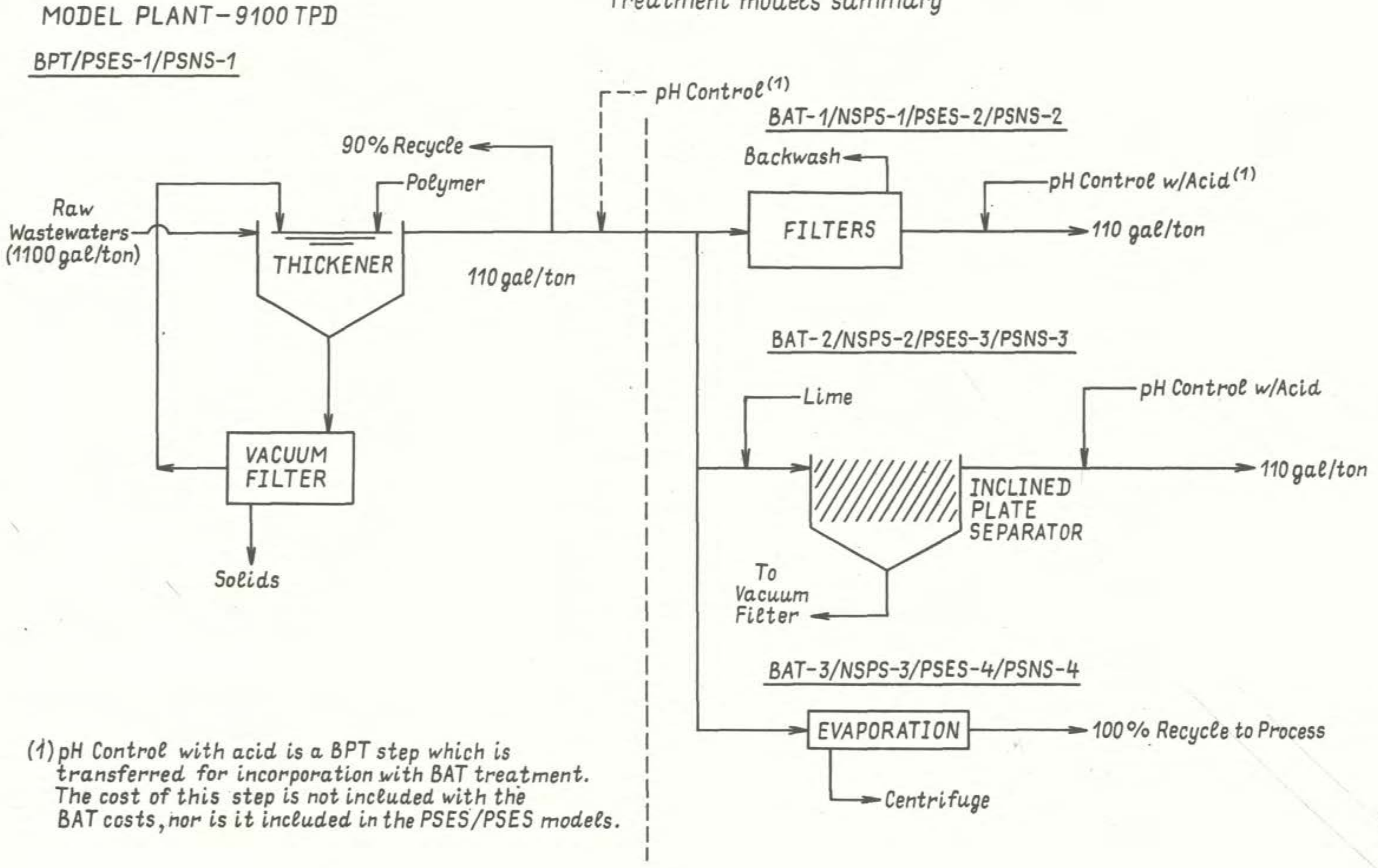
MODEL PLANT - 7400 TPD



(1) pH Control with acid is a BPT step which is transferred for incorporation with BAT treatment. The cost of this step is not included with the BAT costs, nor is it included in the PSES/PSNS models.

Figure 14

Basic oxygen furnace-wet-open combustion
Treatment models summary

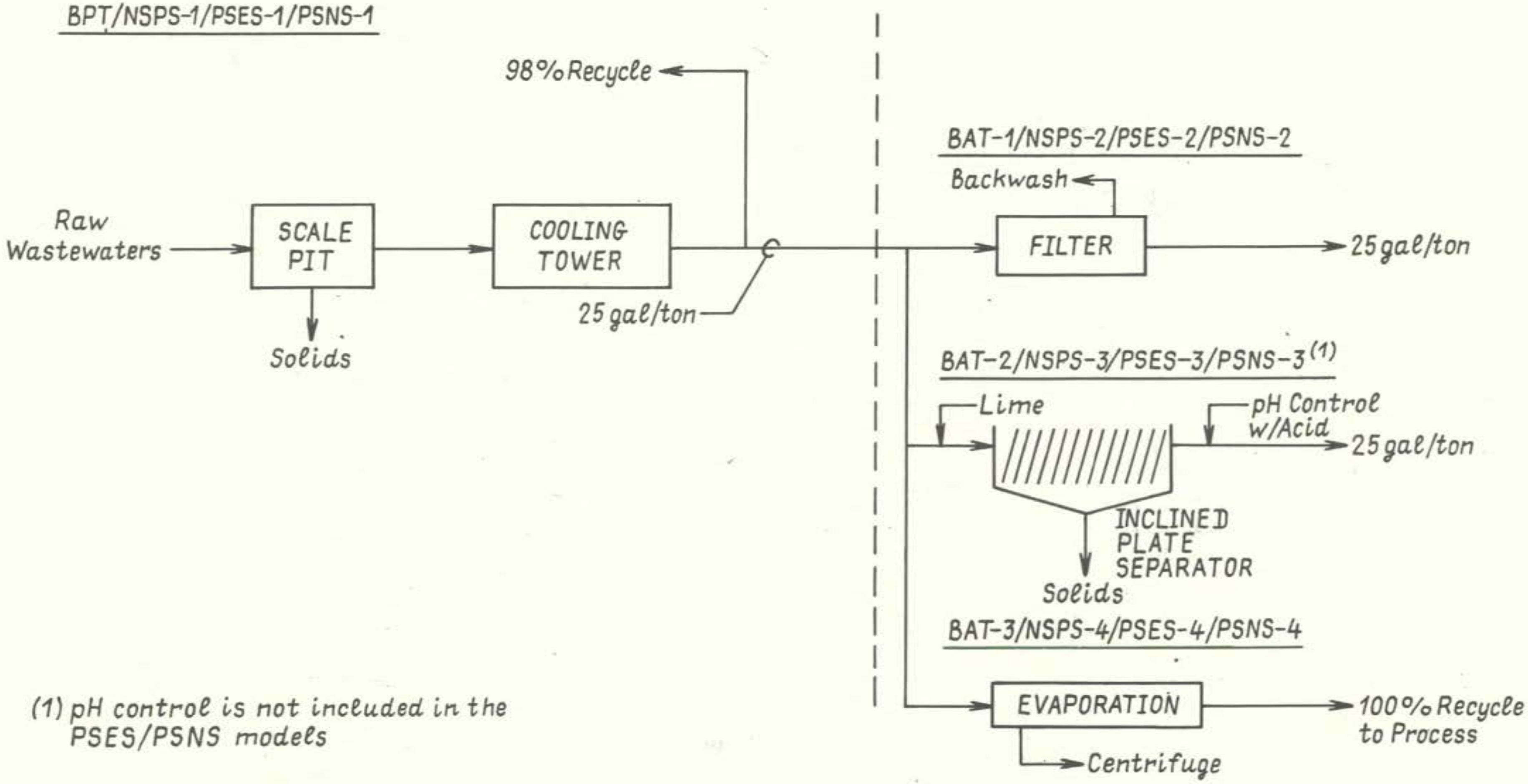


(1) pH Control with acid is a BPT step which is transferred for incorporation with BAT treatment. The cost of this step is not included with the BAT costs, nor is it included in the PSES/PSES models.

Figure 15

Vacuum degassing
Treatment models summary

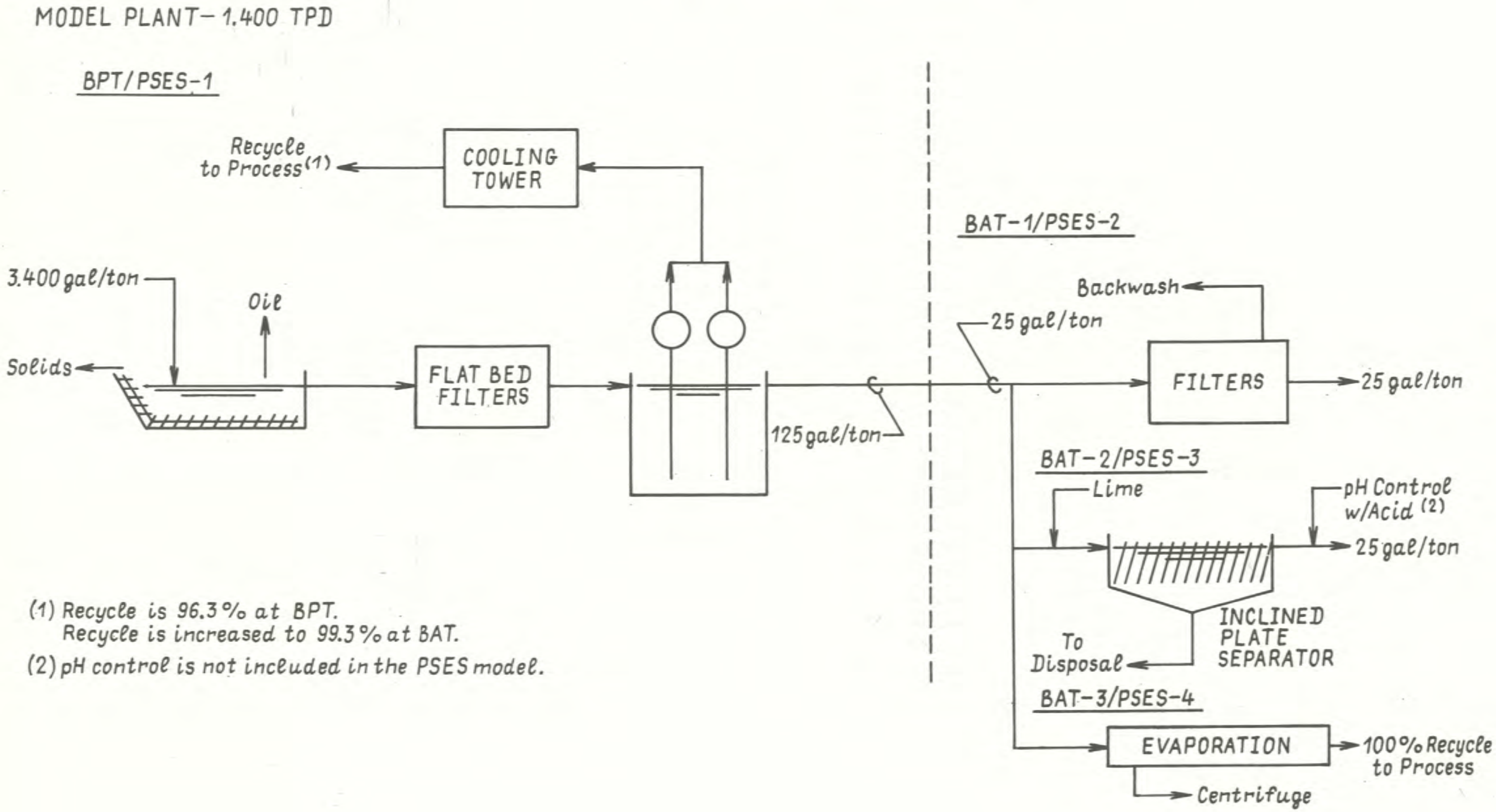
MODEL PLANT-1200 TPD



(1) pH control is not included in the PSES/PSNS models

Figure 16

Continuous Casting
BPT/BAT/PSES
Treatment models summary

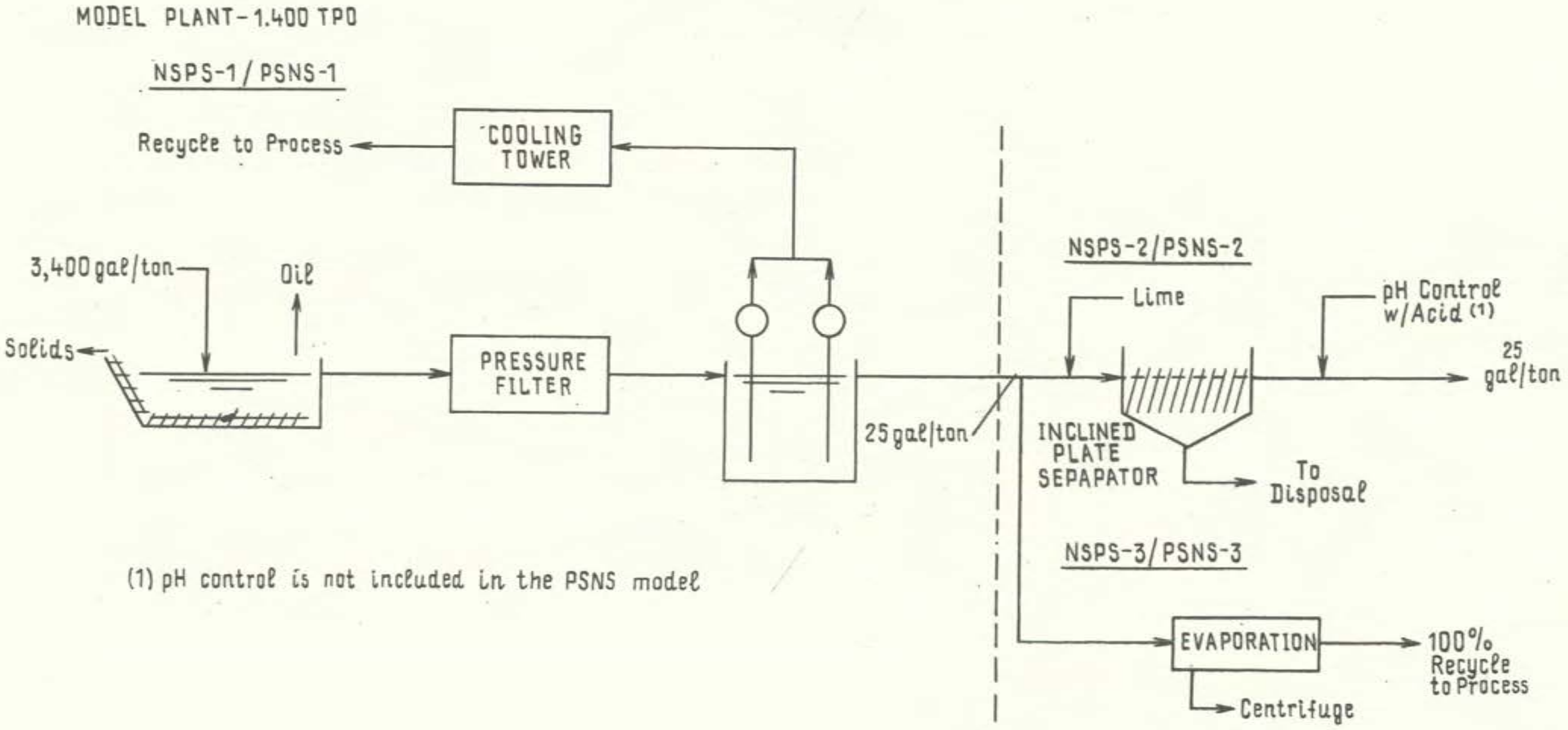


(1) Recycle is 96.3% at BPT.
Recycle is increased to 99.3% at BAT.

(2) pH control is not included in the PSES model.

Figure 17

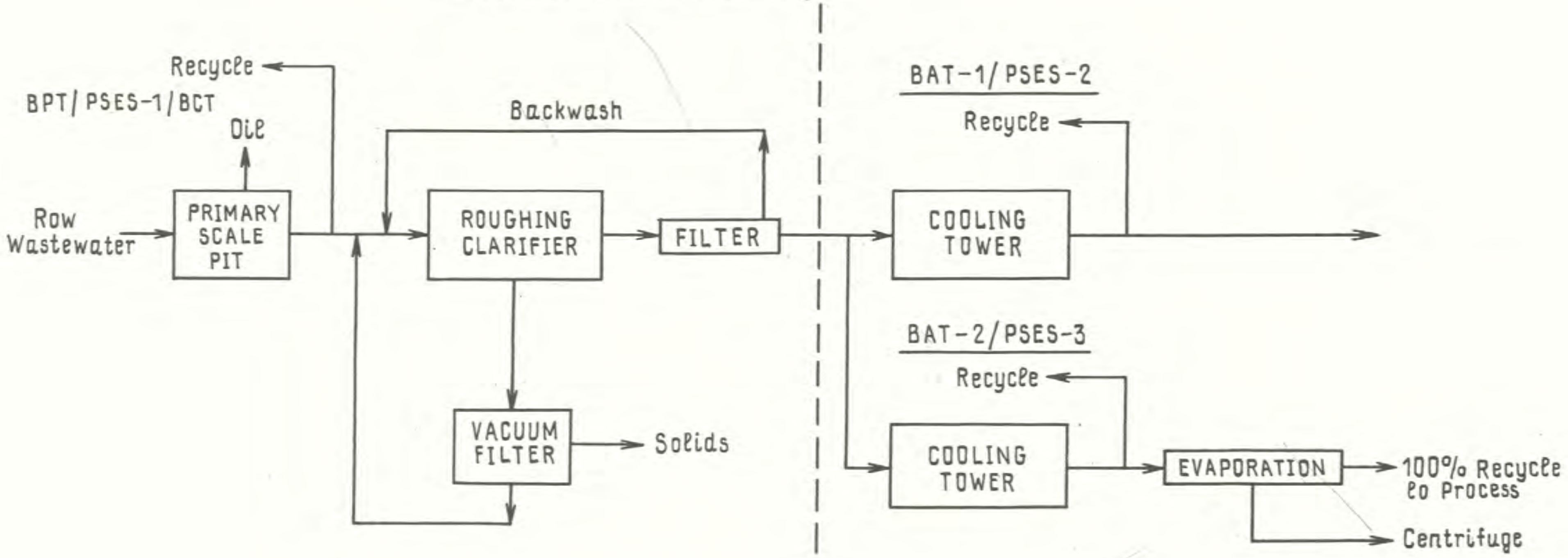
Continuous casting
NSPS/PSNS
Treatment models summary



(1) pH control is not included in the PSNS model

Figure 18

Hot forming
BPT/BCT/BAT/PSES
Treatment models summary

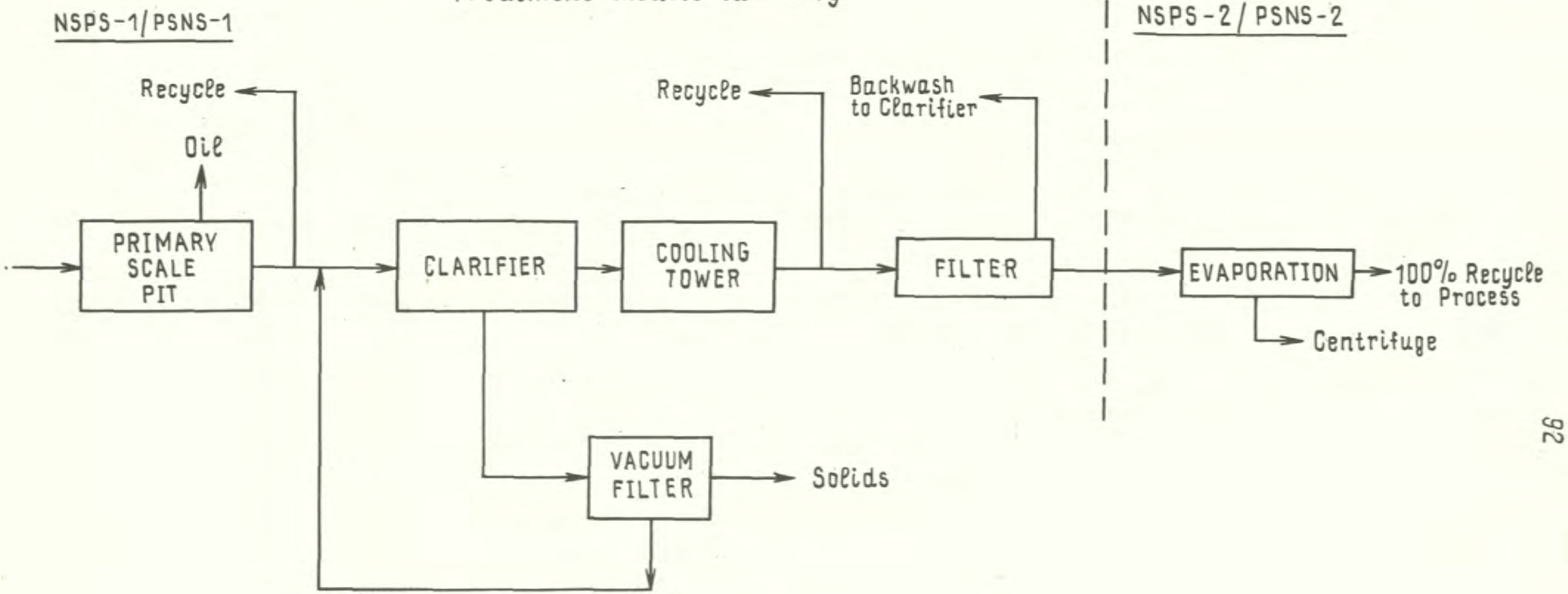


HOT FORMING FLOW RATES

SUBDIVISION		APPLIED FLOW (GPT)	(m^3/t)	PSP RECYCLE (%)	BPT DISCHARGE FLOW (GPT)	(m^3/t)	BAT RECYCLE (%)	BAT DISCHARGE FLOW (GPT)	(m^3/t)
PRIMARY	wo/ Scarfer	2300	9.60	61	897	3.74	35	90	0.38
	w/ Scarfer	3400	14.18	61	1326	5.53	35	140	0.58
SECTION	Carbon	5100	21.28	58	2142	8.94	38	200	0.83
	Specially	3200	13.35	58	1344	5.61	38	130	0.54
FLAT	Hot Strip	6400	26.70	60	2560	10.68	36	260	1.08
	Carbon Plate	3400	14.18	60	1360	5.67	36	140	0.58
	Specialty Plate	1500	6.26	60	600	2.50	36	60	0.25
PIPE & TUBE		5520	23.03	77	1270	5.30	19	220	0.92

Figure 19

Hot forming
NSPS/PSNS
Treatment models summary

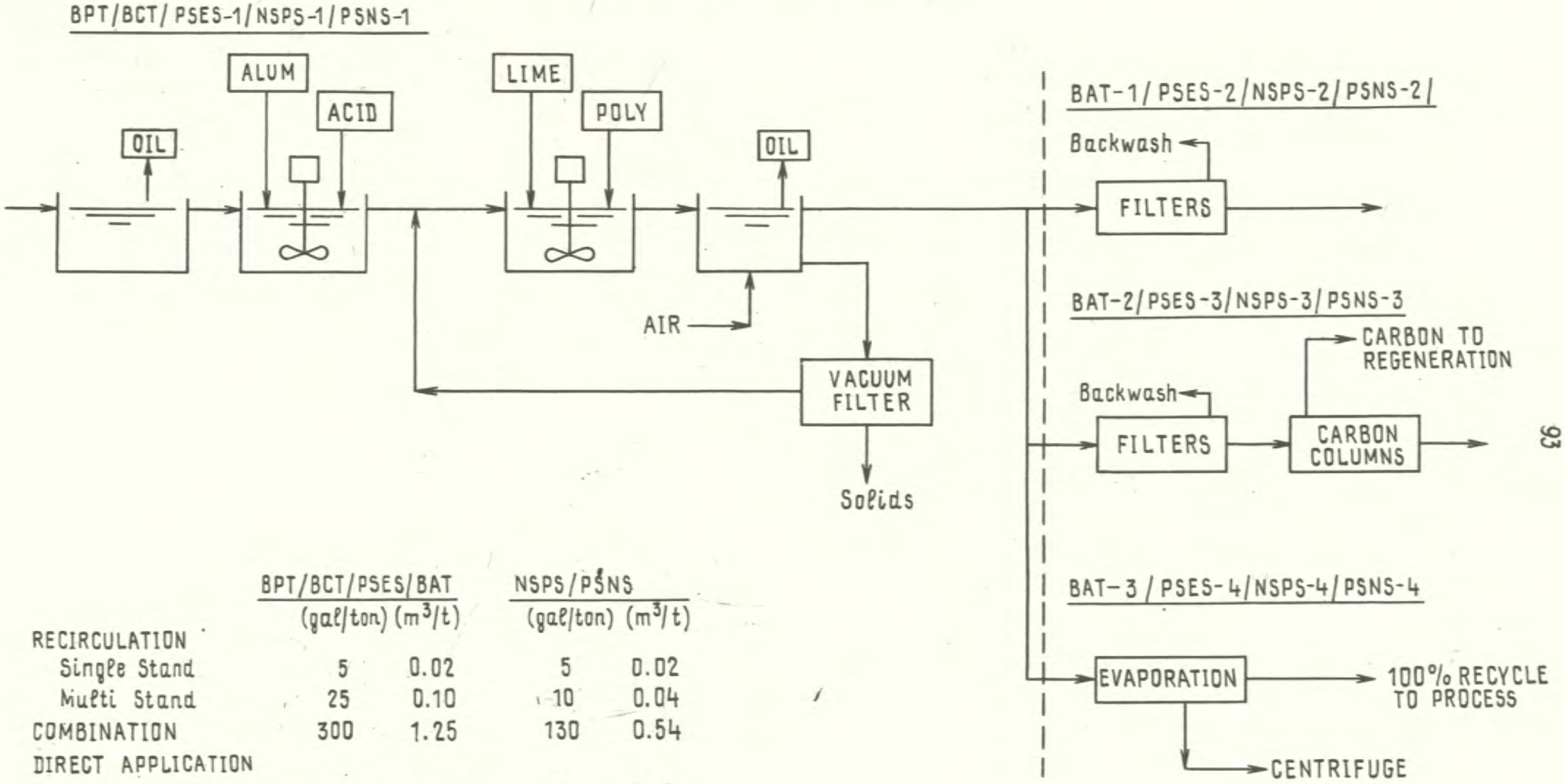


NSPS FLOW RATES

SUBDIVISION		APPLIED FLOW (GPT)	(m^3/t)	COMBINED RECYCLE RATE (%)	DISCHARGE FLOW (GPT)	(m^3/t)
PRIMARY	wo/scarfer	2300	9.60	96	90	0.38
	w/scarfer	3400	14.18	96	140	0.58
SECTION	Carbon	5100	21.28	96	200	0,83
	Specialty	3200	13.35	96	130	0.54
FLAT	Hot Strip	6400	26.70	96	260	1.08
	Carbon Plate	3400	14.18	96	140	0.58
	Specialty Plate	1500	6.26	96	60	0.25
PIPE & TUBE		5520	23.03	96	220	0.92

Figure 20

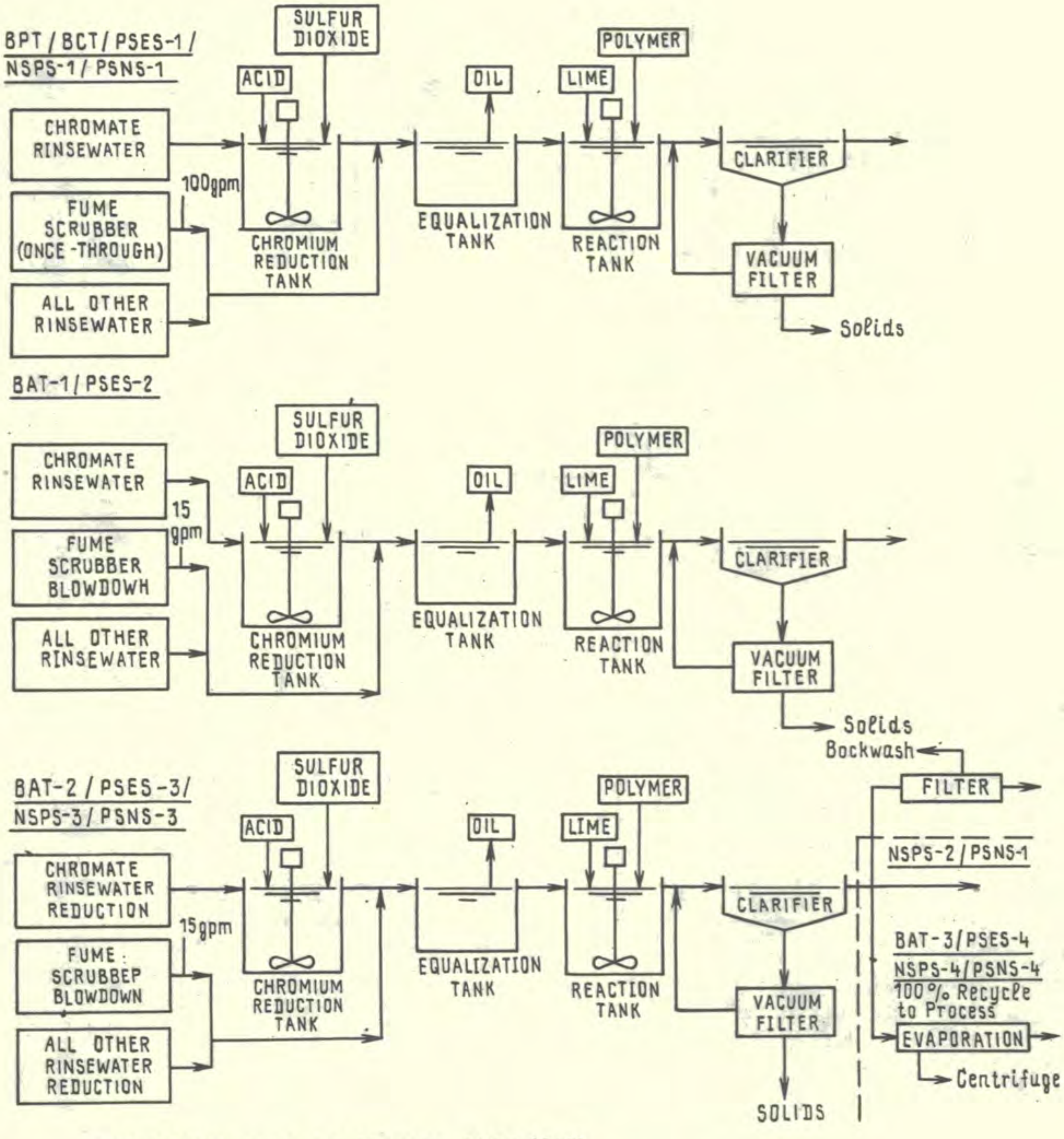
Cold forming : cold rolling
Treatment models summary



	BPT/BCT/PSES/BAT		NSPS/PSNS	
	(gal/ton)	(m³/t)	(gal/ton)	(m³/t)
RECIRCULATION				
Single Stand	5	0.02	5	0.02
Multi Stand	25	0.10	10	0.04
COMBINATION	300	1.25	130	0.54
DIRECT APPLICATION				
Single Stand	90	0.38	25	0.10
Multi Stand	400	1.67	290	1.21

Figure 21

Hot coating/galvanizing
Treatment models summary



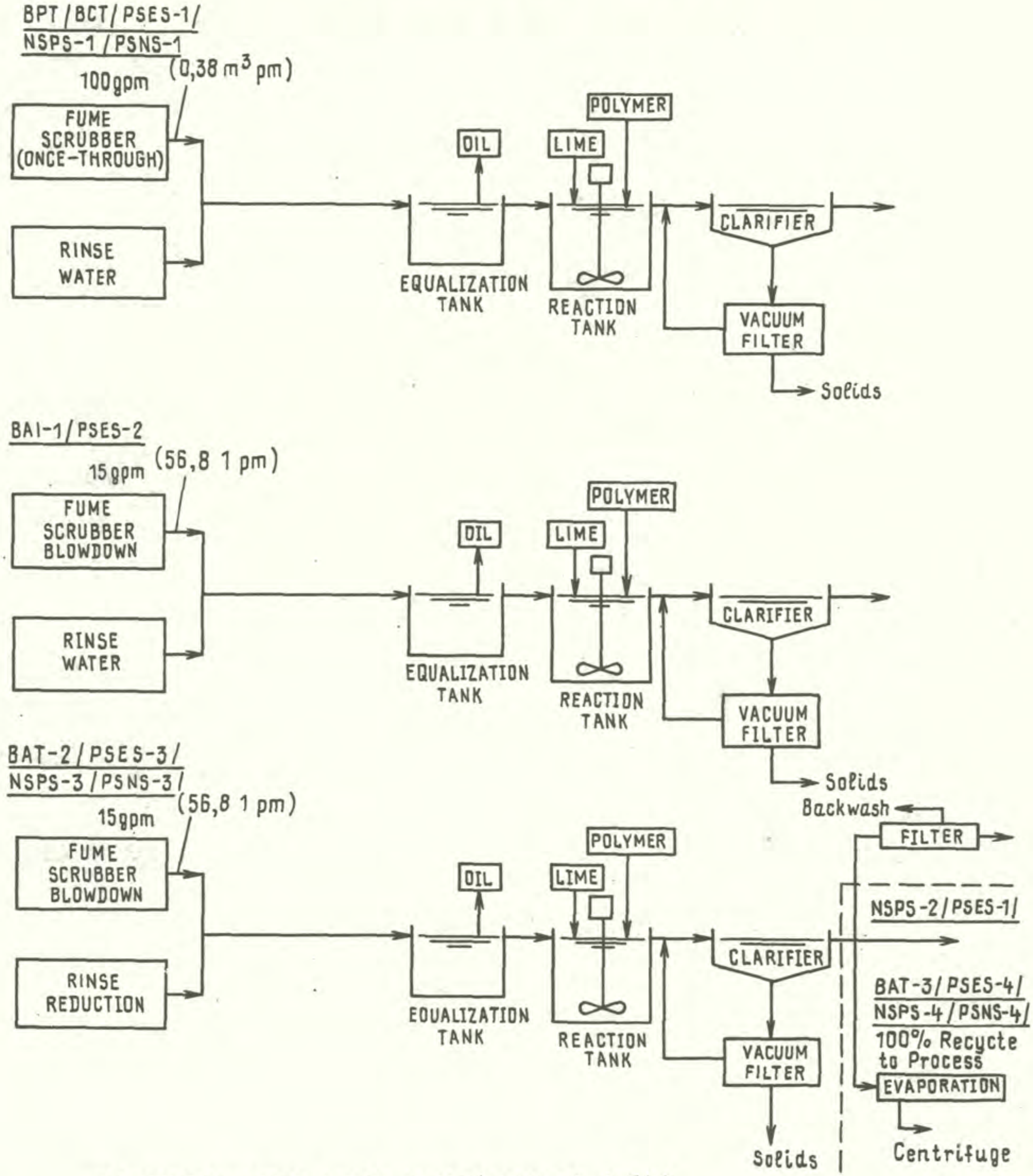
HOT COATING RINSE WATER FLOW RATES (GPT)

PRODUCT	BPT/BCT/PSES 1&2 BAT 1/NSPS 1/PSNS 1(1)	ALL OTHER MODELS(2)
Strip/Sheet & Misc Products	600 (2.50)	150 (0.63)
Wire Products & Fosteners	2400 (10.01)	600 (2.50)

(1) Fume scrubber flow at BPT/BCT/PSES-1/NSPS-1: 100gpm/scrubber

(2) Fume scrubber flow at all other models: 15 gpm/scrubber (0,38 m^3pm)
(56,8 1 pm)

Figure 22
Hot coating/terne and other metals
Treatment models summary



HOT COATING RINGE WATER FLOW RATES (GPT) (m^3/t)

PRODUCT	BAT/BCT/ PSES -1&2/ BAT 1/NSPS-1/PSNS-1 (1)		ALL OTHER MODELS (2)	
Strip/Sheet & Misc. Products	600	(2.50)	150	(0.63)
Wire Products & Fosteners	2400	(10.01)	600	(2.50)

(1) Fume scrubber flow at BPT/BCT/PSES-1/NSPS-1/PSNS-1: 15 gpm/scrubber
(2) Fume scrubber at all other models: 15gpm/scrubber (56.8 1pm)
(56.8 1 pm)

BIBLIOGRAPHY FOR SECTION 5

- Air and water pollution control in the iron and steel industry, Iron and Steel Institute Report No. 61, London, 1958

- Androne, I., and C. Mihailescu, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, August 1971, ECE Report GE. 71-12425

- Barker, J. E., Water Pollution Control Related to Coking and Blast Furnace Operations, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/H

- Chantereau, R., Treatment of ammoniacal liquors at the new coke oven battery of SOLIAC, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/5/124

- Engineering aspects of pollution control in the metals industries, Metals Society Book No. 172, London, 1975

- Exposés à la 6ème table ronde CECA "Recherches sur les cokeries et le coke", Luxembourg, octobre 1980:

- Biggi, B., Application de procédés combinés pour l'épuration des eaux de processus (eaux de barillet) dans les cokeries, Référence 8.2, Ibid

- Bridle T., and M. J. Riddle, Elimination de l'azote dans les eaux résiduaires de cokeries par voie biologique, Ibid,

- Daniel, J. L., Etude des possibilité d'amélioration du traitement final des eaux de cokeries dans un second étage biologique, Ibid

- Garrasi, G., Nouvelles recherches sur le traitement biologique des polluants chimiques contenus dans les eaux résiduaires de cokerie. Nitrification et dénitrification biologiques, Ibid

- Martens, Th., Réalisation industrielle pour l'élimination des polluants volatils des eaux résiduaires de cokerie dans une colonne de stripping à nettoyage automatique et continu, Ibid

- Stefano, V. de., Elimination de phénols et cyanures des eaux de cokeries par charbons actifs dans une installation pilote, Ibid

- Geutskens, R., and C. P. Heijwegen, Breaking oil emulsions from cold rolling mills and other installations at Hoogevens Ijmuiden B.V. *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/4

- Heijwegen, C. P. and P. Van Zijll Langhout, Treatment of waste water from the tinning lines of Hoogevens Ijmuiden B.V., *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/8/144

- Hogan, J. C., and A. F. Gibson, Reclamation of zinc from galvanizing top dross by thermal processing, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/8/145

- Huysman, M., Reduction in the amount of water used at Usinor's Dunkirk Plant, *First IISI Symposium on Environmental Control in the Steel Industry, SECSI 1*, February 1974, Report SEC/7/138

- Josis, Ch., and A. Hans, Lime stripping of coke oven effluents, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/5/123

- Layt, G.H.G., Water pollution control related to rolling mills, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/J

- Lean, J. B., Water pollution control related to surface treatment, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/4

- Management of water in the iron and steel industry, *IISI publication 128*, London, 1970

- O'Connor, A., *et al.*, The Treatment and recovery of chemicals in the effluent from inplating and association processes, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/8/144

- Tanaka, T., Recovery and recycling of waste oils from the cold rolling operation, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/7/142

- Vandevenne, R., Treatment of oil emulsions from cold rolling mills by flocculation and electroflotation, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/7/139

- Wenter, H., Electrolytic cracking of used oil emulsions, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/7/142

SECTION 6

NOISE CONTROL

6.1 Noise Regulations

Two kinds of regulations exist in every country:

- regulations for workers within the works
- regulations for the population living near the works.

6.1.1 Regulations for workers

These are based on estimates of the risk of deafness incurred by personnel if exposed for a long period to a substantial noise (see figure 23). Two notions are taken into account in the ISO standard:

- firstly for an 8-hour day, danger exists if the level of noise to which there is continuous exposure is over 90 dB(A);
- then, as noise is not constant, the figures taken must be weighted to take into account both the length of exposure to each noise level and the corresponding tolerance threshold.

One works in terms of an equivalent acoustic level, i.e. the "level which, were it present for 40 hours per week, would give the same index of exposure to noise as the various acoustic levels measured during the week".

Besides deafness, there are several diseases such as cardiovascular, respiratory etc. caused by noise.

6.1.2 Regulations for the environment

This regulation varies from country to country but in general various levels of noise are distinguished:

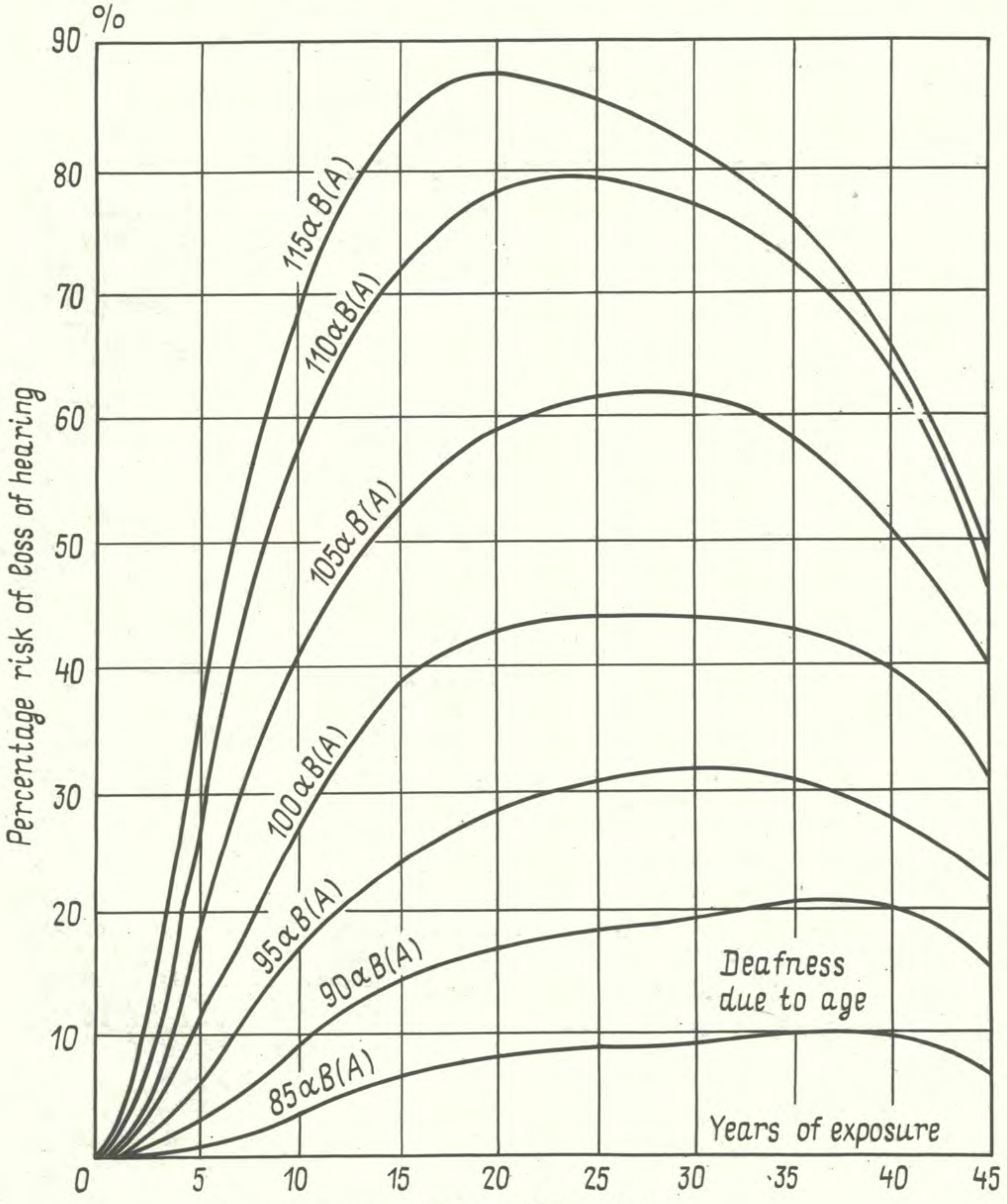
- according to the time of day: often 10 dB(A) less is required for night than for day;
- depending on the use of the zone in which the works is located: rules are stricter in residential areas than in industrial sectors.

6.2 Methods of Reducing Noise

Some parts of a steel works are characterized by high levels of sound emission. The result is a nuisance for those working close to this plant and for those who live nearby. Sometimes sound is

Figure 23

Risk of Loss of Hearing as a Function of the Number of Year's Exposure and according to Equivalent Acoustic Level



Source NOSINE ISO R 1999

reflected either off water or inversion layers in the air and it can be perceived quite distinctly at some distance. In order to reduce noise emission, the steel industry has two major categories of procedures open to it: sound proofing or action at source.

6.2.1 Sound proofing

Classic means of sound proofing around the source of the noise are often used. However they may not be efficient and this situation could get worse in the future if the regulations to be observed become stricter.

6.2.2 Example of sound-insulation of blast furnace

Large capacity blast furnaces (9000 tonnes of pig iron/day) may be a major source of noise to the environment because of the high productivity technologies applied in them.

In general there is no one major source of noise but multiple sources which must be reduced one by one by extensive sound insulation. For example, sources of noise from the blast furnace include:

- the balance of high top pressure
- the charge in the throat
- the hydraulic drive
- the blowers
- the snort valves on the blast
- the inversion of the hot-blast stoves
- the safety valves on the top gas ducts
- cleaning of top gas
- water cooling pumps and circuits

6.2.3 Action at source

Sound proofing is only really a makeshift solution. It does not get at the source of the noise but merely limits the consequences for man. A more radical solution is to eliminate the cause of the noise by action taken directly at source, questioning if necessary the technical process or equipment used.

6.2.4 Examples of action at source on electric arc furnaces

One significant example is the case of the electric arc furnace which may emit up to 120 dB(A) and for which the traditional methods do not work. The electric arc furnace may be insulated from the rest of the bay with a system of a sliding door enclosure. However, further attempts to act at source to eliminate the causes of the noise are being sought.

6.2.4.1 Direct current operation

Although at present supplied with alternating current, steel furnaces could in future operate with direct current. First applications are beginning to be used industrially. The aim is to reduce consumption of electrodes while improving heat exchange between the electric arc and the charge. The noise from the furnace could be reduced since the noise emissions due to the alternating arc (e.g. on 100 Hz) should disappear.

6.2.4.2 Continuous processing furnace

The noise from the arc furnace is linked to momentary variations in power and conditions of instability of the arc. It would appear logical to design a melting furnace in which ideal conditions are permanently maintained for the electric arc with operation on a relatively well melted bath.

6.2.4.3 Changing of steelmaking technology

New electric arc steelmaking techniques are envisaged in the industry. In particular, the induction furnace offers major advantages as far as noise abatement is concerned since it is comparatively quiet.

6.3 Regulations on Vibration

Although the tolerance limit values are not yet well known, the international standard ISO 2631 fixes the orders of magnitude (figure 24). Thus vertical vibration with frequencies between 4 and 8 kHz is the least easily tolerated particularly when the vertical acceleration exceeds 0.6 m/s/s. Moreover, vibration results in substantial noise emissions to the environment.

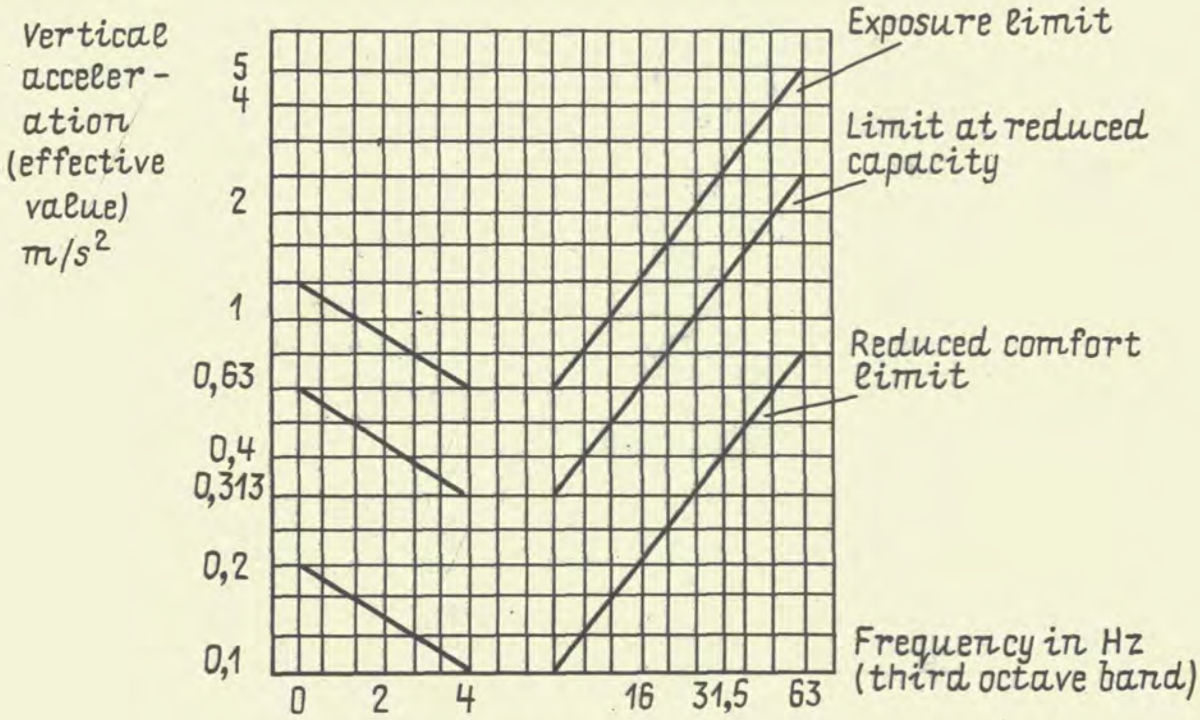
6.4 Methods of Reducing Vibration

Three major categories of vibration calling for different technological solutions can be distinguished:

- mechanical vibration

- vibration by combustion

Figure 24
Tolerable Limits (AFNOR E 90 400 standards)
Case of longitudinal vibrations
(seat-head axis)
transmitted to entire body



- aerodynamic vibration.

6.4.1 Mechanical vibration

This vibration emanates to a large extent from rotating and alternating machines: fans, blowers and compressors, machines which consume power expressed in thousands of kW.

In the case of rotating machines, the vibration is, in general, low frequency and, while it appears in all operating modes, its maximum is reached at a frequency which excites resonance, a function of rotation velocity. The most frequent cause of vibration excitation is lack of dynamic and hydrodynamic balancing.

In reciprocating machines, the vibration appears in association with the movements of the various organs (rods, pistons) which give rise to high frequency vibrations.

Of course, acoustic phenomena are not easy to locate as noise is complex, being generated by mechanical vibration, transmitted by structures as well as arising from the turbulent flow of fluids.

Despite this complexity, theoretical and experimental studies generally allow prediction in advance of the dynamic and acoustic behaviour of machines and application of satisfactory solutions in retrospect by reducing vibration (balancing, elastic suspension, etc.) and also by sound insulation (enclosure).

6.4.2 Vibration due to combustion

Consideration is limited to blast pre-heaters where the vibration may result from unstable combustion. In fact such instability gives rise to a pulsing phenomena with an acoustic wave (λ= 4-10 Hz) similar to that of the "singing" arc. Its appearance is characterized by the existence of a ratio between the length of the oscillation wave and the length of the air and gas ducts of the combustion chamber. In most cases, this vibration is not only unpleasant but it may reach levels which are dangerous for the behaviour and operation of the plant and therefore for the safety of the staff.

Theoretical studies have shown that the combustion chamber behaves like a tube closed at one end and open at the other (cupola). The general rule to be observed is to avoid the presence of a "velocity loop" in at least one of the ducts of less than $\lambda/4$ upstream of the burner, being the length of wave for the air and gas. One must therefore work with appropriate lengths of duct.

In fact, phenomena can be even more complex: for instance, double frequency vibration and frequency variations around a mean value, following changes, even slight, in certain operating parameters (gas pressure, delay in combustion, projected holding temperature in the cupola, fuel injection in the blast furnace, atmospheric conditions). These various parameters are interdependent and some difficult to quantify, but their effect contributes to modifying the acoustic length and increase the possible zones of instability.

6.4.3 Aerodynamic vibration

The transporting and distribution of gas and fumes by numerous ducts equipped with pressure/flow relief and regulation valves may cause vibration which is very disturbing for the behaviour of the plant and for the environment.

Such vibration has three particular causes:

- flow turbulence created by decreases in velocity of the fluids along the inner side wall of the pipes with fluctuation of pressure at the outer limit;
- periodic flow phenomena due to pressure modulation by the ventilator or by pulsating combustion of a burner;
- phenomena of drag and aeroelastic coupling between the flow and the vibration of the obstacle (butterfly valve for example).

This latter phenomenon causes intense fluctuating pressure which may cause the structures to emit intense sound on one frequency if the cavities in which the flow is contained, have similar acoustic modes.

Phenomena of resonance may cause serious damage to plant. They have to be examined closely from the point of view of behaviour and fatigue of materials, safety of staff and acoustic nuisance to the environment.

The remedies are very varied and, in practice, selection depends on the cost and the ease of installation:

- elimination of the phenomenon at source by appropriate design of piping and valves;
- by mechanical de-coupling or by anti-vibratory supports insulating the source of vibration from the rest of the ducts;
- installation of appropriate silencers inside and outside the ducts, devices placed at carefully chosen critical points.

There is a great variety of silencers available: diffusion silencers, which reduce turbulence, absorption silencers, reactive or resonating silencers, the principle of which consists of introducing uneven, multiple dephasing of a quarter of the length of the wave and which is used for low frequency vibration.

BIBLIOGRAPHY FOR SECTION 6

6.1 Noise regulations

- Land Nordrhein Westfalen, Distance between Planned Works and Habitation (Abstande zwischen Industrie - bzw Gewerbgebieten und Wohngebieten im Rahmen der Bauleitplanung), *Rd Erl. D. MAGS*, July 1974, III BI - 8804

6.2 Methods of Reducing Noise

- Campbell, J. M., and R. R. Willis, Protection against noise, *J. Iron and Steel Institute*, May 1973, *211*, No. 5, p. 346

- Campbell, J. M., and R. R. Willis, A practical approach to engineering noise, *Conf. Engineering Aspects of Pollution Control in the Metals Industries*, Nov. 1974, p. 184

- Eschenberg, Frasca and von Branconi, Noise attenuation in blast furnace plants (Lärmminderung in Hochofenwerken), *Stahl und Eisen*, 1975, *95*, No. 11,,p. 486-490

- Eschenberg, R., and J. Philipp, Noise control in pig iron production at the Schwelgern blast furnace, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI* 2, June 1979, IISI Report SEC/2/1/102

- Frasca, Eschenberg and von Branconi, Noise attenuation on blast furnace auxiliaries (Lärmminderung an den Nebenanlagen von Hoch-ofen), *Stahl und Eisen*, 1975, *95*, No. 21, p. 961-966

- Handley, Schiff, Feasible engineering noise control for the primary metals industry, *Iron and Steel Eng*., 1975, 52, No. 3, p. 45-55

- Westin, B., Noise control in the steel industry, *Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2*, June 1979, IISI Report SEC/2/D

6.3 Regulations on Vibration

- Experimental French Standard AFNOR E 90400 (in French)

- International Standard ISO 2631

6.4 Methods of Reducing Vibration

- Bijl, L. A., Measurement of vibration complementary to sound measurements, Concawe Report, September 1977, No. 9/77, 42 p.

- Bojic, M., et al, Reduction of noise and vibration in the iron and steel industry: the French experience, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/1/101

- Mutte, R., and G. Peignelin, Bruits dus aux écoulements des fluides compressibles, Revue Générale de Thermique, Vol. XI, No.177, August-September 1976, p. 707-723

- Pariel, J. M., and L. de Saint Martin, Contribution à l'étude de l'instabilité de combustion dans les foyers industriels, Revue Générale de Thermique, Vol. VI, No. 69, Sept. 1967

SECTION 7

RE-UTILIZATION OF SCRAP AND SOLID WASTE

7.1 Scrap

According to origin, three types of scrap are distinguished:

- scrap arising in individual steel works, which, produced at any point in the process, can be immediately recycled and is not involved in any commercial transaction;

- new scrap, "process scrap" in the USA, which corresponds to steel scrap at all stages of manufacture downstream from the steel works, from both producers and processors;

- commercial scrap which helps utilizers to balance their scrap requirements. This is scrap which is accumulated over a period of time, and whence, in the USA, the expression "capital scrap".

Recovery depends on the useful life of goods. This is several years for consumer goods (e.g. 9 to 12 years for a car) and may be several decades for capital goods. Thus, by taking into account inevitable losses and sometimes scrap accumulation phenomena, which can be explained by geographical factors, demolition and collection would account for about 60 per cent of the apparent steel consumption 15 to 20 years earlier. The diagram in figure 25 shows the cycle of these three types of scrap. Table 13 gives an example of some properties of scrap used in the steel industry, whether this is process scrap or commercial scrap with pre-treatment.

7.2 Waste

7.2.1 Trends

After a possible metal recovery (for instance from steelmaking slag), steel industry waste may be used in the following operations:

- recycling within the works

- sale outside the works

- stocking or dumping

- incineration inside or outside the works

- municipal removal of household waste.

As an example of the waste of the French steel industry in 1974, the distribution was as follows:

Figure 25

Scrap Cycle

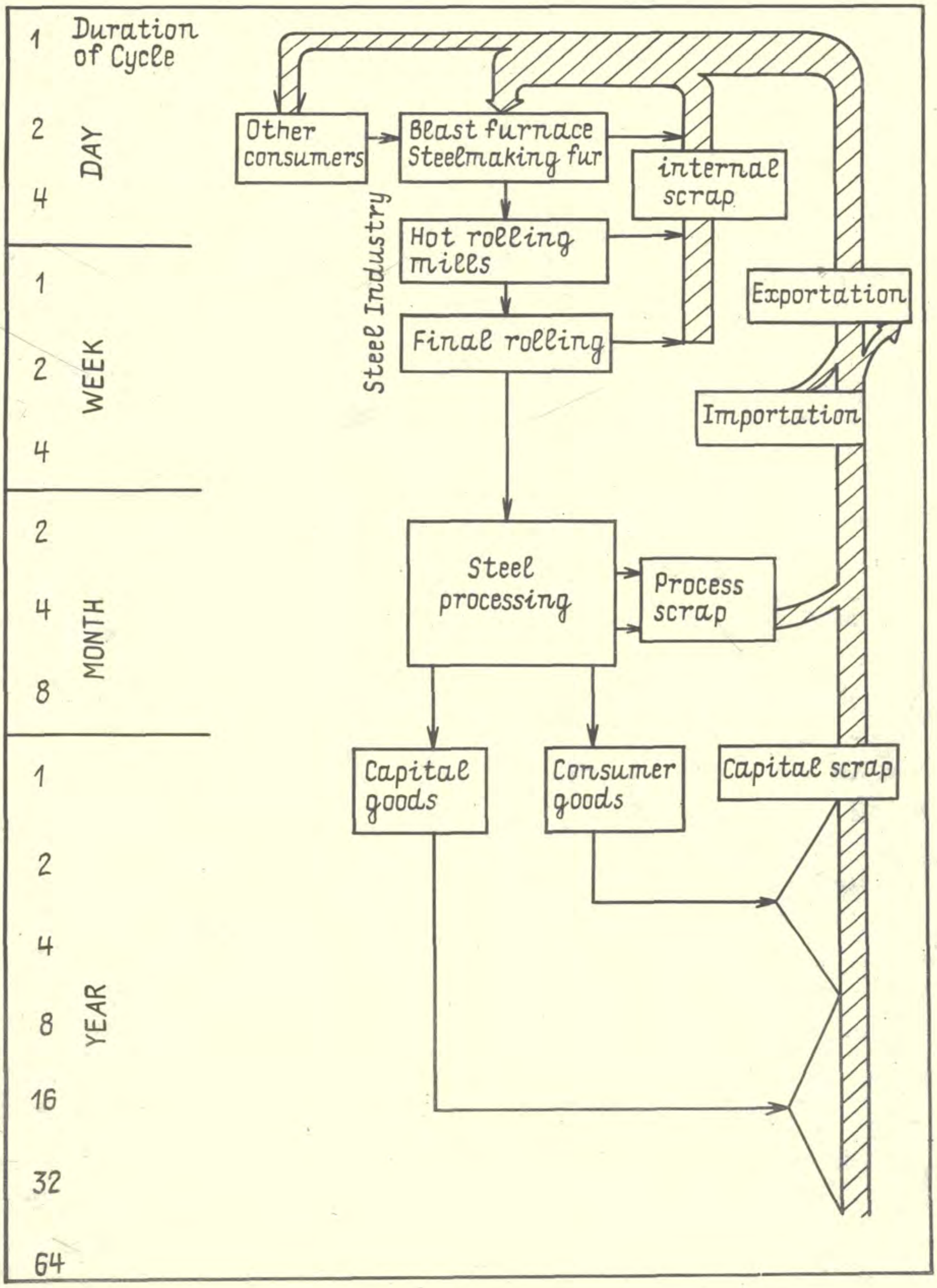


Table 13

Examples of properties for various scrap qualities

Type of scrap	%Fe	C	S	Cu	Ni	Cr	Sn	Density
. Rolling mill off cuts (angles)	99	0.40	0.025	0.018	0.040	0.020	-	1 to 1.5
. Demolition scrap (structure)	99	0.25	0.045	0.070	0.060	0.025	0.015	0.6 to 1.4
. Shredded scrap (classic process)	95	0.50	0.045	0.280	0.100	0.100	0.041	0.9 to 1.1
. Cryogenic scrap	97	0.17	0.040	0.220	0.100	0.120	0.023	0.8
(shredded at low temp.)	92	1.9	0.050	0.500	0.150	0.220	0.040	2.6
. Packets of used scrap	80	0.25	0.110	0.260	0.060	0.030	0.090	
	82	1.3	0.070	0.400	0.060	0.040	0.050	

	Solid waste	Liquid waste
Recycling within works	14%	41%
Sale	74%	-
Stocking/dumping	11%	4%
Incineration and de-oiling	-	55%
Municipal removal	1%	-

This distribution between the various operations is fairly typical for all countries.

Thus, for the most part, the waste is made use of either in the works itself or is sold. The removal to a dump only accounts for a fraction of the tonnages e.g. a tenth in the preceding example.

7.2.2 Possibility of re-use by recycling

Figures 26 and 27 show as an example the uses and recycling of waste from the French steel industry.

7.2.2.1 Sinter dust

During sintering and all handling operations which occur in sinter plants, considerable amounts of dust are produced at the rate of 30 kg/t of sinter. This dust can be recycled on the sinter grate.

7.2.2.2 Blast furnace slag

Apart from liquid pig iron, the blast furnace generates slag which has all the constituents of the gangue charged with the iron ore and coke.

Depending on the nature of the ores, this slag accounts for 300 kg per tonne of pig iron. It is therefore produced in substantial quantities. However, in its composition, it resembles a natural rock. This property explains its uses in road building techniques, cement making and to a lesser extent for thermal and sound insulation.

7.2.2.3 Blast furnace dust and sludge

The top gas taken off the blast furnace is, before utilization, first dry de-dusted, then often scrubbed using the wet method. The blast furnace thus results in the production of dust and sludge rich in ferrous oxides and carbon but also charged with volatile elements such as zinc or lead.

Figure 26

Distribution of solid, sludge and oil waste which were recycled in French steel works in 1974

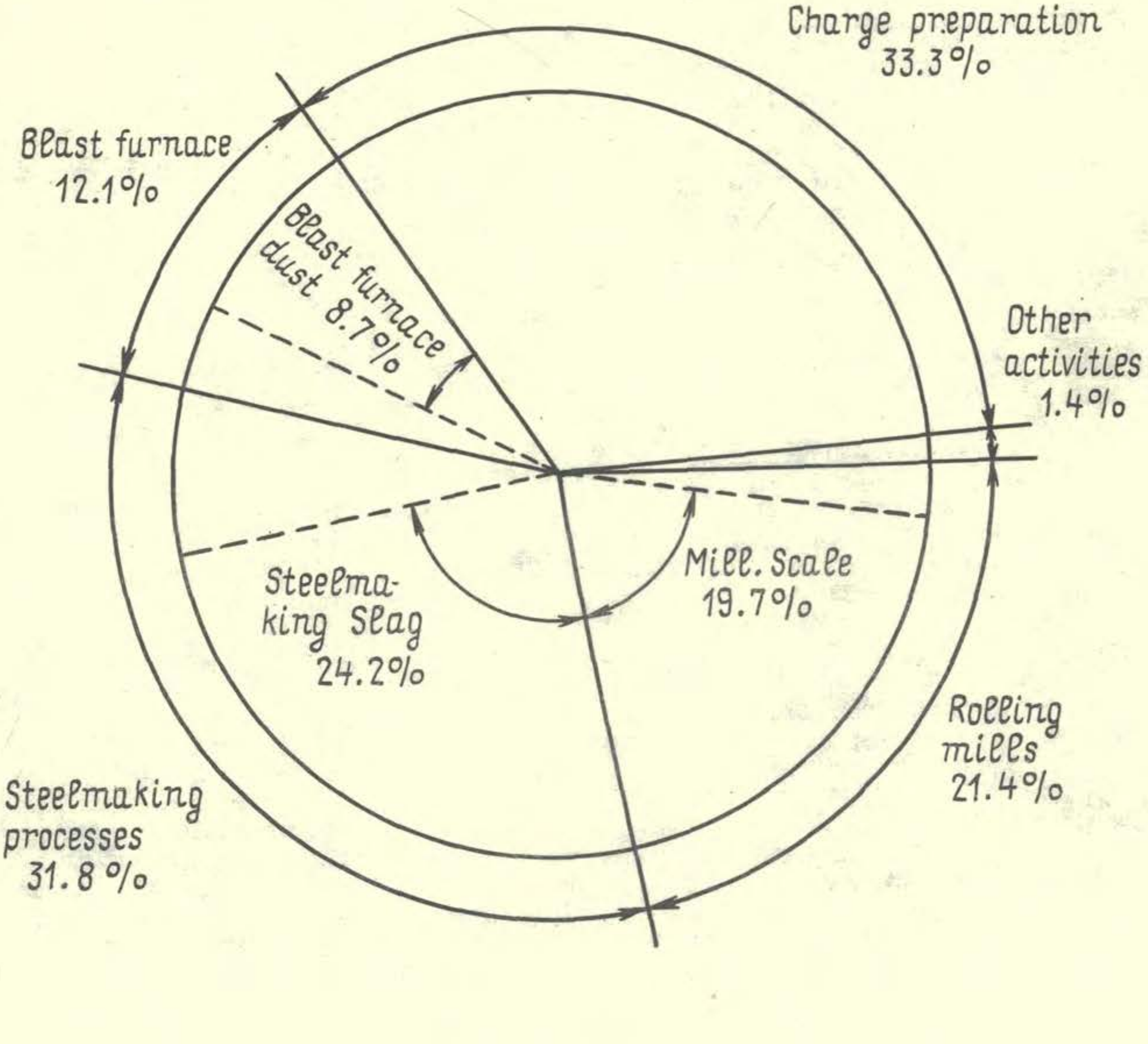
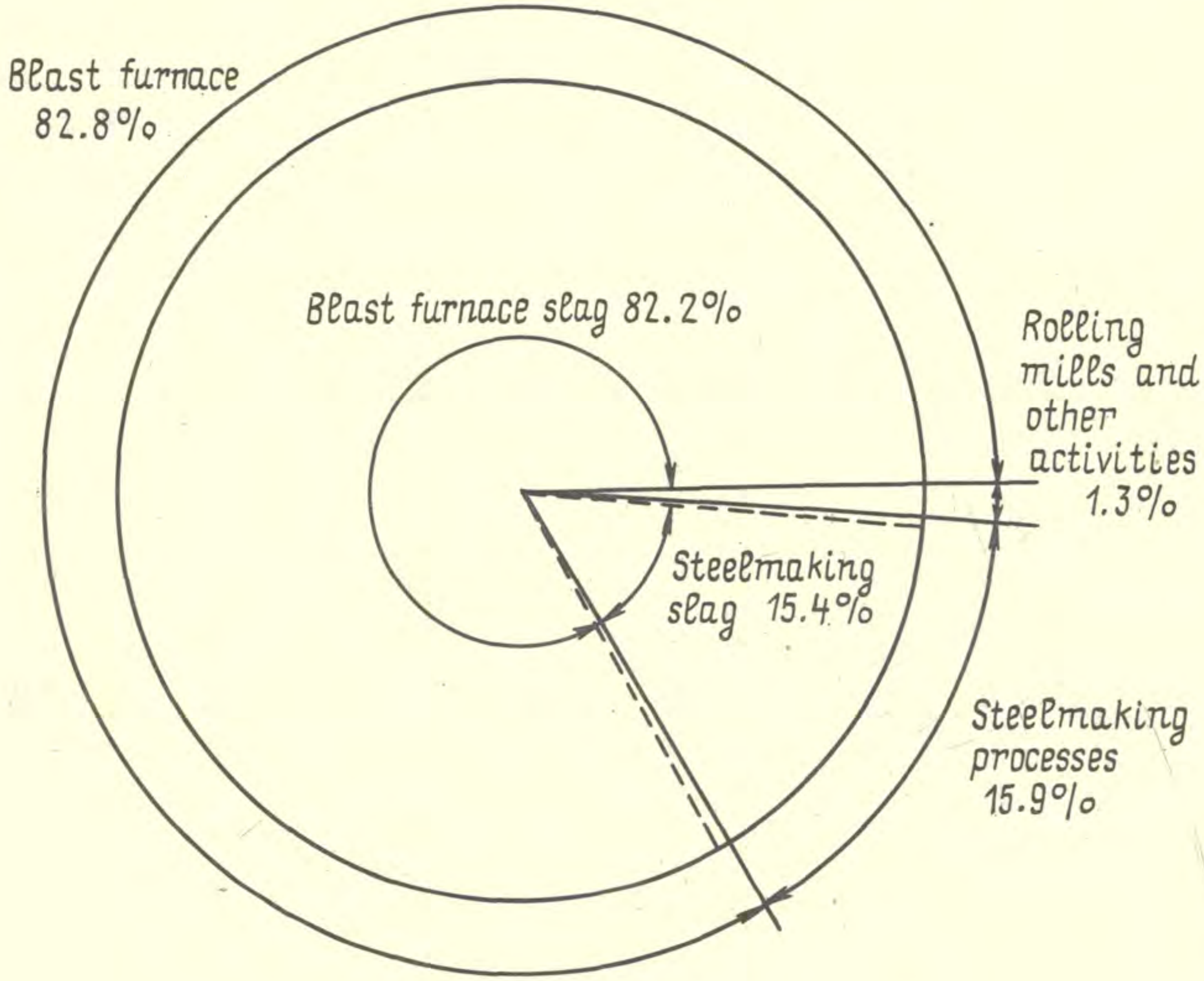


Figure 27

Example of distribution of solid, sludge and oily waste which were sold by French steel works in 1974



Until recently, dust and sludge were recycled in the steel industry process by means of the sinter line. This recycling is less frequently practised now on the high performance blast furnaces in order to avoid operating difficulties due to the recirculation of large quantities of zinc. This zinc is concentrated in lower granulometry and it is possible to recuperate it partly by cycloning of the top gas before the wet cleaning system or by hydro-cycloning of the sludge: the coarser particulates are relatively Zn-poor and can be recycled; the smaller particulates are Zn-rich and can be dumped or sent to the non-ferrous industry like some EAF dust.

7.2.2.4 Oxygen steelmaking slag

Pig iron is either phosphoric (P = 1.7 per cent) or hematite (P = 0.2 per cent). Its refining causes production of either phosphoric or hematite slag. The use for phosphoric slag is currently in agriculture, phosphoric anhydride P_2O_5 constituting an excellent fertilizer. The same is not true for hematite slag, still referred to as LD slag. Prospects for marketing certainly exist in agriculture as a limestone adjuster and in road building. But sales are limited, in view of the competition with other by-products and the long distance transport cost. Hence a certain proportion of hematite pig iron slag is dumped.

7.2.2.5 Oxygen steelmaking dust and sludge

Whether dealing with hematite pig iron or high phosphorus pig iron, oxygen refining also causes the formation of sludge from de-dusting which one seeks to recycle in the steel industry cycle by means of sintering. Such a use is only possible as long as these dusts and sludge do not contain too much zinc i.e. there is not too much scrap charged into the convertor. If this is not the case, the dusts and sludge are discharged.

7.2.2.6 Electric arc furnace slag

The electric arc furnace process implies dephosphorization operation and even desulphurization with the constitution of reactive slags. These slags are cleaned but do not currently have any market outlet. Therefore they are dumped.

7.2.2.7 Electric arc furnace dust and sludge

Electric arc furnaces can remelt coated scrap (e.g. galvanized, plastic coated) or alloy scrap. The dust and sludge recovered from de-dusting then contain volatile additive elements (Pb, Zn, Cr). The recovery of such elements is technically possible in non-ferrous industries by different methods: reduction in a rotating furnace, soda extraction, injection in a plasma. A few installations are operating in the world but for economic reasons cannot be applied in all countries.

7.2.2.8 Spent pickle liquors and sludges

Common steels are, depending on the works, pickled in sulphuric or hydrochloric acid.

Sulphuric acid pickles supply ferrous sulphate. This is a chemically pure product with analysis $FeSO_4,7H_2O$(or$1H_2O$). It cannot therefore be called waste. However, the commercial outlets, for a long time limited to agriculture (role as a weed killer) and now open to water treatment (flocculation and dephosphorization treatments) remain limited. Ferrous sulphate in excess therefore has to be dumped where it is washed by rainwater.

Hydrochloric pickling goes further in the sense of pollution-free technology since after treatment of the used acid, ferrous oxide is obtained as a by-product. This can be sold outside the steel industry but may be recycled in the steel works in the sinter plant.

BIBLIOGRAPHY FOR SECTION 7

7.1 Scrap

- Burghardt, H., Evolution de l'emploi des ferrailles, compte tenu particulièrement des oligo-éléments (in German), Freiberger Forsch., 1977, B 192, p. 61-75

- Khan, Z., et al., Determination of content of combustible material in ferrous scrap recovered from refuse, Resource Recovery and Conservation, 4, 1979, p. 301-304

- Makar, H. V., et al., Removal of copper from molten ferrous scrap, Proceedings of the Third Mineral Waste Utilization Symposium, Chicago, March 1972

- Messin, M., Le recyclage des ferrailles (in French), French Industry Ministry, "La récupération et le recyclage des déchets métalliques", p. 93-100, 1978

- Valorisation de déchets métalliques, La Revue de l'entreprise, "Ingénieurs et techniques, production et gestion", No. 1 November 1976, p. 30-40

7.2 Waste

- Eichberger, H., et al., Recycling of iron and steel mills wastes according to Lurgi rotary kiln processes, SEASI Conference on Prospects for Mini-Steel Mills, Singapore, September 1980, p. 129-150

- Hansen, F., and W. J. Kline, Impact of the Resource Conservation and Recovery Act (RCRA) on the steel industry, Symposium on Iron and Steel Pollution Abatement Technology for 1980, Philadelphia, November 1980

- Kameyama, T., and T. Kuwano, The recovery of valuable metals from waste materials produced as by-products in the stainless steel production process, SEASI Conference on Prospects for Mini-Steel Mills, Indonesia, April 1979

- Kitera, A., Recycling and re-use of products, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/F

- Kossek, et al., Processing of metallurgical by-products using the rotary-kiln volatizing method (Verarbeitung von Hüttenwerksnebenprodukten nach dem Wälzverfahren), Stahl und Eisen, 1976, 96, No. 10, p.482-486

- Levin, G. E., and Ju. M. Suprun, La déshydratation et la récupération des boues riches en fer par les entreprises sidérurgiques de l'Union Soviétique, UN/ECE Seminar on Air and Water Pollution Arising in the Iron and Steel Industry, Leningrad, Aug. 1971, ECE Report GE 1-12015

- Maczek, H., et al, Tests for processing metallurgical wastes using the rotary kiln volatizing method in an industrial plant (Versuchezur Verarbeitung von Hüttenwerksabfällen nach dem Wälzverfahren in einer Betriebsanlage), Stahl und Eisen, 96, No. 24, p. 1233-1238

- Scrap and the Steel Industry - International Iron and Steel Institute, Committee on Raw Materials, Brussels, 1983

- Sugasawa, et al, Direct reduction of metallurgical dusts (Direckt-reduktion von Hüttenwerkstaüben), Stahl und Eisen, 1976, 96, No. 24

- Tsubaki, H., Recycling of waste in the steel industry in: Current Status and the Problems of Environmental Control in the Japanese Steel Industry, International Iron and Steel Institute-Committee on Environmental Affairs, Tokyo, May 1980, p. 79-115

- Utilization of blast furnace and BOF slag - International Iron and Steel Institute, Committee on Environmental Affairs, Brussels 1984, p. 46

- Wanatabe, S., and Y. Yamada, Production of metallized pellets from iron work dust, The Aus, I.M.M. Newcastle and District Branch, Pellets and Granules, Symposium, October 1974, p. 173-180

- Yamada, Y., Reutilization of iron-bearing fines in an integrated iron and steel plant, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/3/110

SECTION 8

LOW-WASTE TECHNOLOGY FOR THE STEEL INDUSTRY

8.1 General Comments

The expression "low-waste technology" is now widely used in specialist and political circles. Initially it was applied only to water, the idea being that it was better not to pollute the water during the manufacturing process rather than having to clean it up afterwards. The expression was then extended to all cases of pollution (dust, gas, odour), nuisance (noise, vibration) and waste (energy, raw materials) not forgetting conditions of work.

8.2 Categorization of Types of Low-Waste Technology

The terminology of "low-waste technology" is not yet fixed but three categories can be mentioned:

-internal action directly on the manufacturing process so that there is no more waste and all products processed can be sold;

-external action consisting of transforming waste into saleable products;

- action on recycling allowing, after intermediate treatment, re-use of waste materials as quality raw materials.

The various possibilities already existing come from one of these three categories.

8.3 Possibilities for the Use of Low-Waste Technology in the Steel Industry

8.3.1 Pre-reduction of ores

Pre-reduction, or direct reduction, offers great advantages for the protection of the environment:

- on the one hand, the coking/sintering/blast furnace stages are removed and with them the generation of by-products from coking plants, blast furnace slag and dust and sludges upstream of the steel shop;

- on the other hand, the dusts recovered by gas cleaning can be directly recycled.

In practice, two main processes are currently used: the HYL and Midrex processes. In the future, other processes may appear; for example, the Swedish PLASMARED (S.K.F.) which uses a plasma reactor to reduce the ore.

8.3.2 Scrap preparation

Scrap is recycled in the blast furnace and the melting shop without any difficulty at the moment. But it brings with it pollutants (oils, coatings and alloy elements) about which the Public Authorities are showing increasing concern. In technical terms, scrap can be treated before recycling although the economic feasibility of this has not been proved:

- shredding with magnetic separation

- cryogenic grinding

- pre-heating to burn off oils and plastic coatings, using the units of heat generated (Ceretti process with rotating furnace placed upstream of the arc furnace from which it recovers the sensible heat and latent heat from the waste gases).

8.3.3 Continuous processing

The blast furnace deserves to be designated as an example of low-waste technology if slag, dust and sludge are made use of.

In the steelmaking shop, continuous techniques could be advantageous from the point of view of energy and for the environment (possibilities for enclosure, relative stability of pollutant emissions).

Continuous refining and continuous electric melting methods are being studied in France by IRSID. Mention may be made of pre-treatment processes in the blast furnace launder for the removal of silica, sulphur or even for dephosphorization. Also the Swedish ELRED process for the production of liquid pig iron associates:

- pre-reduction in a fluidized bed of fine-grained concentrate;

- injection of pre-reduced material by a hollow electrode in an immersed arc furnace;

- operation of the furnace with direct current (reduction of noise).

8.3.4 Low pollution pickling

Any acid pickling (by HCl or H_2SO_4 or for stainless steels $HF-HNO_3$) causes the formation of waste which it is difficult to make use of and which are pollutants. Three new ways are now possible:

- a first step can be made with new mechanical-hydroprocesses, such as the Ishiclean process, which save space and are practically free from pollution;

- secondly it seems to be possible to replace HNO_3 used in the pickling of stainless steels;

- thirdly developments seem possible from the Swedish research using fluonitric pickling of stainless steels.

In general, re-heating before pickling is carried out in slightly reducing conditions, and leads to scale formation, which, being soluble in acid, rapidly soil the pickling baths.

It is possible to work in a slightly oxidizing atmosphere, with precise regulation by means of an electrochemical cell. The more oxidized scale frees itself more readily from the steel, is thermo-dynamically more stable and dissolves less quickly in the acid bath. It can be recovered from the base of the vessel by scraping and can even be recycled. Hence the treatment of the baths used is required less frequently.

8.3.5 Utilization of dusts and sludge

Blast furnace and bulk steelmaking dust and sludge cannot be totally recycled despite their high iron content as they contain nuisance elements (Zn, Pb, Na, K ...). Their re-utilization in the steel industry therefore requires the removal of such constituents which is possible from the technical point of view by means of:

- pre-reduction;

- chemical leaching (an application of this exists in the Federal Republic of Germany for open hearth dust with treatment by soda solution).

8.3.6 Remelting of waste materials for special steels

These waste materials (dust, sludge, scale) contain costly alloy elements which a severe policy of raw materials savings could require to be recovered. Such recovery is possible in technical terms by combining:

- drying of sludge,

- blending and mixing with carbon,

- agglomeration (briquetting or pelletizing),

- addition to an arc furnace.

A plant exists in a Japanese steel works and another is planned in the USA.

8.3.7 Correction of the composition of various slags

Slags are difficult to sell if their chemical or mineralogical analysis differs too greatly from what is expected by the utilizer. Adjustment of the composition may be envisaged either during manufacture (slagging additions in the blast furnace) or in tapping, by taking advantage of the high temperature of the slags and even by operating with a special furnace with thermal input.

BIBLIOGRAPHY FOR SECTION 8

8.1. General Comments

- Steel industry in the 1970s: Progress towards a "clean" industry, Japan Iron and Steel Monthly

8.2 Types of Low-Waste Technology

- Hellot, Y., The iron and steel industry: pollution control and recycling, International Seminar on Waste-Free Production Methods, Paris, 29 November - 4 December 1976

- Royston, M. G., Pollution Prevention Pays, Ed. Pergamon Press Oxford, 1979, 197 p

8.3 Possibilities for the Use of Low-Waste Technology in the Steel Industry

- Astier, J .E. The Impact on the environment of various new possible methods to produce iron and steel materials, UNEP Workshop on the Environmental Aspects of the Iron and Steel Industry, Geneva, October 1978, UNEP Report WS/IS.6

- Astier, J., L. Coche and L. de Saint-Martin, Les réacteurs à haute température et leurs applications aux procédés industriels, International Congress of the British Nuclear Energy Society, January 1975

- Beck, K. G., Nouvelles méthodes de fabrication du coke métallurgique, Stahl und Eisen, 11 February 1980, 100, No. 3, 108-111

- Coche, L., L'évolution technique de la sidérurgie, Annales des Mines, June 1976, p. 21-30

- Gibrat, R., Miami Meeting on Hydrogen Economics, Sciences et Techniques, December 1974, No. 19, p. 45-50

- Miller, C. T., Clean coke process, US Department of Energy, Report FE-1220-36, 1979

- Pazdej, R., and J. Raguin, pollution - and waste free methods in the iron and steel industry, LECES Report RFP/L 14a, March 1979

SECTION 9

CONCLUSIONS

The steel industry plays an important role in the world economy. Its production has increased threefold between 1950 and 1980 (figure 28) and is now stabilized at about 650-700 million tonnes of crude steel.

The steel industry could be a source of pollution and environmental hazard arising from:

- particulate matter and certain gaseous pollutants (oxides of sulphur and nitrogen for example) in the atmosphere;
- suspended particulate matter, oxidizable materials, oils and certain toxic substances in water;
- toxic and other wastes dumped on land; and
- noise and vibration.

If nothing is done to control pollution, the undesirable environmental consequences both within and outside the industry could be considerable. However, abatement and pollution control technologies have been in use for many years which prevent emissions at source or contain harmful discharges. In the same way techniques for reducing and controlling noise and vibration are applied.

The technology used in the steel industry is classical in principle, but must be adapted to the operating conditions of the production processes employed, e.g. high temperature. This has meant that the development of discharge collection techniques was essential.

During the last few years considerable progress has been made in reducing discharges to environmentally acceptable levels. Examples of integrated steel works in Japan, which are practically pollution free, with virtually integral emission control and waste water treatment, as well as highly advanced utilization of by-products and which produce steel at globally competitive costs, are a witness to this assertion.

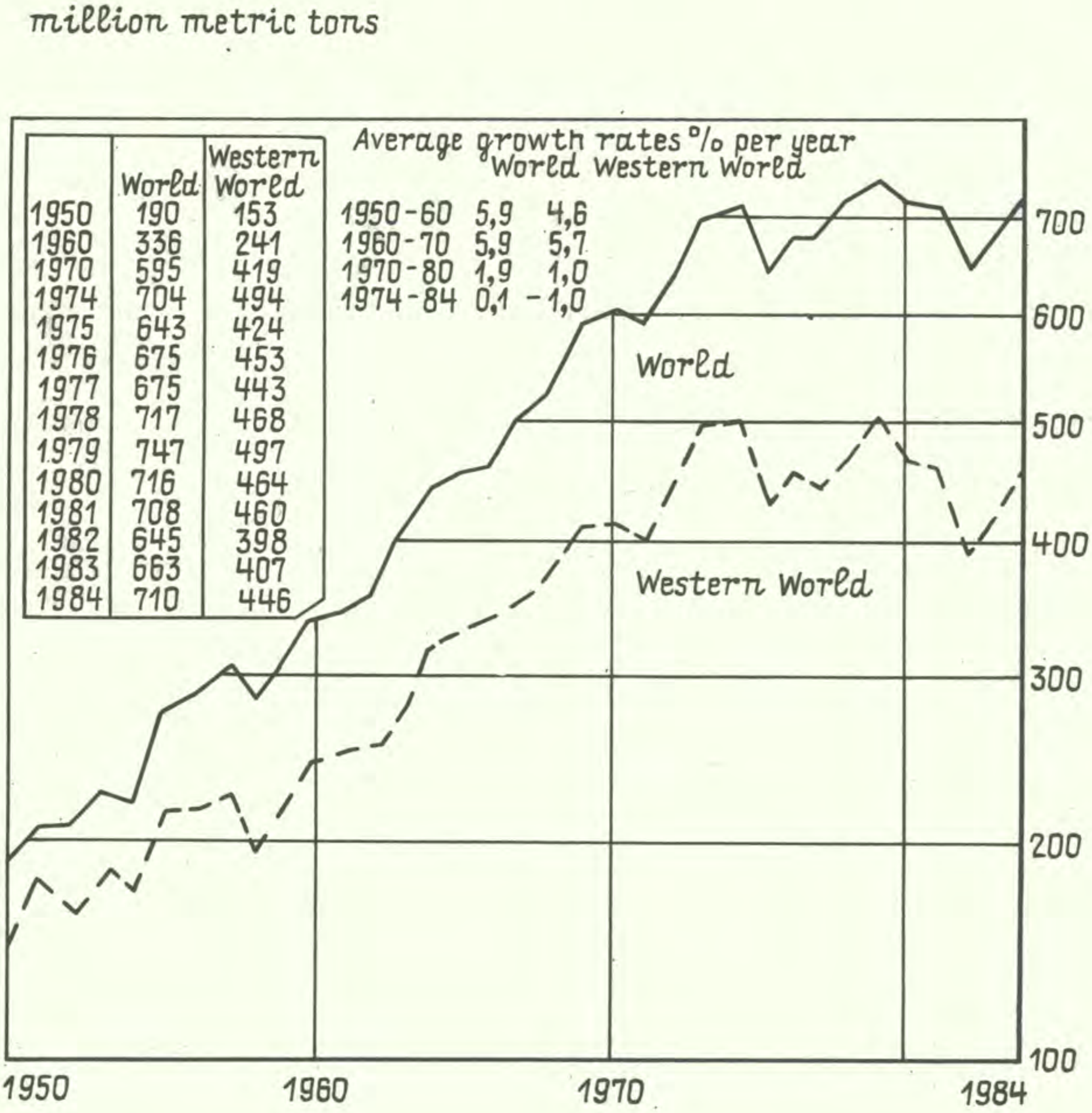
Environmental protection involves considerable expenditure both in terms of investment and operating costs. This expenditure currently accounts for an order of magnitude of 5-10 per cent of the cost of producing steel according to the age and the modernization of the works. The environmental cost is high in new works but can be high in old works whose depollution installations were retrofitted: indeed retrofitting costs are extremely high.

The energy required for pollution control is also considerable and in a new Japanese integrated works may be as high as 100 kWh/t steel produced, i.e. about 20 per cent of electricity consumed in the works.

It must be further borne in mind that protection of environmental quality both within and outside the works depends on a well operated and maintained plant, as well as appropriate environmental monitoring. This calls for enivronmental education and training of management, operating and maintenance personnel throughout the industry. Provision should be made for this education and training before the commissioning of a works, and appropriate arrangements made for their continuation as necessary after the works comes into operation.

During the last decade, considerable progress has also been made in the better use of resources (raw materials, energy, water, manpower, etc.) at integrated steel works. Further progress will continue to be made in development of low- and non-waste technologies as well as in improved efficiency of processes, plant operation and performance of steels. In view of the level of investment required at any integrated steel works, the shortage of investment funds, and the time-frame involved, implementation of such improvements and new developments is bound to be slow.

Figure 28
World crude steel production, 1950 to 1984



	World	Western World
1950	190	153
1960	336	241
1970	595	419
1974	704	494
1975	643	424
1976	675	453
1977	675	443
1978	717	468
1979	747	497
1980	716	464
1981	708	460
1982	645	398
1983	663	407
1984	710	446

Average growth rates % per year

	World	Western World
1950-60	5,9	4,6
1960-70	5,9	5,7
1970-80	1,9	1,0
1974-84	0,1	-1,0

Source: IISI (International Iron and Steel Institute)

BIBLIOGRAPHY FOR SECTION 9

- An Economic Assessment of the Benefits of the Final Effluent Limitations Guidelines for Iron and Steel Manufacturers, Executive Summary, and Volumes I, II and III, US Environmental Protection Agency, Washington DC 20460, Office of the Policy Analysis, Report No. EPA-230/04-82-005

- Barker, J. E., Zero visible emissions: energy requirements, economics, environmental impact, Conference Engineering Aspects of Pollution Control in the Metals Industries, Metals Society, London, November 1974, p.205

- Emission control costs in the iron and steel industry, Organization for Economic Co-operation and Development, Paris 1977, ISBN 92-64-11642-7, 176 p

- Gibrat, R., Sources et techniques nouvelles en matière d'énergie après l'an 2000 (in French), La revue des ingénieurs, July-August 1974, 27, No. 234, p. 29-27

- Greenfield M. S., and H. Ohrt, Cost comparisons of controlling charging emissions from a new BOF Shop versus an existing BOF Shop and cost effectiveness of retrofitting cast house fume control systems to existing blast furnaces, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC/2/6/131

- Kiyotaki, S., Present and future of the water pollution control in Japan (in Japanese), Suiyokwai-shi, Japan, October 1976, 18, No. 7, p. 359-367

- Kobayashi, E., Energy conservation and environmental problems in the Japanese steel industry in: Current Status and Problems of Environmental Control in the Japanese Industry, International Iron and Steel Institute, Committee on Environmental Affairs, Tokyo, 1980, p. 55-78

- Margolin, S. V., and B. S. Old, Environmental costs for the American Iron and Steel Industry, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, IISI Report SEC/2/0

- Nashan, G., Economical consideration for coke ovens in the 80s (Die Kokereiwirtschaft-Bilanz und Orientierungsrahmen für die 80 Jahre), Glückauf, 1978, 114, No. 3, p. 127-136

- Philipp, J., The Cost of Higher Environmental Standards, Conference "The Steel Industry in the 1980s", organized by the Metals Society, Amsterdam, September 1979

- Roederer, Ch., and J. Astier, The iron and steel industry between the years 1970 and 2000 in the world (La Sidérurgie de 1970 à l'an 2000 dans le monde), International Meeting Science and Techniques for Year 2000, Paris, June 1971, 50 p.

- The Cost of Clean Air and Water, Report to Congress 1984, Executive Summary US Environmental Protection Agency, Office of Policy Analysis, Washington, DC 20460, Report No. EPA-230/05-84-008, May 1984

- Terrel, R., Achieving environmental objectives in the steel industry, Second IISI Symposium on Environmental Control in the Steel Industry, SECSI 2, June 1979, Report SEC/2/M

APPENDIX 1

STEEL INDUSTRY WASTEWATER POLLUTANTS

according to a study(1) published by the
United States Environmental Protection Agency

Each number in brackets refers to the American list of regulated pollutants in the EPA study.

Most of these pollutants are found in cokemaking wastewaters, but often in very low concentrations.

---

(1) Development Document for Effluent Limitations Guidelines and Standards for Iron and Steel Manufacturing, Point Source Category Volume I, (p. 167-169), EPA 440/1-82/024, May 1982.

A. - CLASSICAL POLLUTANTS -

(121)	Cyanide	CN
non conventional pollutants	Suspended solid materials	
	Ammonia	(pH) NH_4
	Fluoride	F
	Sulphide	S

B. - METALLOIDS -

(114)	Antimony	Sb
(115)	Arsenic	AS
(125)	Selenium	Se

C. - METALS -

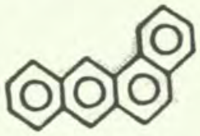
(118)	Cadmium	Cd
(119)	Chromium	Cr
(120)	Copper	Cu
(122)	Lead	Pb
(124)	Nickel	Ni
(126)	Silver	Ag
(127)	Thallium	Tl
(128)	Zink	Zn
non conventional pollutants	Iron	Fe
	Tin	Sn

D. - ORGANIC COMPOUNDS A. 1/2

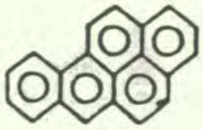
a) **Polynuclear aromatic hydrocarbons (14 compounds consisting of substitued and unsubstitued polycyclic aromatic rings).**

(39) Fluoranthene (1,2-Benzacenaphtene) $C_{16}H_{10}$

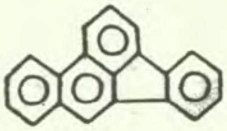
(72) Benzo(a)anthrancene (1,2-benzanthracene)



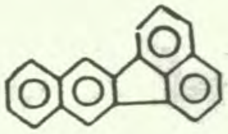
(73) Benzo(a)pyrene (3,4-benzopyrene)



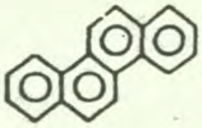
(74) 3,4-Benzofluoranthene



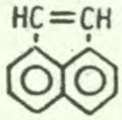
(75) Benzo(k)fluoranthene
(11,12-benzofluoranthene)



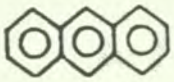
(76) Chrysene (1,2-benzophenanthrene)



(77) Acenaphthylene HC = CH



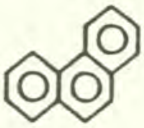
(78) Anthracene



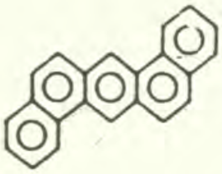
(79) **Benzo(ghi)perylene**
(1,12-benzoperylene)

(80) Fluorene (alpha-diphenylenemethane)

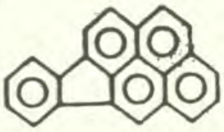
(81) Phenanthrene



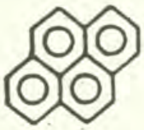
(82) Dibenzo(a,h)anthracene
(1,2,5,6-dibenzoanthracene)



(83) Indeno(1,2,3-cd)pyrene
(2,3-o-phenyleneperylene)



(84) Pyrene



b) Aromatic hydrocarbons.

(4)	Benzene	C_6H_6
(38)	Ethylbenzene	
(86)	Toluene	C_6H_5OH
(130)	Xylenes	$C_6H_4(CH_3)_2$
(65)	Phenol	C_6H_5OH
(non conventional pollutant)	Total phenols	
(34)	2,4-Dimethylphenol	
(55)	Naphtalene	$C_{10}H_8$
(54)	Isophorone	$C_6H_5(CH_3)_3O$

c) Aromatic components.

with Cl

(9)	Hexachlorobenzene	C_6Cl_6
(21)	2,4,6-Trichlorophenol	ClC_7H_6OH
(24)	2-Chlorophenol	ClC_6H_4OH
(64)	Pentachlorophenol	C_6Cl_5OH
(22)	Para-chloro-meta-cresol	ClC_7H_6OH

with N

(35 and 36)	2,4 and 2,6 Dinitrotoluene	$(NO_2)_2C_6H_3CH_3$
(57)	2-Nitrophenol	$NO_2C_6H_4OH$

d) Other components.

(3)	Acrylonitrile	$CH_2 = Cl + CN$
(11)	1,1,1-Trichloroethane	CCl_3CH_3
(23)	Chloroform	
(60)	4,6-Dinitro-o-cresol	
(66-71)	Phtalate Esters	
(85)	Tetrachloroethylene	CCl_2CCl_2

APPENDIX 2

COMPENDIUM OF ENVIRONMENTAL GUIDELINES AND STANDARDS FOR INDUSTRIAL DISCHARGES

Based on World Health Organization, Géneva 1983
Report EFP/8349, p.51-61

Discharge standards

Canada

The Department of the Environment issued National Emission Guidelines for the metallurgical coke manufacturing industry in 1975 as shown in Table A.

Table A

Emission guidelines for the metallurgical coke manufacturing industry (Canada)

Source	Emission Guideline
Charging	100 g/tonne of dry coke
Pushing	0.46 g/Nm^3
Quenching	50 g/metric tonne of dry coke
Crushing and screening	0.046 g/Nm^3 (downstream of gas cleaning equipment
Battery stacks	0.069 g/Nm^3 (in exhaust gases)
Burning of coke oven gas	1300 g SO_2/tonne of dry coke

France

Circulars on iron ore sinter plants and steel works using oxygen lancing were issued by the Minister for the Protection of Nature and the Environment on 24 July 1972 and 8 March 1973 respectively. They apply to all new plants and to existing plants undergoing major modifications. In addition, they are intended to serve as models for existing plants about which complaints have been made. They were drawn up by working parties consisting of representatives of Government, industry, manufacturers of pollution-control equipment, etc.

Iron ore sinter plants - Under normal conditions, the particulate content of the gases discharged to the atmosphere must not exceed 0.150 g/Nm^3. To allow for exceptional circumstances, a particular content of up to 0.5 g/Nm^3 is permitted, but not for more than 200 hours per year.

Steel works using oxygen lancing - The gases discharged must not show any marked coloration, and the particulate content must not exceed 0.120 g/Nm^3. Where for some reason the particulate content cannot be reduced to this level, no new batch of metal may be refined until the gas-cleaning equipment is again operating with the required efficiency. Exceptionally, however, refining may be allowed to continue for a limited period if the plant upstream of the process cannot be stopped without danger to the equipment or the operating personnel.

Germany (Federal Republic of)

Emissions from iron and steel manufacture are governed by the Technical Guide for Air Quality Control of 1974, made under the Federal Law 28 August 1974, on the prevention of pollution, as follows:

Coking plants - The gas used for heating the coke must not contain hydrogen sulphide at an hourly mean concentration exceeding 1.5 g/m^3 or other sulphur compounds at an hourly mean concentration of more than 0.5 g/m^3. In the charging of the ovens, a dust removal efficiency of at least 90 per cent must be achieved. The optical density of the smoke emitted may exceed the generally applicable limit of Ringelmann 2, but only for short periods.

Iron ore sintering plants - Gaseous effluents must not contain more than 5 g/m^3 of inorganic fluorine compounds (expressed as fluoride ion).

Blast furnaces - The dust content of the waste gases must not exceed 20 mg/m^3, or 50 mg/m^3 if the gases are flared. There is no restriction on the sulphur content of the fuel, provided that the sulphur is removed by the slag.

Steelmaking furnaces - The dust content of the waste gases must not exceed 150 mg/m^3. Carbon monoxide must be used, burned or dispersed.

Japan

The ordinances made under the Law of 1968 on air pollution control lay down limiting values for dust emissions from iron and steel manufacture, as shown in Table B.

Table B

Iron and steel manufacture
emission standards for dust
(Japan)

Type of plant	General emission standard (g/Nm^3)	Standard for special areas (g/Nm^3)
Blast furnaces	0.05	0.05
Converters	0.10	0.08
Open-hearth furnaces,		
- emissions of less than 40,000 Nm^3/h	0.20	0.10
- emissions of 40,000 Nm^3/h and greater	0.10	0.05
Sinter plants	0.15	0.10
Electric steel furnaces	0.10	0.05

Sweden

The National Environment Protection Board has issued the following guidelines, expressed as monthly averages, for particulate emissions in iron and steel manufacture.

Table C

Guidelines for particulate emissions
in iron and steel manufacture
(Sweden)

Type of plant	Emission guideline
Blast furnaces	0.3 kg/tonne
Basic oxygen furnaces	0.3 kg/tonne
Sinter plants:	
existing	1.0 kg/tonne
new	0.5 kg/tonne
Electric arc furnace:	
existing	0.6 kg/tonne
new	0.3 kg/tonne
Miscellaneous operations	20-50 mg/Nm^3 dry gas (a)

(a) in practice; no official guideline

United Kingdom

Iron and steelworks are included in the List of Scheduled Works under the Alkali Act 1906. Information on best practicable means for iron and steelworks has been published by the Inspectorate, and certain particulate emission limits specified, as shown in Table D. While these limits do not have the force of law, they are the maximum that will normally be accepted as confirmation that the best practicable means are being used.

Table D

Particulate emission limits for
iron and steel works
(United Kingdom)

Source	Emission limit
Ore preparation and sintering	0.115 g/m^3
Blast furnaces	0.46 g/m^3
Oxygen-using processes	0.115 g/m^3
Hot blast cupolas	0.115 g/m^3

Where no specific limits have been laid down, processes must be operated so as to minimize pollution; thus a code of practice for coke ovens has been published.

United States of America

Under the Clean Air Amendments, the Federal Government was empowered to issue performance standards for new stationary sources. The standards listed in Table E have been promulgated by the US Environmental Protection Agency for new iron and steel plants.

Under the Federal Water Pollution Control Act Amendments of 1972 and the Clean Water Act of 1977, the US Environmental Protection Agency issued limitations for wastewaters from the iron and steel manufacturing industry. A thorough study of the industry showed that it consisted of a series of processes differing so greatly from one another as to require division into the following sub-categories:

cokemaking
sintering
ironmaking
steelmaking
vacuum degassing
continuous casting
hot forming
scale removal
acid pickling
cold forming
alkaline cleaning
hot coating

Table E

Performance standards for new iron and steel plants (USA)

Source	Pollutant	Emission level	Monitoring requirement
Basic oxygen process furnace	Particulate	50/mg/Nm^3	No requirement
	Opacity	10%(20% exception/cycle)	No requirement
			Time and duration of each cycle; exhaust gas diversion; scrubber pressure loss; water supply pressure
Electric arc furnace	Particulate	12 mg/Nm^3	No requirement
	Opacity (a) control device	3%	Continuous
	(b) shop roof	0% except 20%-charging	Flow rate monitoring in capture hood
		40%-tapping	Pressure monitoring in DSE system
Dust handling equipment	Opacity	10%	No requirement

For each sub-category a number of sets of discharge limits have been established. Existing plants discharging to navigable waters are required to meet standards derived from the "best practical control technology" (BPT). For conventional pollutants (total suspended solids, oil and grease and pH) existing plants will be required to meet "best conventional technology" (BCT) limits by 1 July 1984. For non-conventional and toxic pollutants, existing plants will have to achieve limits derived from the "best available technology economically achievable" (BAT) by 1 July 1984. New plants discharging to navigable waters must achieve a performance defined by the new source performance standards (NSPS). Existing plants discharging to publicly-owned treatment works will be required to meet pre-treatment standards for existing sources (PSES) by 27 May 1985, while new plants discharging to publicly owned treatment works are required to meet pre-treatment standards for new sources (PSNS). The by-product cokemaking (iron and steel) sub-category has been selected to exemplify the prescribed limitations. These operations produce coke for use in iron blast furnaces by heating coal in the absence of air. The limitations applicable to this sub-category are given in Tables F to L.

Table F

BPT effluent limitations for existing by-product cokemaking (iron and steel) plants discharging to navigable waters (USA) (kg/1000 of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Total suspended solids	0.253	0.131
Oil and grease	0.0327	0.0109
Ammonia - N	0.274	0.0912
Cyanide	0.0657	0.0219
Phenols (4AAP)	0.00451	0.00150
pH	6.0-9.0	6.0-9.0

(1) Increased loadings, not to exceed 11 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 27 per cent of the above limitations, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

Table G

BAT [1] Effluent limitations for existing by-product cokemaking (iron and steel) plants without physical-chemical treatment systems discharging into navigable waters (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Ammonia - N	0.0543	0.0160
Cyanide	0.00638	0.00351
Phenols (4AAP)	0.0000638	0.0000319
Benzene	0.0000319	-
Naphthalene	0.0000319	-
Benzo(a)pyrene	0.0000319	-

(1) Increased loadings, not to exceed 16 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 39 per cent of the above limitations, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

---

[1] "Best Available Technology"

Table H

BAT effluent limitations for existing by-product cokemaking (iron and steel) plants with physical-chemical treatment systems discharging into navigable waters (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Ammonia - N	0.0645	0.0322
Phenols (4AAP)	0.0000859	0.0000430
Benzene	0.0000215	-
Naphthalene	0.0000215	-
Benzo(a)pyrene	0.0000215	-

(1) Increased loadings, not to exceed 24 per cent of the above limitations, are allowed for by-product coke plants with physical-chemical treatment systems which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

Table I

BCT effluent limitations for existing by-product cokemaking (iron and steel) plants discharging to navigable waters (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Total suspended solids	0.253	0.131
Oil and grease	0.0321	0.0109
pH	6.0-9.0	6.0-9.0

(1) Increased loadings, not to exceed 11 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 27 per cent of the above limitations, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

Table J

NSPS effluent limitations for new by-product cokemaking (iron and steel) plants discharging to navigable waters (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Total suspended solids	0.172	0.0894
Oil and grease	0.00638	-
Ammonia - N	0.0543	0.0160
Cyanide	0.00638	0.00351
Phenols (4AAP)	0.0000638	-
Benzene	0.0000319	-
Naphtalene	0.0000319	-
Benzo(a)pyrene	0.0000319	-
pH	6.0-9.0	6.0-9.0

(1) Increased loadings, not to exceed 16 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 39 per cent of the above standards, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

Table K

PSES effluent limitations for existing by-product cokemaking (iron and steel) plants discharging to publicly-owned treatment works (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Ammonia - N	0.0645	0.0322
Cyanide	0.0172	0.00859
Phenols (4AAP)	0.0430	0.0215

(1) Increased loadings, not to exceed 24 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 58 per cent of the above standards, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

Table L

PSNS effluent limitations for new by-product cokemaking (iron and steel) plants discharging to publicly-owned treatment works (USA) (kg/1000 kg of product)

Characteristic	Max. for any 1 day	Max. ave. of daily values for 30 consec. days
Ammonia - N	0.0645	0.0322
Cyanide	0.0172	0.00859
Phenols (4AAP)	0.0430	0.0215

(1) Increased loadings, not to exceed 24 per cent of the above limitations, are allowed for by-product coke plants which have wet desulphurization systems but only to the extent that such systems generate an increased effluent volume.

(2) Increased loadings, not to exceed 58 per cent of the above standards, are allowed for by-product coke plants which include indirect ammonia recovery systems but only to the extent that such systems generate an increased effluent volume.

BIBLIOGRAPHY FOR APPENDIX 2

Bohus, O., Blast furnace gas cleaning by means of venturi washers. In: Proceedings of Seminar on Air and Water Pollution arising in the Iron and Steel Industry, Leningrad, USSR, 23-28 August 1971, United Nations Economic Commission for Europe, Geneva (1971).

Council of Europe, Exchange of information on national regulations and practices in air pollution control, Strasbourg, Committee of Experts on Air Pollution, EXP/Air (73) 4 rev. (1974).

Cooper, R.L. and J.R. Catchpole, Biological treatment of phenolic wastes. In: The Iron and Steel Institute, Management of water in the iron and steel industry, London, pp. 97-102 (1970).

Davis, C.M., Pollution control legislation in the United Kingdom. In: Commission of the European Communities, Quality of the environment and the iron and steel industry, Oxford, Pergamon Press, pp. 51-72 (1977).

Debrie, J.P., Air pollution control in France. In: Commission of the European Communities, Quality of the environment and the iron and steel industry, Oxford, Pergamon Press, pp. 73-82 (1977).

Eickelpasch, D. and W. Theobald, Laws and official regulations concerning environmental protection in the Federal Republic of Germany, In: Commission of the European Communities, Quality of the environment and the iron and steel industry, Oxford, Pergamon Press, pp. 83-95 (1977).

Federal Republic of Germany, Technische Anleitung zur Reinhaltung der Luft, Bonn, Gemeinsames Ministerialblatt, p.426 (1974).

Flux, J.H., Dust and fume cleaning in iron and steel works. In: Nonhebel, G., ed., Gas purification processes for air pollution control, London, Newnes-Butterworth, pp. 447-457 (1972).

Geny, P. and E. Dohen, Measures against water pollution in the iron and steel industry, Pure and applied chemistry, p.29, 191-200 (1972).

Japan Environment Agency, The quality of the environment in Japan, Tokyo (1981).

Katari, V.S. and R.W. Gerstle, Industrial process profiles for environmental use: Chapter 24, The iron and steel industry, Cincinnati, Ohio, US Environmental Protection Agency, EPA-600/2-77023a (1977).

Kemmer, F.N., Pollution control in the steel industry. In: Lund, H.F., ed., Industrial pollution control handbook, New York, McGraw-Hill, pp. 10-20

Koziorowski, B. and Kucharski, J., Industrial waste disposal, Oxford, Pergamon Press, pp. 76-80 (1972).

Organization for Economic Co-operation and Development, La pollution atmosphérique dans la sidérurgie, Paris (1963).

Organization for Economic Co-operation and Development, Major air pollution problems: The Japanese experience, Paris (1977).

Organization For Economic Co-operation and Development, Emission control costs in the iron and steel industry, Paris (1977).

Pullen, R.A. and J. Booth, Water for fume cleaning kaldo and electric arc furnaces, In: The Iron and Steel Institute, management of water in the iron and steel industry, London, pp. 63-71 (1970).

Speight, G.E. and C.M. Davis, Review of water supplies and effluent disposal. In: The Iron and Steel Institute, management of water in the iron and steel industry, London, pp. 1-6 (1970).

Steiner, E., Particulate emission control in the steel industry. In: Noll, K. and Duncan, J., eds., Industrial air pollution control, Ann Arbor, Mich., Ann Arbor Science, pp. 163-170.

Steiner, B.A., Ferrous metallurgical operations, In: Stern, A.C., ed., Air pollution, vol. IV, 3rd ed., New York, Academic Press, pp. 890-929 (1977).

The British Carbonization Research Association, Practical suggestions for the reduction of the emissions of smoke, dust and grit at coke ovens, 3rd edition., Chesterfield, Special Publication 5 (1974).

Twyford, R.J. and D. A. Harrison, Treatment of blast-furnace gas-cleaner effluent. In: The Iron and Steel Institute, management of water in the iron and steel industry, London, pp. 58-62 (1970)

United Kingdom, Industrial air pollution 1975, London, Health and Safety Executive, HMSO, p.57 (1977).

United Nations, Air pollution by coking plants, New York, ST/ECE/COAL/36 (1968).

United States of America, Standards of performance for new stationary sources - Vol. I: Introduction, summary and standards, Washington DC, US Environmental Protection Agency, EPA/340/1-82-005a (1982).

Внешторгиздат. Изд. № 6298А
ВТИ. Зак. 8215

United States of America, Iron and steel manufacturing point source category, effluent limitations pre-treatment standards and new source performance standards, Federal Register, vol. 47, No. 103, May 27 1982.

Verein Deutscher Ingenieure, Staubauswurf, Eisenhutten-werke, Hochofen, Düsseldorf, VDI 2099 (1959).

Verein Deutscher Ingenieure, Auswurfbegrenzung, Hochofen-betrieb, Erzsinteranlagen, Saugzugpfannen und Bandanlagen, Düsseldorf, VDI 2095 (1963).

Verein Deutscher Ingenieure, Auswurfbegrenzung von Staub bein Löschen von Koks, Kokereien und Gaswerke, VDI 2303 (1966).

Verein Deutscher Ingenieure, Staubauswurfbegrenzung, Stahlwerksbetrieb, brauner Rauch l. Sauerstoffaufblasverfahren, Konverter, Düsseldorf, VDI 2112 (1966).

Verein Deutscher Ingenieure, Entwurf: Staub une Teernebel beim Füllen von Koksofen, Düsseldorf, VDI 2302 (1970).

Verein Deutscher Ingenieure, Auswurfbegrenzung, Schwefeldioxide, Koksofen Abgase, VDI 2110 (1973).

Verein Deutscher Ingenieure, Entwurf: Stahlwerksbetrieb, Elektrolichtbogenofen, Düsseldorf, VDI 3465 (1975).

Verein Deutscher Ingenieure, Entwurf: Auswurfbegrenzung, Kokereien und Gaswerke, Siebbrech-und Mahlanlagen, Düsseldorf, VDI 2100 (1976).

UNEP - Industry & Environment Technical Review Series

Environmental Aspects of the Pulp and Paper Industry
A Technical Review (English and French)

Environmental Aspects of the Motor Vehicle and its Use
A Technical Review (English and French)

Environmental Aspects of Aluminium Smelting
A Technical Review (English only)

Environmental Aspects of the Direct Reduction Route to Steel Making
A Technical Review (English only)