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EXPERIENCE, PERSPECTIVE AND PROJECTION OF DEVELOPING COUNTRIES IN THE IRON AND STEEL INDUSTRY PARTICULARLY IN AFRICA AND THE ARAB WORLD [1]

prepared by

the Secretariat of UNIDO

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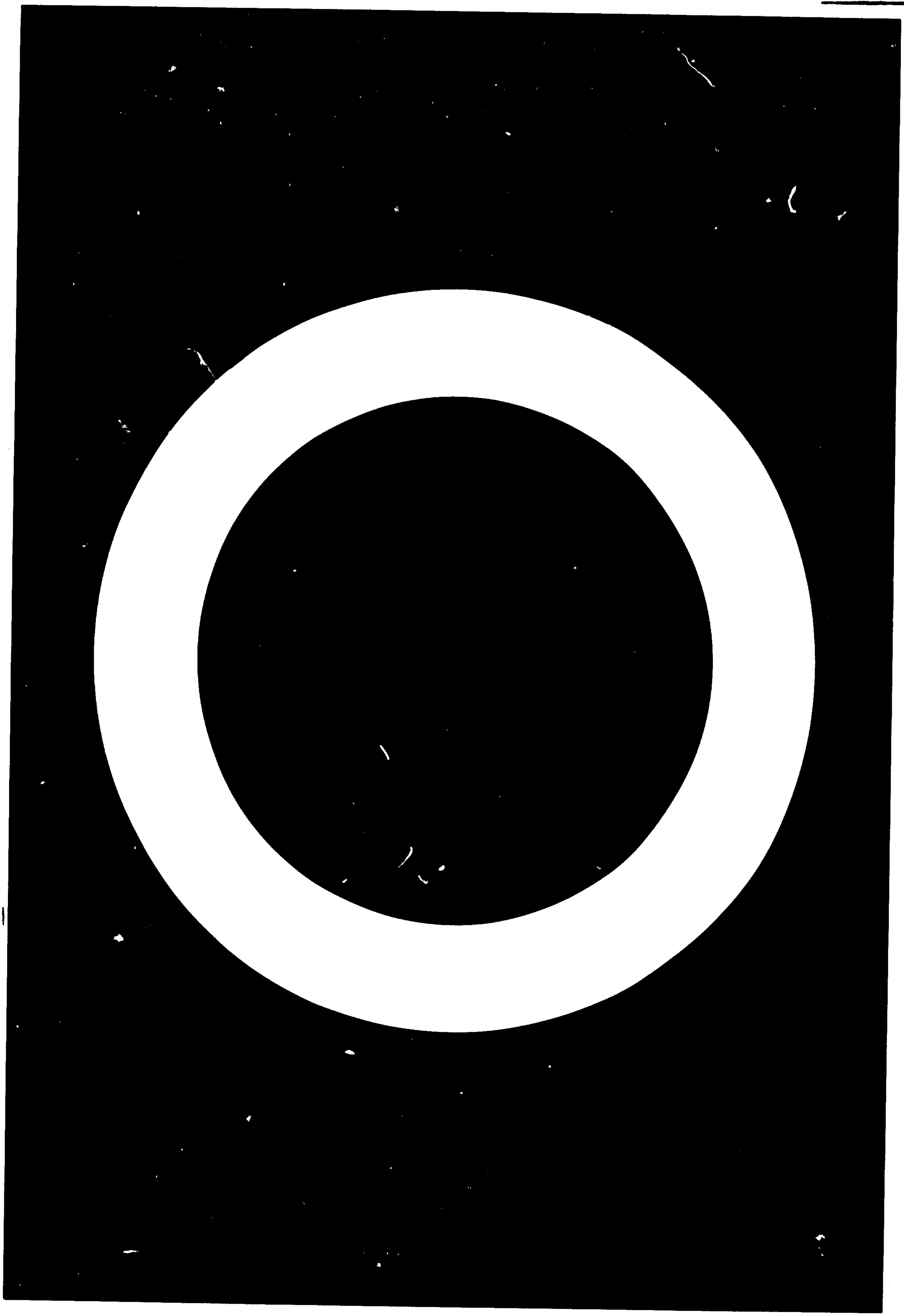

SUMMARY

The document presents in quintessence the experience of the developing countries in the growth of their iron and steel industry and outlines appropriate recommendations for action for the development of the iron and steel industry in developing countries in general and of the African and Arab countries in particular.

The status of the iron and steel industry in African and Arab ountries has been comprehensively elaborated along with supporting charts and tables. Typical examples have been furnished of the experience in the field of co-operation amongst developing countries and between developing and developed countries.

These chapters have been preceded by a detailed treatise on the iron and steel industry in the world setting.

Brief analysis has been made of the situation of developing countries in regard to iron and steel production and consumption along with an elaboration of the iron ore preparation, beneficiation and pelletizing to yield added-value products.

A detailed chapter deals with the foreign exchange savings resulting from the domestic steel industry/capacity in developing countries. There are three detailed Annexures to this document furnishing:

a) Relevant data on world's iron ore reserves/resources and the list of pelletizing plants including their technical details/ parameters in the developing and developed countries;

b) Relevant details of direct reduction processes and sponge production in the developing and developed countries including the world's sponge iron plant, planned in operation and projected and

c) Relevant data on the world's coal reserves/resources inter alia for the iron and steel industry.

The entire subject of the iron and steel industry particularly in Africa and the Arab world and the experience of the developing countries in the growth of their steel industry has been discussed threadbare and presents a fascinating spectrum of current status and future potentialities and projections of the steel industry in the developing world.

The global setting of the iron and steel industry, potentialities of trade in raw materials for the iron and steel industry and the role of developing countries therein have been highlighted whilst outlining the regional possibilities in these fields. It is hoped that this study will stimulate dynamic and practical action for the growth of the iron and steel industry in the developing world.

CONTENTS

Explanatory Notes:
Reference to "tons" indicates metric tons.
Reference to "dollars" ($) indicates United States dollars.
The terms "billion" is used to signify a thousand million.

INTRODUCTION

A survey of any industry ought to be done appropriately in the context of its world setting. This stipulation is equally if not more important in the case of a heavily capital intensive industry such as the iron and steel industry. It will be, therefore, necessary to outline in general the world's iron and steel industry, followed by a survey of the iron and steel industry in developing countries (Africa, Arab Countries, etc.) and by referring to UNIDO's technical assistance activities in the field of iron and steel industry for the developing countries and regions.

A survey of the iron and steel industry, national, regional or interregional is inevitably linked up with its future plans and the possibilities of their implementation; it is in the latter fields that constraints, obvious or oblivious, crop up in the case of developing countries with their limitations of scarce capital, scanty trained manpower and an extant or lean technological base.

I. IRON AND STEEL INDUSTRY - THE WORLD SETTING

The world production of crude steel has more than doubled in the last thirteen years, from 346 m tons in 1960 to 710 m tons in 1974. The growth rate of course was with regard to the individual steel producing countries not equal. Japan's share in the global growth rate was extraordinary. The big question for the future is: What about the growth rate of the steel industry in the developing countries. It is said that steel consumption is somewhat characteristic of the standard of living in a country. In this light the world still lacks a lot of steel. At present, Sweden has one of the highest per capita consumption of 700 kg, closely followed by the United States, then inter alia, by Great Britain with a per capita consumption of 400 kg; and then tail the numerous developing countries where the per capita rate is only a few kilograms of the decimal of a kg. If the developing countries increase their consumption only by a few kilograms per head, the quantities of additionally required crude steel would rise enormously.

The iron and steel industry is notably capital-intensive, with a specific requirement of $400-600[1] for each ton per year of steel-ingot production capacity. In addition, in certain cases, particularly in developed countries, substantial infrastructure investment has to be made. Accordingly, the establishment of an integrated iron and steel plant with a capacity of 1 million tons per year of ingots will require an investment

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[1] This figure is now approaching a $1,000 mark.

of $400 million to $600 million. Additional investment "upstream", i.e. for supply of the necessary inputs, and "downstream", i.e. for processing of steel into manufactured products, will have to be considered in addition and may amount to investments of the same order of magnitude. A large portion of the capital invested in iron and steel installations correspond to heavy industrial equipment and heavy industrial construction. The iron and steel industry is, thus, a large buyer of heavy capital goods. For developing countries this may mean a heavy burden on their balance of payments.

World steel output is expected to keep growing in the future as in the past because steel is one of the most basic industrial material. This long term growth seems assured, if only because the drive to industrialise will relentlessly augment steel demand in many emerging nations. But the uptrend will continue to mask profound changes in the pattern of world consumption and production of steel.

Over the past 100 years, the rise in the world's output of steel has been spectacular. In 1870, it was just short of 10 million metric tons. A half-century later, in 1920, it had increased nearly eightfold to 75 million metric tons. By 1974, it had climbed to 710 million metric tons.

As a nation starts to industrialize, a first surge of steel demand is likely to reflect heavy investment in its economy's infrastructure - the development of a transportation and communications network, electric-power generation and distribution, and other essential facilities. A broader impetus to steel consumption comes from the industrial expansion itself, which is both a cause and a prime beneficiary of the infrastructure improvement. As economic growth takes off and affluence starts to spread, demand escalates for key consumer durables such as cars and major appliances - which in turn, boosts the use of steel.

The country's demand for steel is likely to be satisfied at first by imports. But as its requirements increase, it will attempt to shift to domestic production - initially, perhaps only for large-volume items. The establishment of a domestic steel industry will be recommended increasingly on grounds that it will stimulate supplier and use industries, provide employment and save scarce foreign exchange. It will seem attractive, too, for reasons of self-sufficiency and defence - and at times because of the prestige surrounding steel mills.

When a country enters the rapid-growth stage, the "steel intensity" of its economy usually rises. Steel intensity is measured by the quantity of gross national product, GNP, measured in real, noninflationary terms. The rapid growth phase is often defined as the stage in which real GNP per capita is between $400 and $2000 at 1963 prices.

A booming automobile market, trade in capital goods, rapid increase in investment in fixed assets and building up of a high level of inventory throughout the developed world largely enabled the steel industry to perform at its peak in 1974.

However, the full impact of the hike in oil prices, rising wages, declining productivity and depreciating currencies came to be felt by the beginning of 1975. And the world recession in 1975 was the worst-ever since the Great Depression of the 1930s. Among the major economies of the world, real gross national product in 1975 declined in the US, West Germany, the UK, France and Italy. Again, industrial production declined in all the major developed economies, including Japan. The decline varied from 4.4 per cent in the case of Canada to 10.6 per cent in the case of Japan. Coupled with this, while double digit inflation remained (excluding West Germany) lead by the UK (24 per cent), productivity declined in all these countries except in West Germany and the US.

PRODUCTION DECLINES

Since steel production is linked with the real growth in GNP and industrial production, world raw steel production at 656 million tonnes in 1975 declined by almost 9 per cent over the 1974 level. The 9 per cent decline in the production of crude steel in 1975 was distributed unevenly. Hence while the shares of some declined marginally that of others fell steeply. The US and the EEC suffered a decline of 20 per cent in crude steel production. Germany's steel industry suffered the highest setback of 23 per cent. While Britain's production declined by 12 per cent, that of Italy's was off by 8 per cent. Japan's production declines by almost 13 per cent. Against this general pattern of falling production, the USSR was able to maintain its rising production - production rose by 4 per cent.

But 1976 saw a revival in world industrial output. The US economy in the first half of 1976, backed by a revival in the demand for automobiles (both home and external) promised almost a 14 to 15 per cent annual increase in total output. This provided a stimulus to the revival in demand and increase in production, first Japan and West Germany and afterwards to the rest of the developed world. Simultaneously, capital goods were again stocked owing to a feeling that domestic and world demand would continue. However, the world economy, which appeared to be racing to the 1974 level, slowed down perceptibly during the second half of 1976. The slow-down was much more pronounced in the case of the US, the UK and most of the EEC economies. The increase in industrial production for the developed countries in 1976 averaged around 10 per cent. Total production of crude steel during 1976 increased to 683 million tonnes, an increase of 5.8 per cent over the 1975 level. The largest quantum increase was witnessed in the US followed by the USSR, Japan, the UK, Italy, West Germany and other relatively small West European and Asian countries. Incidentally, the largest single steel producing unit in the world, Nippon Steel Corporation, which produced 34 million tonnes in 1976, is in Japan. Three of the next seven top steel producing units are also in Japan.

What are the implications of this so far as future prospects for the steel industry are concerned? Will it perform better in 1977 than in 1976? What are the long-term prospects? Before we answer these and some other relevant questions, a look at the country-wise production data would be worthwhile. Between 1950 and 1976, the share of the US in world steel production declined from almost 46 per cent to 17 per cent. Its production at 116.3 million tonnes in 1976 was second to that of the USSR. Simarly, the share of the EEC rose from 24.6 per cent to 28.3 per cent in 1960 but declined to 17 per cent in 1976. The decline in the EEC share was largely because of a decline in the share of the UK.

As against the above, the USSR has continued to increase its production of steel and emerged as the largest producer of steel in the world in 1974, a position it retained till now. From 14.6 per cent in 1950, production in the USSR in 1976 at 147 million tonnes was 21.5 per cent of the world steel production of crude steel in the recession -- hit year of 1975. Incidentally, the USSR was the only major developed country which increased its production.

But the most impressive performer in the area of steel production has been Japan. Between 1950 and 1960, Japan's share in world steel production rose from 2.5 per cent to 6.4 per cent. By 1974, Japan's production at 119 million tonnes was 17 per cent of world production. Thus, while world production rose by 150 per cent between 1950 and 1974, that of Japan shot up by an amazing 1,200 per cent, giving Japan the third place among steel producers of the world, immediately below the USSR and the U.S.

Japan's production 1976 at 107 million tonnes, though lower than that in 1974, was still the third highest in the world with its share at 15.7 per cent. Japanese production, while way above that of West Germany, the fourth largest producer, was close to the total production of steel in the EEC.

WORLD TRADE

The prospects, both immediate and long-term, of the steel industry are intimately linked with the world trade in steel. A good part of the world steel production is exported. For instance, in 1955, almost 13 per cent of the world steel production was exported. Today, close to 23 per cent of the world production is exported. Japan, the largest quantum exporter exported almost 37 per cent of its production, followed by West Germany. Belgium exports more than three fifths of its production plus imports. Italy, France, Luxembourgh and Czechoslovakia also export quite a substantial portion of their production.

Several of the developed countries find Japanese steel cheaper than their own. Hence, the users are shifting to Japanese steel from their own. For instance, the seond largest steel producer in the world, the U.S., was a net importer of finished steel in 1975 to the extent of 15 per cent of its domestic production. The UK, Poland, Canada, Rumania, Brazil, South Africa, East Germany and Sweden were the other major importers in 1975. In 1976, even West Germany emerged as a net importer. Japan has been traditionally the largest exporter in the world.

Thus, world trade in steel has greatly increased over a period of time. The rising trade has been engineered by Japan. The planned manner in which the top six steel producers in Japan have been pushing their steel everywhere, especially in West Europe and the US, has upset the steel production programmes in several of these countries.

One does not have to seek far for the reasons for the Japanese surge in exports. The unit costs of production in Japan is still about 40 per cent of that in the US, 45 per cent of that in West Germany, and 60 to 65 per cent of that in France, and these figures Japan is steadily still improving upon. Japan, having joined the steel producing countries' group more recently than all the other developed countries, has more up-to-date, scientifically advanced and technologically superior machinery.

In 1977, it took US steel producers some 15 man-hours to produce a tonne of steel. In 1974, it took them 11 man-hours for the same job. West Germany spent almost 37 man-hours in 1955 but only 20 man-hours in 1974. In the case of France, the man-hours spent for producing a tonne of steel came down from 35 hours to 26 hours. But the productivity of steel makers in Britain during 1974 remained almost at the same level of 35 hours. However, in the case of Japan, the man-hours needed to produce a tonne of steel came down sharply from 69 in 1955 to 9 in 1974! This alone is enough to demonstrate why Japan has forged ahead so fast while countries like the UK have remained where they were two decades ago.

The EEC members have been the worst affected by the combined onslaught of Japanese Steel and the slow-down in the demand for steel in their own countries. Countries like Belgium, Luxembourg and France have been hit most since their export outlets are being captured by Japan. Even India exported 2-35 million tons of steel in 1976[1] despite stiff overseas competition. The pressure of events has brought all the major steel manufacturers in the EEC under a common cartel, Eurofer. The strategy as worked out is to cut back production and limit Japanese imports through a negotiated agreement.

The outback in production was necessitated by world economic outlook becoming bleak towards the beginning of the fourth quarter of 1976. Capacity utilization in the EEC, which was 85 per cent in the boom year in 1974, had declined to 65 per cent in 1975 as a whole. In 1976, it was still well below the 1974 level. The weakness in demand resulted from the tough competition in foreign countries and the low level of inventory building operations at home. The lack of investment was because of a decline in profitability. And this situation is causing worry to major firms in France, West Germany and Belgium where they have gone in a big way for loans to modernise and expand their plants. In Belgium and West Germany, workers in several units were working for only three weeks in a month. In addition, workers in Belgium have been retrenched on a large scale.

Big Japanese steel companies have promised Eurofer that they would not only export less to West Europe including the EEC but will also convince small manufacturers within Japan to curtail their shipments to

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these countries. But this agreement between the EEC and Japan has caused anxiety in the US where the steel manufacturers feel that a good part of the steel which used to be sent to the West European countries from Japan would now find a way to the US. Even when the export trade weakened in 1976, Japan could raise its exports by 23 per cent. Japan is known to have often exported steel at marginal costs.

The lower projected rate of real world GNP growth for 1977, according to an analysis of the Organization for Economic Co-operation and Development, has further dimmed the prospects for steel. According to this report, real growth for the OECD is estimated at 3.25 per cent against 5 per cent in 1976. Only Japan is expected to maintain its growth rate of 1976. Steel production in the 29 countries represented by the International Iron and Steel Institute indicate that between October 1976 and January 1977 crude steel production was down by 9 per cent in the EEC, 11.3 per cent in the US and 9 per cent in Japan.

Despite all this, major exporters like Japan, the US, West Germany, and other West European countries feel that the present slump in demand does not mean a deadend for world steel export prospects. They cite various instances in Asia, W.Asia and Latin America where steel is consistently in short supply. Despite the huge investment in Japan, Brazil, West Europe, Iran, Saudi Arabia, India and other countries, world exporters of steel feel that steel will continue to be in demand in the long run.

The big exporters are aware that the W. Asian and African developing countries, moving towards higher economic levels, will continue to provide a boost to the production of steel in exporting countries. As the gestation period is pretty long before steel plants come into production, countries in Latin America, Africa and W. Asia will continue to demand steel.

But what is not being considered in the proper perspective is that while this diagram of steel production and consumption may actually tally with the real situation in the short term, the long term situation may open up altogether new vistas and projections. Capacities now being built or added cannot be removed. When production does go up in the new steel producing countries, their demand may be met. While some import will always be necessary, especially of special steels which cannot be produced in all the countries, demand for the other types of steel may slump.

THE INDIAN SCENE

A word about the steel scene in India. Total production of crude steel during 1976 at 9.4 million tons in integrated steel plants was 17.5 per cent higher than in 1975. This rate of growth was almost three times the average for the world as a whole. A significant fact about steel production in India was the extremely smart improvement in capacity utilization. Bhilai and TISCO performed at 101 per cent of their installed capacity. At the Rourkela plant, the utilization was 95 per cent. Even Durgapur and IISCO, the sick units of the Indian steel industry, could produce at 70 per cent against 55 per cent in 1975. Therefore, any increased production in 1977 will come from Bokaro, TISCO and Durgapur, since the other plants are already performing at their optimum level. Mini steel plants produced about 0.8 million t in India during 1976, giving an aggregate of over 10 million tons in 1976.

If steel production in India is to continue to expand, the major impetus for it must come from domestic demand. Though domestic sales picked up towards the end of 1976, it is yet to be seen whether they will be sustained during 1977 although the trends are promising.

TABLE — 1 : MAJOR PRODUCERS OF CRUDE STEEL

(Million tons)

		Production in		Per cent share	
		1955	1976	1955	1976
U.S.S.R.	..	45.3	147.0	16.8	21.5
U.S.A.	..	106.2	116.3	39.4	17.0
Japan	..	9.4	107.4	3.5	15.7
W. Germany	..	21.3	42.4	7.9	6.2
China	..	2.9	26.0	1.1	3.8
Italy	..	5.4	23.4	2.0	3.4
France	..	12.6	23.2	4.7	3.4
U.K.	..	20.1	22.7	7.5	3.3
Poland	..	4.4	15.9	1.6	2.3
Czeckoslovakia	..	4.5	14.7	1.7	2.2
Canada	..	4.1	13.2	1.5	1.9
Belgium	..	5.8	12.1	2.2	1.8
Spain	..	1.2	11.0	0.4	1.6
Rumania	..	0.8	10.5	0.3	1.5
India	..	1.7	9.4	0.6	1.4
Brazil	..	1.2	9.2	0.4	1.3
Australia	..	2.2	7.8	0.8	1.1
S. Africa	..	1.6	7.1	0.6	1.0
East Germany	..	2.5	6.6	0.9	1.0
Mexico	..	0.5	5.3	0.2	0.8
Netherlands	..	1.0	5.2	0.4	0.8
Sweden	..	2.2	5.1	0.8	0.7
Luxembourg	..	3.2	4.6	1.2	0.7
Austria	..	1.8	4.5	0.7	0.7
Others	..	7.5	32.9	2.8	4.9
		269.3	683.5	100.0	100.0

Source : United Nations Statistical Year book, 1964, and Monthly Statistics, various Issues.

The attached graphs depict the trend of world iron and steel production, exports and productivity.

TABLE — 2 : MAJOR TRADERS IN STEEL : 1975

(Million tons)

Country	Imports of Steel	Exports of Steel
Russia	7.1	7.8
U.S.A.	10.8	2.8
Japan	0.1	28.9
West Germany	8.9	16.2
Italy	3.4	6.3
France	5.9	8.6
U.K.	3.8	3.2
Poland	3.8	1.5
Czeckoslavakia	0.6	3.3
Canada	1.4	1.3
Belgium	2.5	12.6
Spain	1.4	1.6
Romania	1.9	1.5
Brazil	2.8	0.1
South Africa	1.0	0.3
East Germany	4.0	1.5
Sweden	2.2	1.7

Source: International Iron and Steel Institute

TABLE — 3 : RECENT AND EXPECTED GROWTH IN THE OECD

Country		Average 1963-64 to 1973-74	Variation over the previous year 1975	1976	1977
			Real GNP		
Austria	..	5.2	— 2.0	4.0	3.2
Belgium	..	5.0	— 1.8	3.0	2.5
Canada	..	5.4	0.6	4.7	3.5
West Germany	..	4.4	— 3.2	5.5	3.5
Japan	..	9.4	2.1	6.0	6.0
United States	..	4.0	— 1.8	6.2	4.5
			Real GDP		
Denmark	..	4.3	— 0.7	4.5	1.7
France	..	5.4	— 1.2	5.0	3.0
Italy	..	4.7	— 3.7	4.5	— 0.5
Netherlands	..	5.3	— 1.1	3.5	3.2
Spain	..	6.6	0.8	2.0	1.5
U.K.	..	2.7	— 1.8	1.0	1.5
Total OECD	..	5.0	1.2	5.0	3.7

Source: International Monetary Fund. I.M.F. Survey. January 10, 1977

The world's top steel producers in 1976 are shown below:

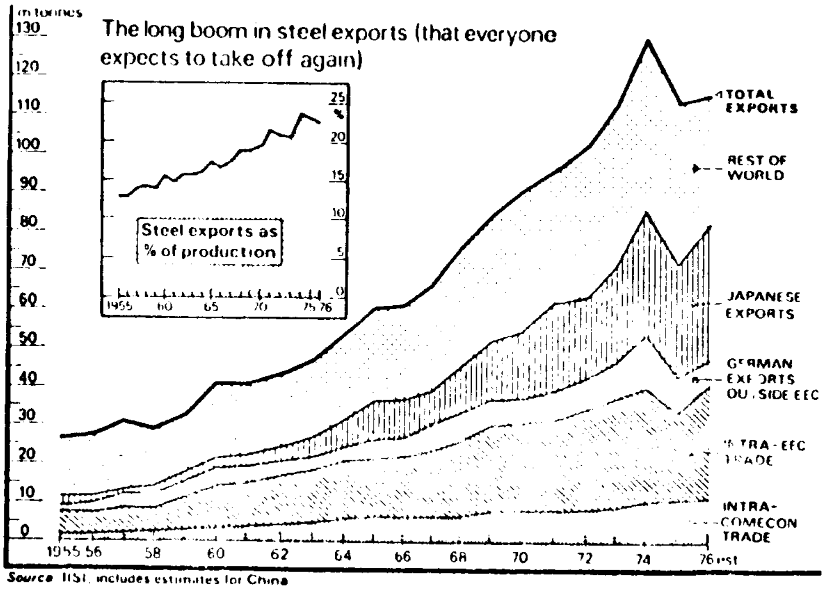
Table No.4

Top steel producers in 1976

(million metric tons)

	1975		1976	
	Ranking	*Output*	*Ranking*	*Output*
Nippon Steel	1	32.50	1	33.97
US Steel	2	23.93	2	25.67
BSC	3	17.24	3	19.07
Bethlehem	4	15.87	4	17.14
NKK	5	14.60	5	15.67¶
Finsider group	7	12.86	6	13.43
Sumitomo	6	13.40	7	13.30
Kawasaki	8	12.60	8	13.30
ATH	9	12.17	9	12.82
Estel*	11	9.71	10	10.40
National	15	7.80	11	9.77
Arbed group†	10	9.75	12	9.72
Usinor**	14	7.90	13	8.90
Republic	13	7.98	14	8.73
Kobe Steel	16	7.70	15	7.81
BHP	12	8.01	16	7.78
Inland	17	6.60	17	7.17
Armco	18	6.34	18	6.80
Sacilor group‡	19	6.00	19	6.60
Jones & Laughlin ..	20	5.20	20	6.32
Stelco	22	4.90	21	5.19
Iscor	24	4.65	22	5.18
Cockerill	23	4.80	23	5.12
Ensidesa	21	5.10	24	4.99
Youngstown Sheet & Tube	26	4.05	25	4.60
Krupp	29	3.41	26	4.13
Peine-Salzgitter	27	3.90	27	4.11
Mannesmann§	25	4.60	28	4.05
Vöest-Alpine	28	3.63	29	3.90

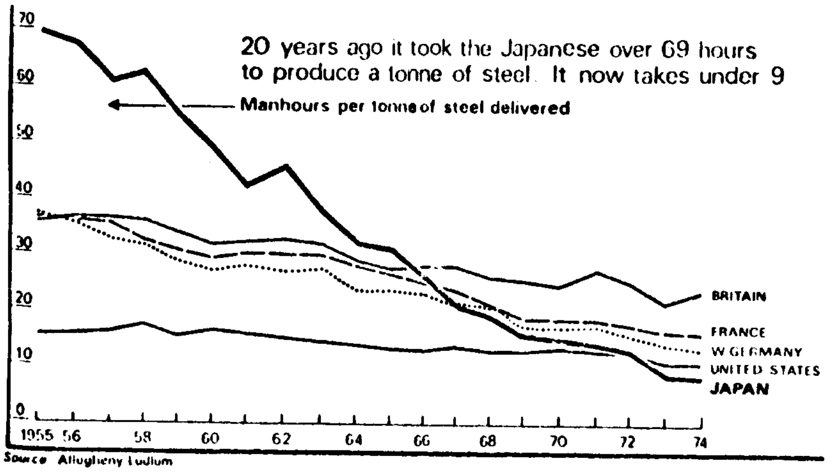
*†Includes 5.7m tons from subsidiaries. *Haesch 5.6m tons, Hoogovens 4.8m tons. ‡Includes share in Salmer. §Includes subsidiaries. ¶Includes 1.01m tons from subsidiaries. **Includes subsidiaries—Alpa, share in Salmer, etc.*



Source IISI, includes estimates for China

Table No.5

Table No. 6



Source Allegheny Ludlum

Table No.

World raw steel production

Source: Eisen und Stahl, Statistisches Bundesamt, Dusseldorf

	RAW STEEL OUTPUT ('000 tons)					OUTPUT PER CAPITA (kg.)					% World Output	
	1970	1973	1974	1975	1976*	1970	1973	1974	1975	1976*	1970	1976
Europe												
W. Germany	45,041	49,521	53,232	40,415	42,415	732	799	858	654	688	7.52	6.23
Belgium	12,607	15,522	16,725	11,584	12,146	1,303	1,509	1,654	1,183	1,238	2.10	1.78
France	23,774	25,270	27,020	21,530	23,226	468	485	514	407	436	3.97	3.41
Italy	17,277	20,995	23,803	21,836	23,416	322	382	430	341	415	2.89	3.44
Luxembourg	5,462	5,921	6,448	4,624	4,566	16,065	16,926	18,163	18,163	12,341	0.91	0.67
Netherlands	5,042	5,623	5,840	4,826	5,185	387	418	431	354	377	0.84	0.76
Denmark	473	449	535	559	723	96	89	106	110	142	0.08	0.11
UK	28,316	26,649	22,426	20,198	22,268	508	476	400	261	398	4.73	3.27
Irish Republic	80	116	110	81	58	27	38	36	26	18	0.01	0.01
EEC	138,072	150,069	155,639	125,653	134,003	546	585	603	486	516	2.305	19.67
Finland	1,169	1,615	1,656	1,618	1,646	249	348	356	344	345	0.20	0.24
Greece	348	753	612	700	700	51	84	68	77	77	0.06	0.10
Norway	870	963	944	919	894	224	243	237	230	222	0.15	0.13
Austria	4,078	4,238	4,699	4,068	4,478	552	563	622	541	598	0.68	0.66
Portugal	385	459	377	430	428	43	54	44	49	48	0.06	0.06
Sweden	5,497	5,664	5,989	5,611	5,213	684	696	734	684	632	0.92	0.76
Switzerland	524	584	593	420	520	84	91	92	66	82	0.09	0.08
Spain	7,429	10,809	11,646	11,242	11,058	220	310	331	313	310	1.24	1.62
Turkey	1,520	1,169	1,464	1,464	1,770	43	31	39	38	44	0.25	0.26
W. Europe	159,692	176,323	183,619	152,125	160,710	432	467	483	398	418	26.70	2.359
E. Germany	5,425	6,640	6,165	6,480	6,650	318	391	365	385	396	0.91	0.98
Bulgaria	1,800	2,246	2,188	2,265	2,450	212	261	252	260	280	0.30	0.36
Yugoslavia	2,228	2,676	2,836	2,916	2,712	109	128	134	134	126	0.37	0.40
Poland	11,750	14,057	14,556	15,007	15,450	362	421	432	438	450	1.96	2.27
Rumania	6,517	8,161	8,840	9,549	10,500	322	389	420	451	492	1.09	1.54
Czechoslovakia	11,480	13,158	13,640	14,324	14,550	794	902	929	970	981	1.92	2.14
Hungary	3,110	3,332	3,466	3,671	3,650	302	319	331	348	344	0.52	0.54
Europe†	202,202	226,593	235,310	206,337	216,672	408	448	462	402	420	33.76	31.80
USSR	115,889	131,481	136,206	141,325	144,900	477	526	542	555	565	19.35	21.27
Asia												
Bangladesh	30	64	82	100	100	3	1	1	1	1	0.03	0.01
Burma	15	40	40	40	40	1	1	1	1	1	0.00	0.01
Taiwan	733	956	825	847	1,000	25	35	57	63	61	0.06	0.15
China	18,000	23,000	24,000	25,000	26,000	24	31	32	30	31	3.01	3.82
Hong Kong	50	70	70	70	80	13	17	17	16	18	0.01	0.01
India	6,271	6,915	7,068	7,989	9,313	12	12	12	13	15	1.05	1.37
Indonesia	10	50	80	100	100	1	1	1	1	1	0.00	0.01
Iran	—	240	567	551	550	—	21	20	18	16	—	0.08
Israel	60	65	75	60	70	41	37	23	18	20	0.02	0.01
Japan	93,322	119,322	117,131	102,314	107,377	903	1,101	1,068	914	940	15.58	15.76
N. Korea	2,180	2,630	2,700	2,900	3,000	105	174	174	183	185	0.37	0.44
S. Korea	481	1,157	1,935	2,010	3,500	15	35	58	59	102	0.08	0.51
Lebanon	15	15	15	15	15	1	1	1	1	1	0.00	0.00
Malaysia	122	193	183	195	200	13	16	16	17	17	0.02	0.03
Philippines	131	254	279	250	250	4	6	7	6	6	0.02	0.04
Singapore	107	204	186	187	200	68	92	84	83	88	0.02	0.03
Thailand	174	347	351	258	250	8	8	9	6	6	0.04	0.04
Vietnam	7	5	5	5	5	0	0	0	0	0	0.00	0.00
Asia	121,708	155,527	155,592	142,891	152,050	62	74	72	65	68	20.31	22.32
America												
Argentina	1,823	2,205	2,354	2,205	2,415	79	91	95	89	94	0.30	0.35
Brazil	5,390	7,149	7,502	8,308	9,189	58	70	74	78	84	0.90	1.35
Chile	592	549	635	488	492	67	54	61	48	49	0.10	0.07
Canada	11,212	13,386	13,623	13,025	13,229	525	605	606	571	571	1.87	1.94
Colombia	310	362	333	366	320	15	16	13	15	13	0.05	0.05
Cuba	140	221	240	240	250	17	25	26	26	26	0.02	0.04
Mexico	3,881	4,760	5,138	5,291	5,295	79	88	91	87	85	0.65	0.78
Peru	94	356	450	443	330	7	24	31	28	20	0.02	0.05
Uruguay	16	12	14	16	15	6	4	5	6	6	0.00	0.00
Venezuela	927	1,063	1,058	1,075	930	89	94	89	90	75	0.15	0.14
USA	122,120	139,950	135,235	108,250	118,740	596	665	638	507	554	20.39	17.[illegible]
Central America	8	10	10	10	10	0	1	1	1	1	0.00	0.00
America	146,513	170,021	166,592	139,715	151,215	285	315	304	251	268	24.46	22.20
Africa												
Algeria	330	395	450	450	450	23	25	25	27	26	0.06	0.07
Egypt	300	290	300	400	400	9	8	8	11	11	0.05	0.06
S. Africa	4,757	5,633	5,833	6,580	7,144	217	236	240	258	268	0.78	1.05
Rhodesia	150	250	270	300	300	28	42	44	47	44	0.03	0.04
Tunisia	30	137	132	130	150	19	25	23	23	27	0.02	0.02
Uganda	20	14	12	15	15	2	1	1	1	1	0.00	0.00
Morocco	5	5	5	5	5	0	0	0	0	0	0.00	0.00
Africa	5,692	6,724	7,002	7,880	8,464	15	17	17	20	20	0.93	1.24
Australia	6,909	7,699	7,785	7,869	7,794	553	586	584	582	570	1.15	1.14
New Zealand	157	190	194	185	200	56	67	64	60	63	0.03	0.03
Australasia	7,066	7,889	7,979	8,054	7,994	367	389	385	383	375	1.18	1.17
World	599,100	698,300	708,700	646,300	681,300	165	187	183	164	170	100	100

*Provisional or partly estimated (as at February 1, 1977). †Excl. USSR.

Table No.8

World pig iron production

	PRODUCTION ('000 metric tons)					OUTPUT PER CAPITA (kg)					% World Output	
	1970	1973	1974	1975	1976*	1970	1973	1974	1975	1976*	1970	1976
Europe												
W. Germany	33,627	36,828	40,221	30,074	31,849	546	594	648	486	517	7.87	6.53
Belgium	10,955	12,767	13,152	9,180	9,956	1,132	1,308	1,346	938	1,014	2.56	2.04
France	19,128	20,302	22,517	17,921	19,035	377	389	429	338	357	4.48	3.90
Italy	8,354	10,098	11,761	11,412	11,694	156	184	212	204	208	1.96	2.40
Luxembourg	4,810	5,089	5,468	3,889	3,756	14,147	14,540	15,403	10,655	10,151	1.13	0.77
Netherlands	3,594	4,707	4,804	3,970	4,266	276	350	355	291	310	0.84	0.87
Denmark	215	76	—	—	—	44	15	—	—	—	0.05	—
UK	17,672	16,830	13,903	12,131	13,859	321	301	248	217	248	4.13	2.84
EEC	98,355	106,705	111,826	88,577	94,415	389	416	434	343	364	23.02	19.35
Finland	1,223	1,412	1,381	1,368	1,240	260	304	297	290	260	0.29	0.25
Norway	678	700	661	638	630	175	177	166	159	156	0.16	0.13
Austria	2,964	3,006	3,443	3,056	3,325	401	400	456	406	444	0.69	0.68
Portugal	315	348	365	327	350	35	41	43	37	39	0.07	0.07
Sweden	2,609	2,569	2,979	3,309	2,600	325	316	365	404	315	0.61	0.53
Switzerland	28	26	35	35	35	4	4	5	5	5	0.01	0.01
Spain	4,164	6,269	6,900	6,842	7,000	123	180	196	193	196	0.97	1.43
Turkey	1,156	1,044	1,317	1,337	1,350	33	28	34	34	34	0.27	0.28
W. Europe	111,492	122,079	128,907	105,489	110,945	301	324	340	276	289	26.09	22.74
E. Germany	1,994	2,202	2,280	2,456	2,460	117	130	135	146	147	0.47	0.50
Bulgaria	1,201	1,566	1,483	1,509	1,600	141	182	171	173	183	0.28	0.33
Yugoslavia	1,275	1,955	2,126	2,001	1,950	63	93	101	94	91	0.30	0.40
Poland	6,984	7,731	7,787	7,752	7,900	215	232	231	228	230	1.63	1.62
Rumania	4,211	5,713	6,081	6,602	6,650	208	272	289	312	312	0.99	1.36
Czechoslovakia	7,548	8,534	8,905	9,290	9,400	522	585	606	629	634	1.77	1.93
Hungary	1,828	2,105	2,290	2,219	2,200	177	202	219	211	208	0.43	0.45
Europe†	136,533	151,685	159,859	137,318	143,105	275	300	314	268	278	31.95	29.33
USSR	85,933	95,933	99,868	102,968	105,500	354	384	397	405	411	20.11	21.62
Asia												
Taiwan	320	550	460	470	550	23	36	29	29	34	0.07	0.11
China	16,500	21,000	22,000	22,500	23,000	22	26	27	27	28	3.86	4.71
India	6,901	7,344	7,223	8,353	8,730	13	13	12	14	14	1.61	1.79
Japan	68,048	90,007	90,437	86,877	86,500	658	831	825	793	757	15.92	17.73
N. Korea	2,400	2,700	3,000	3,100	3,100	173	179	194	195	191	0.56	0.64
S. Korea	35	482	1,022	1,194	1,500	1	14	31	36	44	0.01	0.31
Thailand	30	50	50	40	40	1	1	1	1	1	0.01	0.01
Asia	94,234	122,133	124,192	122,534	123,420	48	58	58	56	55	22.05	25.30
America												
Argentina	815	804	1,068	1,038	1,100	35	33	43	41	43	0.19	0.23
Brazil	4,205	5,540	5,989	7,260	7,700	45	54	57	68	70	0.98	1.58
Chile	481	458	516	417	400	54	45	50	41	40	0.11	0.08
Canada	8,243	9,535	9,422	9,150	9,750	387	431	419	401	421	1.93	2.00
Colombia	229	271	269	297	260	11	12	11	12	10	0.05	0.05
Mexico	2,261	2,775	3,208	2,961	3,000	46	51	55	49	48	0.53	0.61
Peru	86	253	303	307	220	6	17	20	19	13	0.02	0.05
Venezuela	510	546	545	535	480	49	48	47	45	39	0.12	0.10
USA	83,294	91,614	87,007	72,505	79,150	407	436	411	339	368	19.50	16.22
America	100,124	111,996	108,327	94,470	102,060	195	208	198	170	180	23.45	20.92
Africa												
Egypt	200	200	200	250	250	6	6	5	7	7	0.05	0.05
S. Africa	3,947	4,355	4,627	5,197	5,720	183	183	190	204	215	0.78	1.17
Rhodesia	250	290	300	310	310	47	49	49	48	46	0.06	0.06
Africa	4,397	4,845	5,127	5,757	6,280	12	12	13	13	15	1.03	1.29
Australasia												
Australia	6,148	7,659	7,250	7,476	7,500	492	583	543	553	548	1.44	1.54
Australasia	6,148	7,659	7,250	7,476	7,500	319	377	350	356	352	1.44	1.54
World	427,400	494,500	504,600	470,500	487,900	118	133	130	119	122	100	100

**Provisional or partly estimated. †Excl. USSR*

Source: Eisen und Stahl, Statistisches Bundesamt, Dusseldorf
Metal Bulletin - June 10, 1977

Since the Fifties there has been much technological development in the steel industry. The locational problem has been idely studied for reduction in construction costs, operating costs and, above all, pollution control. Bigger units are favoured for savings in capital cost and operating cost per tonne. The following tabulations are presented to indicate the investment made, capital costs of selected major steel works. The size of the blast furnace of Fukuyama grows with every stage of expansion.

	Inner Vol. of B.F. Cu.m.
Stage 1	2004
Stage 2	2828
Stage 3	3016
Stage 4	4197
Stage 5	4400

The average investment pattern during 1971-75 in the four main steel making countries will reflect the pattern of huge capital requirement of the industry.

	Capacity Mty.	M.$ Investment
1. U.S.A.	150	1850
2. Japan	144	2880
3. W. Germany	63	774
4. France	34	860

The BSC's Ten-Year Development Strategy involves £ 3,000 m for building a capacity of 33 to 35 mty. by the late Seventies and 36 to 38 mty. during the first half of the Eighties.

Investment costs of selected major steelworks are shown below:

Table No. 9

Country	U.S.A.	Japan	France	Japan	Japan
Company	Bethlehem	Kobe	Usinor	NSC	NKK
Works	Burns Hbr.	Kakogawa	Dunkerque	Oita	Fukuyama
Cap. Mtpa	4.0	6.0	8.0	8.0	16.0
When Built	1964-75	1968-73	1960-74	1971-76	1963-73
Actual Cost	$1½ bill.	$1½ bill.	$1.1 bill.	$2 bill.	$2 bill.
Poss. 1976 Cost	$3½ bill.	$3½ bill.	$5½ bill.	$4 bill.	$8 bill.

The world production of steel by processes is shown below:

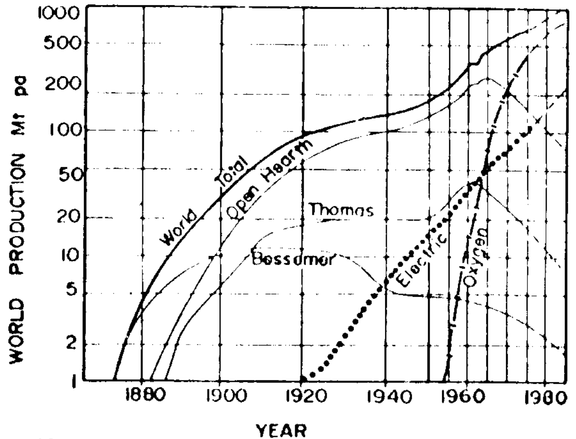


Table No. 10

The growth of the Third World steel industries is another structural effect and is an important factor to be reckoned when discussing world steel production.

Western World Steel Production in 1985, UNIDO Forecast 1/

Table No. 11

	1974 m.tons	%	1985 m.tons	%	1974-1985 growth rate
Industrialized countries	462	93	613	83	2.6
Developing countries	36	7	125	17	12.0
Total Western World	498	100	738	100	3.6

Most of the Third World steel producers will be state-owned and export-oriented. Governments of the industrialized countries will try to assist the Third World development with a cut of the big steel markets. This will necessitate established exporters to restrict their share of certain major markets so as to accept Third World producers' participation.

World steel demand will grow at a much slower rate than before and production will match demand. The production pattern will transform with a shift from the industrialized countries to the developing world.

Already occuring is a diversification by the private sector into other related industries and into more sophisticated products and technologies. For a more detailed analysis of a UNIDO study, reference should be made to UNIDO/IOD 50 of 22 November 1976 entitled "Problems and opportunities in the World's Iron and Steel industry".

1/ Summary extract from IISI 68th Annual Meeting

II. Brief analysis of the situation of developing countries in regard to iron and steel production and consumption [1]

The situation of developing countries can be summarized as follows:

(a) Developing countries have increased their share of world production of raw steel (ingots) from 1.5 per cent in 1950 to about 8 per cent in 1973;

(b) In 1973, their share of world production was roughly 55 megatons, or 8 per cent, while their share of consumption was roughly 80 megatons, or 12 per cent;

(c) Their per capita production and consumption (as a whole) are extremely low, about 20 and 30 kilograms, respectively;

(d) Even the most developed of the developing countries show per capita indices much lower than developed countries, i.e. about 100 kilograms and 400-600 kilograms respectively;

(e) Only a few (about 13) developing countries in Africa, Asia and Latin America have established integrated iron and steel plants, however small;

(f) The iron and steel production of developing countries has grown at about 10 per cent per year since 1950, with apparent consumption growing at about 8 per cent per year;

(g) Developing countries still depend on imports for about one-third of their needs for steel, about 25 megatons per year;

(h) Developing countries are heavy exporters of raw materials to developed countries. They supply about 125 megatons per year, or 16 per cent of all iron ore consumed in the iron and steel industry (compare that with their share of 8 per cent of world steel production). Since the ore they export is of a very high grade, their ore output represents about 20 per cent of the iron contained in the world ore output;

(i) Many developing countries are now engaged in major efforts to plan, establish or expand thier steel industry, which is generally considered a high priority sector;

(j) The growth of steel production and consumption, respectively, in developing countries in the period 1950 - 1972 has been as follows: 20 per cent and 10.6 per cent for the Middle East; 11.9 per cent and 8.3 per cent for Latin America; 9.7 per cent and 8.4 per cent for Asia (developing countries only); 9.8 per cent and 6.0 per cent for Africa.

(k) The degree of self-sufficiency (percentage of demand covered by local production) attained in the last few years is roughly estimated as follows: 73 per cent for Latin America; 56 per cent for Asia; 12 per cent for the Middle East; 7 per cent for Africa.

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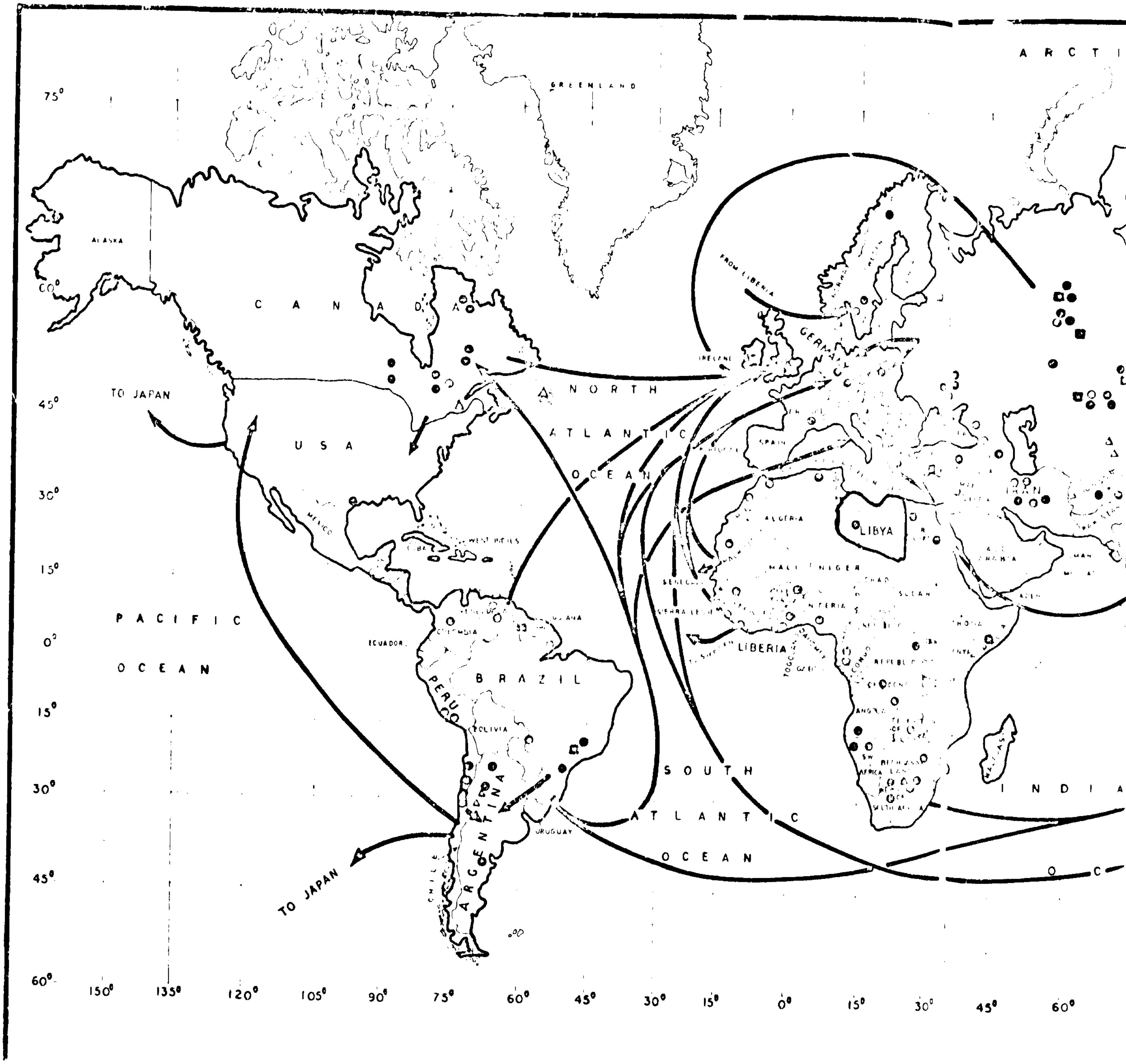
[1] Source - Problems and opportunities in the World's Iron and Steel Industry - UNIDO/IOD/50 22 November 1976

The attached global chart depicts the raw materials' resources and movement (trade - current and potential) of the developing and developed countries of the world. It provides the qualitative trends rather than quantitative data; the latter are readily available in UN and other international Statistical Year Books.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A T L A N T I C
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FROM LIBERIA
IRELAND
GERMA
SPAIN
MEXICO
WEST INDIES
P A C I F I C
O C E A N
ALGERIA
LIBYA
IRAN
MALI
NIGER
CHAD
SUDAN
NIGERIA
SENEGAL
SIERRA LEONE
LIBERIA
TOGO
CONGO
ANGOLA
SW AFRICA
SOUTH AFRICA
ECUADOR
COLOMBIA
GUIANA
B R A Z I L
PERU
BOLIVIA
ARGENTINA
CHILE
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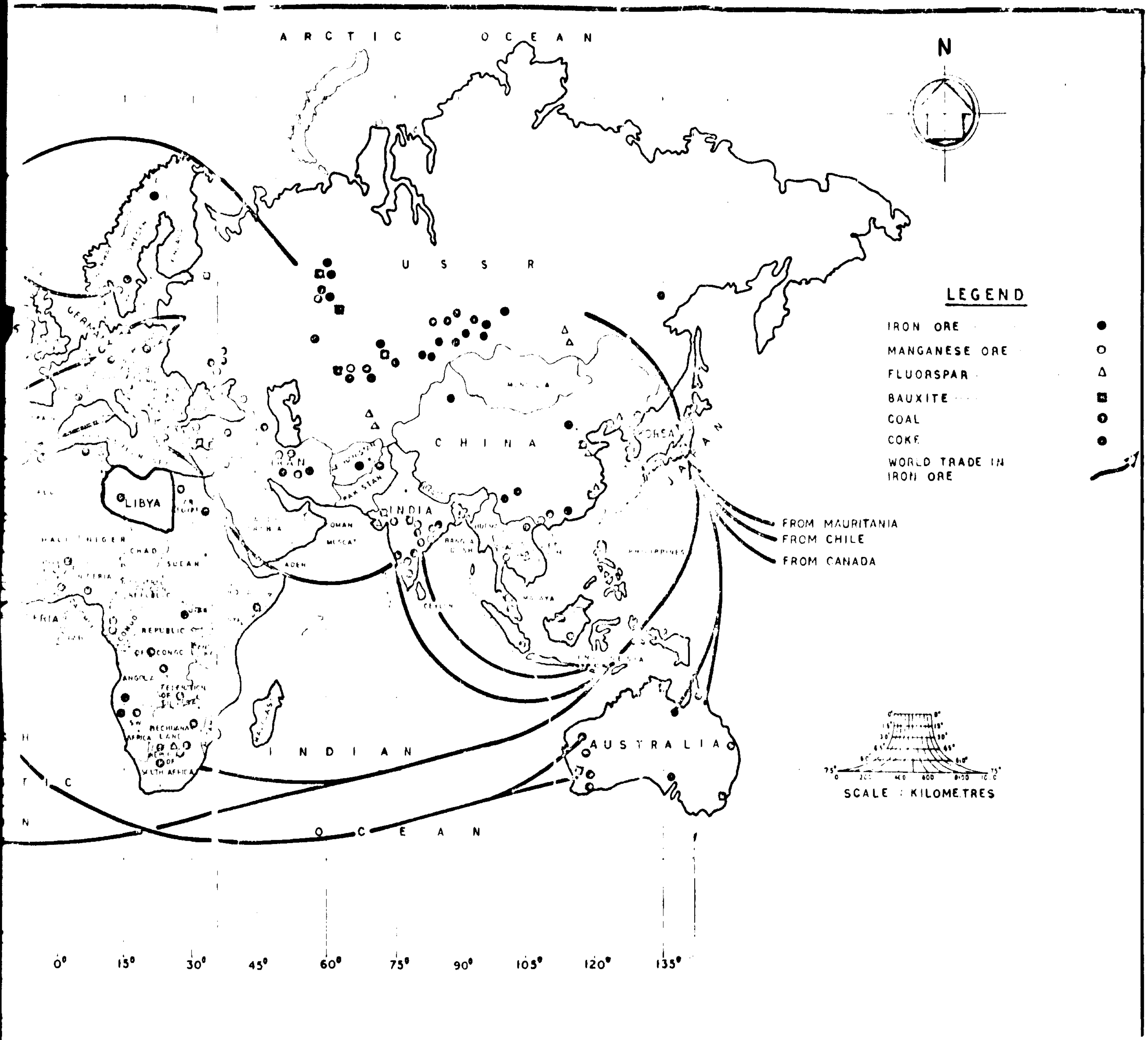
SECTION 1


ARCTIC OCEAN
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PHILIPPINES
INDONESIA
LIBYA
CHAD
SUDAN
NIGER
REPUBLIC OF CONGO
ANGOLA
S.W. AFRICA
BECHUANALAND
REPUBLIC OF SOUTH AFRICA
AUSTRALIA
INDIAN OCEAN
LEGEND
IRON ORE ●
MANGANESE ORE ○
FLUORSPAR △
BAUXITE ▣
COAL
COKE
WORLD TRADE IN IRON ORE
FROM MAURITANIA
FROM CHILE
FROM CANADA
SCALE : KILOMETRES
0°
15°
30°
45°
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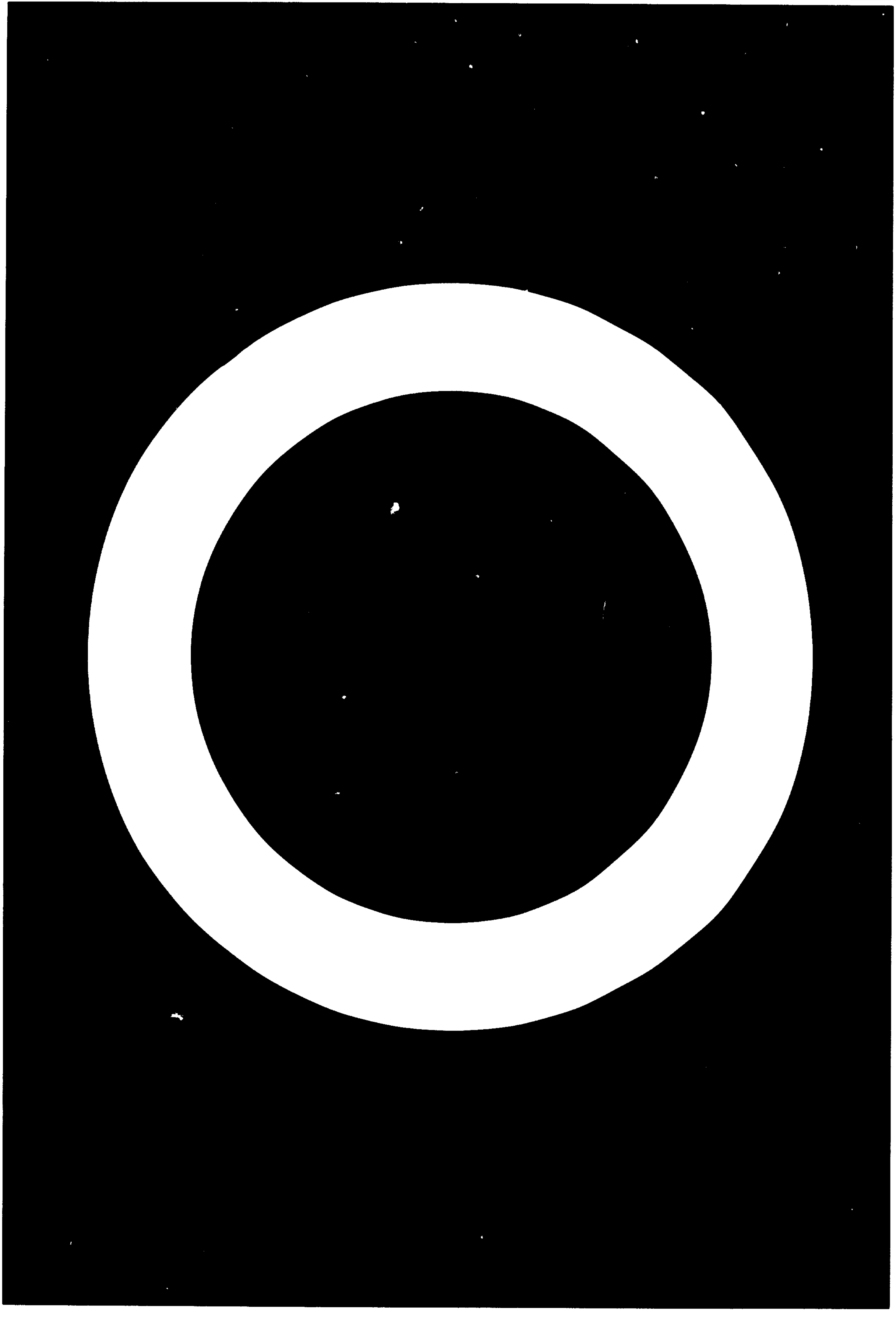
90°
105°
120°
135°

SECTION 2



Iron ore preparation, beneficiation and pelletizing

Iron ore preparation is almost synonymous with ore beneficiation aiming at the treatment of the low grade ores and in some cases even the rich iron ores, to upgrade their metallic contents and to lower their impurity gangue contents that are detrimental for the iron production. Drying of the iron ores and their washing and scrubbing are simple beneficiation techniques designed to improve ore handling and to lower the harmful gangue such as, alumina and silica. Any such preparation of the iron ore and its treatment outside the iron blast furnace will reflect in lowered slag volumes, reduced flux and fuel rates and improved iron productivity and the metal quality. Blending of iron ores can be one simple mode of ore preparation. Gravity treatments such as heavy media separation, jigging, hydro-cyclone operation, Hymphrey's spiral, are all well known modes of iron ore beneficiation. Some oxidized ores are amenable to froth flotation treatments. Highly siliceous iron ore may have to be wet ground fine, followed by wet magnetic separation and agglomeration, etc., such as sintering, pelletizing and briquetting. In each case, the basic considerations are the overall economic and quality of the treated ore. In some cases, suitable combinations of different treatment cycles are applied such as in the case of taconites, etc. In some cases, pyro-metallurgical treatments may be applied such as magnetising reduction roasting for ferruginous manganese ores. And so, the ore processing varies depending on the starting raw materials, the techniques available to upgrade the metallic contents and lower the impurity gangue; a line has to be drawn in between in balancing the quality of the upgraded ore with metallic recovery (yield) figures and the overall economics and operational costs. Still newer processes are now emerging such as, cyclone-heavy-media process, stripa-heavy-media treatment and so on. Likewise, agglomeration techniques present a wide spectrum to choose from, covering pelletizing, sintering, briquetting, etc. The sintering of iron ore fines today finds universal applications. Pelletizing has also now become universal as a means to achieve added value to the exports, increase iron productivity of the blast furnace and provide a basic feed for sponge production. The reserves of iron ores in developing countries cover both high and low grades. Some developed countries mainly import high grade iron ores from the developing countries in view of the intrinsic economic value of using high grade ores. The developing countries are producing mostly high grade ores whilst the low grade ore is dumped at the mine sites.

Additionally, large scale mechanized mining operations and sizing of the ores have led to the generation of large quantities of iron ore fines. The natural iron ore fines, such as "blue dust" of extremely fine size mostly below -200 mesh also occur as sizeable pockets in many countries including India; blue dust veins being almost pure Fe_2O_3 with very little gangue (of the order of 1-2%), offer attractive scope for pelletizing in the run-of-mine conditions. The low grade fines are beneficiated appropriately, mixed with the naturally high grade fines and with blue dust wherever available, and used as the feed for pelletizing. Complementarily, iron ore fines of -3/8" to 64 mesh are used for sintering; the former are beneficiated wherever and to the extent necessary. Sintering and pelletizing are thus complementary processes which provide the feed for modern iron smelting in the high capacity blast furnaces of today (daily rated capacity of up to 12,000 tons per day of molten iron); the pelletizing additionally provides the desirable feed to modern direct reduction plants for the production of sponge iron. The earlier practice of using lumpy high grade iron ores for sponge production in many cases being replaced by high grade oxide pellets for some of the gaseous direct reduction processes. Other gaseous direct reduction processes are based on fluidized bed reduction of ground iron ore fines, preferably of high grade. Solid reductant based direct reduction processes use either high grade lumpy ores, pellets or in some cases green pellets and concentrate obtained from low grade ore fines such as titaniferous magnetites.

The physical size requirements of iron ores depending upon their reducibility and hardness are for pellets = 9 to 16 mm, sinter = 5 to 50 mm, lumpy ore = 10-25 mm with -10mm not exceeding 5%. Of the sized lumpy ores, friable and sticky ores are not favoured - sticky ores are washed and screened. Friable ores are crushed to sinter feed size and used as coolant in LD oxygen steel converters provided the gangue impurity contents are low. Sinter feed should have adequate shatter strength (minimum 85% + 10 mm) and sufficient tumble strength (minimum 70% + 10 mm).

Naturally occurring iron ores contain iron bearing minerals, gangue materials and other impurities. The value of a high grade iron ore is determined not only by its high iron content but also by its gangue and impurity contents; the latter will exercise significant effects on the economics of iron- and steelmaking. The beneficiation methods and flowsheets depend mainly upon the physical, chemical and mineralogical characteristics of the ore and are based on the physical properties thereof such as specific gravity, magnetic, electrostatic and flotation characteristics, etc. The metallurgical value of an iron ore does not merely depend upon its iron content but has to be rationally adjudged in the light of its gangue content, the nature and characteristics of ingredients composing the gangue and the latter's physical mode of distribution and structural association with the iron minerals. The gangue's selective presence in different ore fractions will determine its liberation size to which the ore will need to be crushed/ground before applying beneficiation treatments. Some of the classic high grade iron ores will fail to meet the metallurgical characteristics in terms of their deleterious gangue present and the latter's adverse effects during the iron smelting. In most iron and steel producing countries of the world, these aspects have received comprehensive study and practical action in terms of what is currently termed preparation, sizing and treatment of the iron ores with a view to charge prepared burdens in the blast furnace to obtain maximum iron productivity and low coke rates consistent with the quality of iron ore charges for iron smelting in the blast furnace to provide the latter with a "prepared burden".

In the case of ore fines which cannot be charged directly into the blast furnaces, sintering of the ore fines (-3/8" to 64 mesh) and pelletizing of the finer fractions (natural ore fines including blue dust) have to be undertaken. Iron ore fines are also not acceptable for many of the direct reduction processes and have, therefore, to be agglomerated. The choice of agglomeration process will depend upon the nature and size of the ore fines or concentrate. Sintering is one of the most widely adopted processes at present because of its economic and technological advantages. The sintering plant has to be located close to the blast furnace as long distance transport of the sinter is to be avoided due to the degradation and decrepitation characteristics of the sinter although one plant in the Phillippines has reportedly started exporting sinter to Japan (Kawasaki) recently without much degradation losses.

Pelletizing of the ore fines to produce high grade oxide pellets is now universally accepted for iron and sponge production because of their high iron content, uniform size, strength and optimum reducibility characteristics. The pellets can also withstand long distance rail and ocean transports.

The international trade in iron ore both in natural lumpy ores and fines and of pellets has been progressively rising in unison with world's iron and steelmaking capacity. Though the pellet production got off to a start in 1950, it now accounts for over 1/5th of the total usage of iron ore. There has been a phenomenal rise in the output of the pellets from about 70 million tons in 1960s to about 175 million tons in 1974.

It is necessary to apply measures for a mutually advantageous exchange of raw materials and fuels through equitable price rationale so that both developed and developing countries can achieve their steel production targets. These subjects have come into limelight somewhat more recently. Apart from cost and price parameters, the exchange of raw materials and fuels (energy) has to be promoted on regional (bilateral) and inter-regional (multi-lateral) basis through trade and barter; these parameters apply in relation to developing and developed countries and the developing countries themselves.

Pelletizing

Table 15 shows the chemical analyses of pellets from selected developing countries.

Table 12

Region	(Percentages)						
ASIA	Fe	SiO_2	Al_2O_3	CaO	MgO	P	S
India	65-66	2.1	1.75	0.7	—	0.06	0.03
Philippines	62.5	6.09	1.76	0.72	0.65	--	0.018
AFRICA							
Liberia	64.5	4.2	2.0	1.1	0.06	0.06	0.003
Morocco	65.5	2.6	1.2	0.8	0.97	0.006	0.008
LATIN AMERICA							
Brazil	66.3	1.00	0.8	0.6	0.1	0.024	0.009
	68.1	1.5	0.9	1.4	0.2	0.027	0.01
Peru	65.00	3.0	1.0	Trace 1.00		0.01	0.01
	67.00	4.0		CaO+MgO			to 0.03

Source: Compiled from various journals and Metal Bulletin - Special Issue 1969.

Some of the latest pelletizing plants have been built at the ports from which pellet shipments are made for exports such as by CVRD (Brazil), Hammersley (Australia) and Lamco (Liberia). Pelletizing plants for using pellets at home are built close to the mine sites or near the steel plants for the local blast furnaces e.g. by Imjuiden (Netherlands) and Kawasaki (Chiba, Japan).

The principal iron ore pelletizing processes for heat-hardening of the pellets are based on:

(i) Grate-kiln process,
(ii) Travelling grate process,
(iii) Shaft furnace process,
(iv) Circular grate process.

The shaft furnace process has not been much used since 1967/68 and is restricted to magnetites and somewhat small pelletizing plants.

The new techniques relate to the Grengcold process where cold-bonded pellets are indurated by the addition of about 10% cement clinker, and the circular grate process which uses a circular system for pellet induration. A latest installation by Fukuyama Nippon K.K. is based on a grate type pre-heated and a rotary kiln for sponge production.

Production of pellets involves grinding of iron ores and binding agents, mixing and green balling mostly on disc pelletizer followed by hardening. Binding agents are bentonite, hydrated lime or both; the latter is much cheaper than the former.

Dry grinding of ore fines is preferred when the fines are of high grade-blue dust is handled in a dry circuit prior to mixing to the pellet feed. Wet grinding is done if the fines have high Al_2O_3 content. Disc pelletizers or drum pelletizers are commonly used. Hardening of the green pellets is based on:

Drying at 300 - 400°C

Preheating at 800 - 850°

Roasting at 1250°C - 1350°C

Recuperation and cooling

Heat Hardening

Shaft furnace operates on the principle of counter-current hot gases meeting the pellets inside the shaft furnace. The maximum capacity of the shaft furnace ranges from up to 500,000 tpy for magnetics only. Hematite concentrates, unless it is in a very small quantity in the pellet feed, creates thermal imbalance inside the shaft furnace. Travelling grate comprises a chain of pellets moving on two sprockets. The hearth extends over the entire length of the machine and is divided normally into five zones. Waste gases from the roasting zone after cleaning are used in the drying and preheating zones. This process is suitable for both fluxed and unfluxed pellets for different types of iron ores. Use of bottom and side layers is important to protect the grate bars and pellets from being overheated.

Grate Kiln consists of travelling grate for drying and preheating and rotary kiln for hardening, followed by a cooler for cooling the pellets. Waste gases from the kiln are used for drying and preheating the pellet feed. This equipment like the travelling grate, is flexible and suitable for most raw materials. The use of bedding layer is not needed due to relatively lower temperatures in the travelling grate.

Circular grate is the latest development and incorporates the advantages of the other three types of equipment. It is compact, simple and less costly. The operational and maintenance costs are also loss due to use of cold fans, stainless steel grates and elimination of return strand, hearth layer screens and pellet wheels. The green pellets are fed by means of reciprocating conveyer and the heat hardened pellets are discharged by means of scoop unloader. The depth of the bedding layer is flexible and can be controlled by suitable adjustment of the unloader. The pellets are of uniform quality due to effective water coal. The circular grate has lower thermal requirements than the other systems.

Amongst the cold induration processes, the latest is the Swedish Grancold process which can use up to 10% of portland cement, possalinic and slag cements for binder purposes; these are mixed in the pellet feed before balling. The green balls are subsequently coated with iron concentrate to prevent sticking and clustering of the pellets; they are allowed to harden and cure for periods up to a month. The blast furnace smelting of these pellets have produced good results. Other cold induration processes include the carbonate bond process, the corrosion bond process and autoclave bonding with tars and pitches. In the carbonate bond process, the feed concentrate is mixed with 7% lime prior to balling; the green pellets are partially dried and hardened at 250 to 300°F in a CO_2 atmosphere under pressure. In the corrosion bonding method, iron chips and sodium chloride are added to the pellet feed which hardens as a result of corrosion products. Amongst these cold indurating processes, the Grancold process has found the maximum acceptance due to less capital costs and ability to be designed and fabricated locally under licence in the developing countries themselves such as in Brazil, India, etc.

In 1974 (30 years after the first reference to pelletizing was published in the USA), the actual pellet production reached 172 million tons/year. In 1964, the pellet production after the first decade of its active development rose to about 45 million tons i.e. about one fourth of the current production. The greatest growth in pelletization has occured during the last decade. Table 16 shows the pellet production in 1974.

Table 13
(1974) Production of Pellets

Ore (type)	Production	Percentage
Magnetite	101,430,000	59
Hematite	26,300,000	15.3
Magnetite and Hematite	18,600,000	10.8
Hematite and Limonite	7,850,000	4.5
Limonite	5,000,000	2.9
Ore mixture	12,850,000	7.5
Total	172,030,000	100

During 1974, the following plants came on stream:

(a) Pena Colorado (Mexico)
1.5 million tons of pellets/year for sponge production

(b) Tilden, Marquette Range, Michigan (USA)

4 million tons/year of pellets (grate kiln process) for iron smelting in the blast furnace

(c) Kirkenes (Norway)

Addition of 1.2 million tons/year of pellets capacity by the grate-kiln process.

(d) La Perla Mine (Mexico)

0.6 million tons/year of pellets for iron blast furnace (circular grate process).

(e) Hammersley (Australia)

3.1 million tons/year of pellets (grate process) for blast furnace iron production.

(f) Sumitomo Metals Industries (Japan)

Pellet plants for converting steel plant residues wastes and sludges for prereduction; the prereduced pellets will be charged into the blast furnace.

(g) Fukuyama, Nippon Kokan (Japan)

0.4 million tons/year pellets for prereduction using steel plant wastes and residues to provide the blast furnace feed.

(h) Krivoi Rog (USSR)

4.5 million tons/year of pellets for iron smelting in the blast furnace.

The current 172 million tons pellet production comprises - 52% in North America, 24.6% in Europe and the balance 23.4% in other parts of the world. USSR today leads Europe in pellet output of about 26 million tpy. USSR which had a belated start relative to other countries, in pellet production, will cross the 40 million tpy mark by 1976, 90 million tpy mark by 1980 and 161 million tpy by 1990[1]. Of the 1974's total pellet production, 53.6% were made on firing grates, 31.2% in grate kiln and 14.4 in shaft furnaces. Approximately 3.35 million tons of pellets were prereduced in 1974 (31.4% in stationary retors, 48.7% in shaft kilns and 19.9% in rotary kilns); [2] [3]

1/ Popov F.V. et al Metallurgicheskaya i Gornorudnaya Promyshlennost 1974, Nov. 5, p. 15-17

2/ Kalla U., Steffen R. Stahl and Eisen, Nov. 7, 1974, Vol. 94, No. 23 p.1109 - 1114

3/ Greenwalt R.B. Mining Eng. Feb. 1974, Vol. 26 pa. 69-70

Methods of evaluating pellet properties are being enlarged continuously, such as strength, reducibility, abrasion resistance (now being developed), tumbler test (a mini-tumbler test has been developed)1/. New abrasion tests and drop strength properties appear to be decisive in evaluating pellet performance during handling, transfers and transport. Mathematical modelling of pelletizing process and of firing of pellets is under investigation. Much research and development effort is being directed towards magnetic oxidation process for self-fluxing and unfluxed pellets.

Economic aspects of pelletizing

Capital costs for pelletizing plants and operational costs for pelletizing vary widely. During recent years these costs have more than doubled compared to the mid-sixties corresponding figures due to heavy escalations and inflation. Table No. 16 depicts the general trend of current pelletizing costsdata.

Table 14

Cost of Pelletizing (US$)

Serial No.	Cost elements	Unit	Rate	Consumption	Cost/ton pellet
I	1. Iron ore fines CIF	tonnes	18	1.14	20.52
	2. Bentonite	"	41	0.012	0.492
				Total materials	21.012
II	3. Labour and supervision				0.30
	4. Services				
	i) Natural gas	Km^3	0.0125	40	0.50
	ii) Power	KWH	0.0206	35	0.72
	iii) Others				0.28
			Total services	=	1.50
	5. Operating supplies				0.26
	6. Repair and Maintenance				0.50
	Total cost above material				2.56
III	Overheads				1.2
	Total cost of production excluding capital depreciation and interests				24.722

It must be pointed out that capital costs of pelletizing plants depend upon the economies of scale(inversely)and the cost of pelletizing itself will depend upon many factors, external and internal.

1/ Grebenkin G.A. et al, Metallurg, 1974, No. 10, p.10 - 12

Developments in developing and developed countries during 1976/77 in the field of pelletizing have been characterized by:

a) Increased production capacity at new and existing plants;
b) Application of solid fuel in the pelletizing process;
c) Increased applied research and development work concerning the technological processes and final properties of the pellets.

<u>Annexure "A"</u>

furnishes the relevant details of world's iron ore reserves/resources and the list of pelletizing plants including their technical details/parameters in the developing and developed countries.

<u>Annexure "B"</u>

presents the relevant details of direct reduction processes and sponge production in the developing and developed countries, including the world's sponge production plants in operation, planned and projected.

<u>Annexure "C"</u>

deals with the world's coal reserves/resources inter alia for the iron and steel industry.

III. THE IRON AND STEEL INDUSTRY IN AFRICAN AND ARAB COUNTRIES

The current per capita steel consumption in Africa is one of the lowest in the world estimated at 8 kg compared to 250 to 300 kg on an average in developed countries. The consumption of steel in Africa primarily relates to steel rods (RCC), bars, light merchant mill sections, wire rods, rails, plates and sheets. It is currently projected to rise at an annual rate of growth of 9-10%. This means that the total steel consumption in Africa will exceed 60 million tons by the year 2000. This, however, is considered to be a pessimistic projection as will be depicted later in this paper. The growth rate is relatively low for countries at an early stage of development but it is more than adequate for the establishment of iron and steel industry in each of the African countries and the sub-regions. Economies of scale should be taken into account; the production facilities should, therefore, be based on a sub-regional basis with phasing of projected steel industry's development. If this co-ordination materialises, the pace of development will rise and so will the steel consumption which may as a result rise to 3 times the above figure to give a total of 180 million tons by the year 2000. In some African countries, there are abundant reserves of high grade iron ores, oil and natural gas. Charcoal can be considered for iron smelting in countries which lack coal resources but possess good forests and forestry development programme. The annual capacity of operational iron and steel plants in African member countries of Organization of African Unity is now much less than two million tons; this capacity is expected to rise 15 million tons of steel by 1985. Compare this with the world picture around 1950, the total annual steel production in developing countries was less than three million tons; mid-fifties one often heard that the world's steel industry's capacity had reached saturation levels and that the developing countries could, therefore, import their entire steel requirements from the advanced steel producing countries and further that the developing countries should not enter into the highly capital intensive and the highly technological fields of the steel industry which was stated to be beyond their means financially and technically. However, by 1970, the annual steel production capacity of the developing countries attained a figure of 27 million tons. The phenomenal increase in world annual crude steel capacity from the World War II figure of 180 million tons and 200 million tons in the immediate post-War years to its present output exceeding 700 million tons annual production represents the gigantic growth of world iron and steel industry.

International developments in the iron and steel industry have been characterised by vigorous recovery in the post-War years in various countries and regions in the world. In some countries such as Japan, the growth rate of iron and steel industry has been so dynamic as to leave some of the other advanced countries such as the U.K. way behind in the race to produce steel and more steel. When a basic requirement, i.e. the indigenous availability of abundant and high grade raw materials, for the establishment and for the growth of the iron and steel industry is considered and when it is realised that Japan imports for its iron and steel industry practically all the raw materials such as high grade iron ore, coking coals, etc. one is struck with the almost unparalleled growth of the Japanese steel industry during the last decade or two; its reported steel production during 1973 has been about 120 million tonnes. In the USSR, steel production has more than doubled itself during the last decade and has been reported to be about 130 million tonnes during 1973. In the USA the annual crude steel production during 1973 has been reported to be 137.55 million tonnes.

What are the steel production figures for Africa? Extremely low, and the following figures for the whole of Africa speak for themselves:

Steel Production in Africa

x 1000 tons

	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Africa	3,269	3,493	3,503	3,926	4,312	5,116	5,346	5,533	6,064	6,405

Excluding South Africa and Rhodesia, the steel production figures for Africa are less than 1 million tons; 1973 and 1974 figures are 0.76 and 0.791 million tons respectively.

Future Projections

The following Table 6, gives a forecast made a few years back of the annual production capacity of raw steel for different regions of the world and their totals.

Raw steel annual production capacity forecast

Table 15

(millions of metric tons)

Regions	Forecasts 1975	Forecasts 1980
North America	163.2	186.0
South America	30.2	50.0
Western Europe	186.7	190.0
Eastern Europe	210.8	260.0
Africa	15.6	30.0
Asia	165.0[1]	242.0[2]
Mainland China	20.0	30.0
Oceania	9.5	12.0
World total	783.0	1,000.0

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[1] Including 150 million tons in Japan

[2] Including 200 million tons in Japan

Position of Africa Countries

The growth of Steel Consumption and local production in Africa during 1950-1972 at a compound rate (per cent per annum) has been estimated at 5.95 and 9.78 respectively. The percentage of regional steel consumption covered by regional production over 1950-1972 for Africa is derived to give a figure of 3 for 1950, 5 for 1960 and 1965, 8 for 1970 and 6 for 1972.

In terms of population, only five countries namely Ethiopia, Zaire, Gambia, Uganda and Tanzania have a population of more than ten million each; only two African countries have a steel consumption level of more than 100,000 tons and five African countries more than 50,000 tons per year. In Central Africa, only Zaire has a moderate steel consumption to justify a small scale steel plant based on local raw materials. Gabon's steel consumption currently is of the order of 80,000 tpy. Ethiopia with a population of 26 million has a large market for steel but hardly any production. Kenya is building up his industries and steel consumption is growing. Zambia with a population of 4.5 million has its northern part somewhat industrialised where copper industry is operating and its steel consumption is rising.

In West African countries, there is no steel production except small plants in Ghana and Nigeria that are scrap based with small merchant steel rolling mills. Steel consumption in Nigeria has currently been of the order of 650,000 tons/year followed by Ivory Coast with a steel consumption exceeding 100,000 tpy. In Nigeria, plans are under implementation for the establishment of an integrated iron and steel plant, using the Direct reduction sponge iron - electric arc furnace route. It would produce 0.5 million tons/year of sponge for export and 0.5 million tons of semis for home market; natural gas will be used for sponge making. This project will reportedly have the collaboration of C. Itoh (Japan) for marketing/financing and of Korf (FRG) for technology.

An agreement has recently been signed by the Government of Zaire and FINSIDER (Italy) for the latter's collaboration in the management of the Société Nationale de Siderurgie at Maliku during the first ten years of operation; this plant will have a capacity of 120,000 tons per year. In Egypt, identical developments are taking place at the present time.

The Egyptian General Organization for Metallurgical Industries (EGOMI) has prepared a comprehensive and long-range plan for the utilization of mineral resources for iron and steel industry in the Arab Republic of Egypt, aiming to meet the increasing demand for the iron and steel products during the period 1975 - 1985. The Helwan Steel complex, the only integrated steel plant in the country, is currently expanding its initial crude steel capacity of about 300,000 tpy to about 1.5 million tpy in two phases (each phase based on an addition of 0.6 million tpy capacity); this expansion is being carried out with Soviet technical assistance and is scheduled to be completed by 1977. Other units of the steel industry in ARE are based on the melting of steel scrap in electric arc furnaces and basic open hearth furnaces (all cold charge); these plants have captive merchant steel rolling mills and steel foundries. The total capacity of the non-integrated small plants, viz. Delta Steel, the Egyptian Copper Works and the National Metal Industries Co., is of the order of about 300,000 tpy of liquid steel.

Non-integrated small steel plants in Egypt using cold charges consisting of steel scrap/pig iron, are equipped with basic open hearth and electric arc furnaces. At the Delta Steel, alloy and tool steels are mainly produced whilst the other plants mainly produce plain carbon mild steels for rolling into rods (Reo), bars, etc. These non-integrated small steel plants comprise the following:

Table No. 16

Plant	Type of furnaces		Capacity tpy crude steel	Product
National Steel, Cairo	Open hearth,	2x35 tons	100,000	mild steel, Reo rods, bars
Copper Works, Alexandria	Open hearth,	2x30 tons 1x50 tons	100,000	-do-
	Electric Arc Furnaces,	1x25 tons 1x 5 tons		
Delta Steel, Cairo	Electric Arc Furnaces	1x25 tons 1x18 tons 1x12 tons 3x 3 tons	70,000	alloy and tool steels and plain carbon steels

Ghana has a small plant based on electric arc furnace. Ivory Coast has large reserves of low grade iron ore only.

In Liberia, the demand for iron and steel has risen sharply in recent years. In 1967, UNIDO had sponsored a detailed study of the iron and steel industry situation in Liberia; the latter has highly developed its iron ore mining and pelletising industries.

Crude steel production in some of the Afro-Arab countries is shown below (x1000 tons/y)

Table No. 17

	1970	1971	1972	1973	1974
Algeria	330	335	335	395	410
Tunisia	60	70	85	87	90
ARE	300	256	227	260	270
Total	690	661	647	742	770

(SOURCE: Statische Bundesamt, Düsseldorf)

Afro-Arab countries with a population exceeding 15 million, are: ARE, Morocco, Algeria and Sudan; total crude steel consumption in all these countries has been of the order of five million tons currently. Algeria is an agrarian country with good petroleum industry. Potential reserves of iron ore are also high and it has fully integrated steel plants in the country (El Hajdar) - plans are afoot to raise Algerian steel production to over ten million tons by 1980. Mauritania has good reserves of high grade iron ore but no steel industry.

Table 18 1/ Average Chemical Analysis of high grade lumpy iron ores/ concentrates/pellets of selected African countries

Lumpy ore	Fe	SiO_2	Al_2O_3	% CaO	P	S	Mn
Algeria	52.56	2-6	0.6-1.5	1.8	0.01- 0.03	-	0.2-1.6
Gabon	64.8	1.7	2.0	7.0	0.15	-	-
Liberia	65.8	2.5	1.0	-	0.05	0.005	-
Mauritania	65.0	4.3	1.2	0.2	0.03	0.01	0.12
High grade concentrate (ore fines)				%			
Liberia fines	65.1	4.5	1.24	-	0.09	0.10	-
Liberia fines concentrate	64.4	5.3	0.51	-	0.037	0.022	-
Mauritania fines	62.7	7.2	1.6	-	0.018	0.002	-
Pellets - high grade				%			MgO
Liberia	64.5	4.2	2.0	1.1	0.06	0.003	0.06
Morocco	65.5	2.6	1.2	0.8	0.006	0.008	0.07

1/ World Market for Iron Ores, UN New York, 1968 and Metal Bulletin 1969.

It will now be relevant to furnish some data concerning the capital and production costs of steel on an average basis under overall African conditions. Steel production costs through various process routes applicable to African conditions and raw materials are furnished in the following Tables assuming reasonable unit costs and norms; these will provide the general trends on the subject.

Average Chemical Analyses of Raw Materials (Per cent) Table19

%	Fe	SiC_2	Al_2O_3	CaO	MgO	S	F.C.	Ash
Iron ore pellets	65	2.4	1.5	-	-	-	-	-
Iron ore lumps	52	7.0	3.5	1.0	0.4	-	-	-
Blast furnace limestone	-	3.5	0.6	50.0	1.0	-	-	-
Dolomite	1.4	1.8	1.0	31.0	19.0	-	-	-
Coke	1.0	4.0	2.9	0.3	0.2	1.0	89	10

Table 20 - Unit Costs (Latest price US$ per ton)

Iron ore pellets	65% Fe	28
Iron ore lump	52% Fe	19
Iron ore fines	52% Fe	10
Manganese ore (high grade)		65
Limestone/dolomite		7
Fluorspar		120
Blast furnace coke		100
Nut coke		50
Fe Mn		450
Fe Si		400
Natural gas 10^6 Kcal		1.0
Power kWh		0.1

Table 21 - Estimates of production costs by different process routes (average approximations) 1/

	Direct Reduction HyL gaseous process and electric furnace			Sub-merged arc electric smelting of pig iron and LD oxygen steel-making		Blast furnace LD oxygen steel-making	
Liquid steel production x 1000 t/year	300	1,000	2,000	3000	600	1,000	2,000
Capital cost US$ per annual ton liquid steel capacity	100	85	80	150	135	119	109
Production cost US$/ton							
Sponge iron	39	37	35	-	-	-	-
Hot metal				78	77	70	68
Liquid steel	70	69	67	99	96	87	84
Fixed charges US$/ton 2/	10	8.5	8.0	15	14	11	10.0
Total cost of production of liquid steel - US$/ton	80	77.5	75	114	110	98	94

1/ These estimates do not relate to any particular African country but provide approximate averages which vary from one African country to the other.

2/ Fixed charges are based on the following:

- Interest on capital at 4.5% on 50% of the capital
- 5% depreciation
- Interest on working capital for three months production cost at 6.5%
- Total fixed charges are calculated adding 30% to the capital costs to cover infrastructure facilities (raw materials handling transport etc.)

Reserves of African Iron Ores [1] - Table 22

Fe % range	1 Proved reserves million tons	2 Potential reserves (unproved) million t	Total 1 + 2 million tons
30 - 67	6,800	24,500	31,300

Grades of Iron Ores in Selected African Countries - Table 23

Country	Reserves mill. tons	Fe%	SiO_2%	Al_2O_3%	Mn%	P%	S%	Others %
Mauritania	465	65.0	4-3	1.2	0.12	0.03	0.01	-
Morocco	149	60.0	-			0.05	1.5	14.6 BaO
		43.0	[illegible].6	1.2	2.3	0.01	-	2.2 CaO
		52.2	8	5.9	0.2	1.04	0.03	
Algeria	1,979	40.0-56	3.8	-	2.0	-	0.5	3.4 CaO + 1.0 MgO
		49 - 54	4.9	4.3	-	0.8	-	0.3 MgO + 0.3 Ti
Tunisia	75	54.0	4.0	0.8	2.1	0.03		0.5 CaO
		58.0	4.0	3.7	2.0	0.10		0.3 CaO
Libya	3,525	49.0	10.9	4.9	-	0.94	-	-
		50.5	7.05	4.6	-	1.03		
		51.75	6.15	4.9	-	0.92	-	-
Mali	432	46.9	14.10	NA	2 - 4.3	0.6-1.0	NA	
		49 - 59	2.6-9.1		NA	0.19-0.6		
		43	20 - 25	NA	NA	NA	NA	
Sudan	61	37 - 61	NA	NA	NA	NA	NA	NA

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[1] World Reserves of Iron Ores, United Nations, 1970

Table 24

Iron Ore Production and Fe Contents of Iron Ores of African countries

Country	Grade Fe	Production 1965	Production 1970	Production 1973	Fe Content 1965	Fe Content 1970	Fe Content 1973
ARE	50	508	454	325	254	227	163
Algeria	54	3,144	2,868	2,600	1,637	1,546	1,404
Angola	62	815	6,048	5,000	509	3,752	3,100
Guinea		755	-	-	378	-	-
Liberia	68	16,152	23,601	21,500	10,985	15,388	14,620
Morocco	56	951	872	300	567	522	207
Mauritania	65	5,964	9,108	9,400	3,875	5,923	6,016
Sierra Leone	60	2,148	2,292	2,400	1,286	1,377	1,440
Sudan	50	36	20	20	18	10	10
Swasiland	61	1,070	2,371	2,900	642	1,409	1,769
Tunisia	54	1,117	744	755	609	422	427
TOTAL		32,660	48,378	45,598	20,760	30,636	29,156

Source: Stahl und Eisen, No. 10, May 1974

Reserves of Coal in Africa[1/]

There are no deposits of coking coal in African countries represented on OAU. The resources of anthracite through sub-bituminous coal in these countries are of the order of 7,000 million net tons including 1,500 million net tons in Swasiland.

Table 25 -

Reserves of non-coking coal in Africa, in million tons

Country	Non-bituminous	Anthracite	Lignite
Swasiland	5,022		
Algeria	20		
Nigeria	350		
Zaire	73		
Morocco	68	28	
Mozambique	700		
Tunisia			20
Zambia	115		

Source: Statistical Yearbook, United Nations 1973

[1/] Survey of Energy Resources - World Power Congress 1968

Table 26 -

Oil and gas resources of Africa[1] - 1973

Country	Oil million cu m	Gas billion cu m
Algeria	7,550.00	2,960.00
Angola (incl. Cabinda)	192.00	28.40
Congo (Bras.)	800.00	
Dahomey	832.00	213.00
ARE	100.00	
Gabon	176.00	198.00
Libya	4,864.00	781.00
Morocco	160.00	40.00
Nigeria	2,400.00	1,136.00
Tunisia	160.00	28.40
Zaire	80.00	
TOTAL	17,314.00	5,384.80

As on 1 January 1974, Africa's (Algeria, Angola, Congo, ARE, Gabon, Libya, Morocco, Nigeria, Tunisia and Zaire) crude oil and natural gas reserves have been estimated at 10,701.34 million cu m and 5,315.59 billion cu m, respectively.

Table 27 -

Estimates of natural gas flared in some African countries[2] - billion m^3

Country	1965			1975 (estimates)		
	Produced	Quantity flared	Proport. flared	Produced	Quantity flared	Proport. flared
Algeria	3.97	2.10	53 %	11.33	2.27	20 %
Libya	8.61	8.61	100 %	17.85	12.24	70 %
ARE	0.31	0.25	84 %	2.83	1.42	50 %

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[1] Oil Statistics - Government of India, Jan - March 1973, Petroleum Information Service, New Delhi

[2] Development and utilisation of natural gas resources and their vital role in accelerating economic development by Abdel Dayem A. El-Sani, Planning and Development Adviser, Kuwait

IV. Recommendations for Action for the development of the iron and steel industry in African and Arab countries

In making recommendations for the development of the iron and steel industry in African Countries one is of course, conscious of the fact that such recommendations cannot be regarded as all embracing in absolute terms. The endeavour is to focus attention on some of the problems and factors that are of critical value for the development of the iron and steel industry and seek to find pragmatic ways to tackle them. UNIDO will endeavour to assist the African countries in promoting the growth of their iron and steel industry albeit within its technical assistance programme and the means at its disposal which are not unlimited.

However, it is to be stressed that UNIDO can seek to promote and catalyse the implementation of these recommendations only at the request of the Government(s) concerned through appropriate technical assistance programme.

a) The establishment and growth of the steel industry are based on a complex network of project activities; some of the latter must precede the actual establishment of the steel industry, others have to be undertaken concurrently with the installation of the industrial plant and some perforce follow the commissioning and operation of the steel plant itself.

Thus techno-economic feasibility studies must precede the establishment of the steel industry; these studies comprise a vast spectrum covering inter alia the evaluation of raw materials and energy resources, technological process routes and choice of appropriate technology, plant layout and services, market demands and choice of product-mix, capital and production costs and financing of the industry, technical trained manpower and efficient business management, steel plant maintenance and infrastructure, etc. All such studies must be undertaken in advance of the establishment of the iron and steel industry such as at a green field site.

The steel plant's installation requires another set of co-ordinated activities concerning inter alia civil works and foundations, structural work and foundations, structural work and assembly, provision of utilities and services, commissioning of the plant units and operational trials.

The steel industry's practical operations themselves call for another set of well planned and co-ordinated activities covering the actual production of iron and steel and the product-mix based on maximum capacity utilisation and adherence to optimum production norms and operational costs.

In all those fields comprehensive planning and planned action are essential to maintain a chain of inter-related activities in order to get co-ordinated results. The African countries, like any other country, developed or developing, have to plan for the steel industry and its growth to optimum targets and endeavour to link the steel industry to overall economic development of the country; the objectives being to make the fullest possible use of the natural resources and talents.

b) In preparing the economic development plans, including those for the iron and steel industry, the need will inevitably arise to formulate the overall strategy for the growth of the iron and steel industry, and prepare a Master/National Plan for the iron and steel industry in the individual countries and regionally co-ordinate these Master plans as pragmatically as possible.

This then is a basic recommendation to the African world in which UNIDO can play an expanding and increasingly useful role.

c) In the wake of long term planning and preparation of Master Plans of the steel industry, the need to develop technical consultancy services and establish a base for indigenous technical designs and project engineering services, will be felt for the iron and steel industry and this will, of course, be a long term strategy to be recommended to the African world and UNIDO will be ready to catalyse and promote its formulation.

The technical consultancy organisation for the iron and steel industry will *inter alia* provide the following services to the latter:

a) Pre-feasibility and Feasibility surveys and reports;
b) Techno-economic project evaluation;
c) Detailed project reports and engineering;
d) Plant and equipment specifications;
e) Detailed layout, utilities and services;
f) Materials balance and cost analyses;
g) Capital costs and investment potentials;
h) Production cost analyses and profitability;
i) Market studies and demand projections;
j) Mode of financing and methodology of project implementation;
k) Civil works and foundation analyses;
l) Installation of plant and services;
m) Commissioning and plant running;
n) Overall plant operations and unit production including ancillary services;
o) Training services and expatriate expert services.

The Technical Consultancy Services will provide comprehensive services in the above fields for the iron and steel industry from a green field site to full operations of the steel plant, covering the entire gambit of technical self-sufficiency.

d) The strategy for steel development would also entail the evaluation of schemes to maximum the socio-economic benefits of the steel industry; in other words social cost analysis is recommended to be studied in order to convince the steel industry's critics who continue to maintain that the steel industry is too highly capital intensive and uneconomic for developing countries to project and further that the developing countries can buy all the steel in the world markets; but at what cost and at whose cost - these questions are mostly ignored. It is therefore recommended:

i) That the economic appraisal of the steel industry in the African countries (and developing countries) should not be undertaken in isolation or on absolute terms but on a national basis; the steel industry providing the basic raw materials (steel sections, profiles, rods, bars, plates, sheets, structurals to name a few) for the light, medium and heavy engineering industries (transport - rail, road and shipping, consumer products, bridges and buildings, tools and machines) and so on. Apart from providing a main sinew for industrial development, the economic growth of the country is promoted through the training of technical manpower, technicians and skilled workers and of business managers. True, the quantitative measure of such benefits can be only qualitatively measured and assessed nevertheless. There now exists appropriate methodology to undertake social cost analysis and benefits of the steel industry and project them quantitatively to discerning planners and investors.

e) It is also <u>recommended</u> that studies on the sectoral steel demand on a national and regional market basis should be sponsored for African countries (OAU). These studies will provide to the planners with the category-wise steel demand, based on the steel consumer industries. The value of these studies on national and regional basis is important to the African steel industry as a whole; more so, in view of the diversity of steel product-mix and the category-wise demand of steel in individual countries. The iron and steel in individual countries may be inhibited by the limited domestic markets and therefore, the possibilities of developing sub-regional markets and co-operation should be pragmatically studied in order to counteract the effects of the national market constraints.

f) It is also <u>recommended</u> that co-operation amongst African countries (OAU) should be examined and promoted in the following specific areas:

i) - <u>Interchange and supply of raw materials</u>

African countries (OAU) should take steps to promote the inter-change of raw materials (high grade iron ores/pellets), directly reduced sponge iron, etc. on a mutually advantageous basis. For example, high grade pellets from Morocco (RIF Mines in North Morocco) could be exported to Alexandria in ARE; the latter could from its projected DR sponge plant, export highly metallised sponge to Morocco for its new steel plant's electric arc furnaces. Identical bi-and multilateral exchange of raw materials, sponge and steel is strongly advocated amongst African countries of OAU.

ii) - Interchange of metallurgical know-how, expertise and consultancy services amongst African Countries

A developing country within or outside Africa which has attained high standard metallurgical expertise, technical know-how and consultancy services could assist another developing country lacking such specialisation. This type of interchange can be promoted through government or private action.

iii) - Interchange of steel plant and equipment manufactured indigenously

A developing country within Africa or outside which has set up technical design and manufacturing facilities for the fabrication of iron and steel plant equipment and machinery can supply them to another developing country lacking corresponding design and manufacturing capabilities; such exchanges can be promoted through bi- and multilateral trade in raw materials, fuels, finished steel products or semis, on mutually beneficial terms.

iv) - Interchange of trained manpower and business management

Some developing countries have achieved high standard business management and executives and have trained personnel (operational and administrative) for the iron and steel industry. They can assist other African developing countries in training of plant managers and executives, steel plant operators, skilled workers, technicians and trouble shooters at various levels. Foremen, superintendents, supervisors, etc. are being trained in some developing countries. Additionally, the provision of such short or long term expatriate staff and trained personnel can be mutually arranged amongst the developing countries through mutually acceptable terms.

v) - Interchange of capital investment, equity partnership and sharing of financial resources amongst African countries

Developing countries relatively well endowed with capital resources including foreign exchange while lacking raw materials could assist others in Africa through joint capital investment, equity participations and formulation of joint Consortia; long term loans and bilateral financial aid may also be arranged.

vi) - Interchange of trade and complementarity of production

Developing countries in Africa can establish mutually beneficial interchange of trade in finished steel end-products and semis (billets, blooms and even steel ingots, etc.) and market arrangements, so that complementarity of their efforts may lead to mutual gain.

On the basis of the above guidelines it is recommended that specific project studies should be sponsored for technical co-operation and assistance amongst developing countries themselves. Plans for bilateral and multilateral iron and steel industry development based on technical co-operation and assistance amongst African countries themselves should be promoted.

g) Production of sponge iron using high grade iron ores/pellets and natural gas

Several African countries such as Nigeria, Algeria, Gabon amongst others have good resources of natural gas and have also fairly good reserves of iron ores. It is strongly recommended that industrial scale production of highly metallized sponge should be taken up in African countries based on proved gaseous DR processes (HYL, Midrex, etc.). It is necessary to pelletize the iron ore fines with or without prior beneficiation as appropriate and set up pelletizing plants; the high grade pellets will provide the feed to the DR sponge plants and also an added value product for export. It is recommended that a Master Plan should be prepared for the African countries for the establishment of sponge iron plants in African countries based on the use of high grade African iron ore fines pellets and natural gas resources. The highly metallised sponge could be exported with advantage outside Africa as also mutually traded amongst the African countries themselves on barter or cash basis. UNIDO can assist in the preparation of the Regional Sponge Master Plan for Africa.

h) Production of alloy, tool, special and stainless steels in African countries

The ratio of alloy, tool, special and stainless steel output to that of mild and plain carbon steels is normally between 5 - 15%. In African countries (OAU) there is practically no production of alloy, tool, special and stainless steels except in the ARE in a small way. It is highly important to plan the production of alloy steels on a national and regional co-ordinated basis. National and regional Master Plans should be prepared for the production of alloy, tool, special and stainless steels in the African countries (OAU); UNIDO can promote the preparation of such Master Plan on request by the countries concerned under their respective Country Programmes for UN technical assistance.

i) The production of ferro-alloys and steel plant Refractories in African countries

There is very little production of ferro-alloys and steel plant refractories in African countries (OAU). It is strongly recommended that techno-economic feasibility studies should be undertaken with UNIDO assistance for the production of ferro-alloys and steel plant refractories in African countries (OAU); these projects are of direct and indirect value to the iron and steel industry irrespective of the latter's establishment on a national or regional basis. The production of ferro-alloys should cover ferro-manganese (different grades), ferro-silicon, ferro-chrome (different grades of high and low carbon ferro-chrome), ferro-vanadium, etc; the steel plant refractories should include acid, basic and neutral refractories, e.g. high silica bricks, magnetite and dolomitic refractories, chrome-magnesite and carbon blocks, etc. A beginning has to be made in these fields.

j) Iron and steel industry documentation and statistical data for African countries

The importance of documentation, dissemination and cataleguing of technical information and data pertaining to iron and steel industry and technology is obvious; however, statistical data concerning iron and steel industry in African countries are not readily and fully available. A good start has been made by Arab Iron and Steel Union and IDCAS (Industrial Development Centre of Arab States). A centralized technical data bank for the African countries (OAU) will be most useful to the latter.

k) Standardization of steel products in African countries

It is never too early or late to study the standardisation of multiple grades of plain carbon and mild steels as also of alloy, tool, special and stainless steels. Unified and mutually accepted standards (standard specifications) will greatly facilitate mutual co-operation and trade amongst African countries (OAU). The current practice is to apply standards and relevant specifications as formulated in developed countries (ASTM, BSS, etc.) in African countries. Whilst this may appear inevitable, sooner or later, African standards have to be prepared, accepted and applied in practice. It is strongly recommended that action in these fields should be initiated and UNIDO can assist in undertaking such work on request of the countries concerned.

l) Manpower and training of steel industry personnel for African countries

The training of personnel, skilled workers and technicians, foremen at operational levels and of business management executives and managers, it is strongly recommended, should receive concerted attention of African countries (OAU). This subject is of short term and long range importance. Very little appears to have been done in these fields except possibly on an ad-hoc manner in a few African countries. A review is also recommended of the educational and vocational training facilities in African countries (OAU) with a view to identify the capacity, future potential and types of technical educational facilities available in African countries. The need to do so is urgent.

It is emphasized that in the above technological training and industrial fields relating to the iron and steel industry, the process of study, survey and examination is self generating giving rise to fresh issues, connected with the continuous growth and expansion of the iron and steel industry. An open mind will need to be kept on new issues and dimensions in order to rationally study the individual factors and needs of developing African countries and coordinate them on a regional platform. The importance and value of such national and regional studies and surveys of basic issues and plans cannot, therefore, be over-emphasized.

In conclusion, it is stressed that dogmatic approaches should be avoided in the establishment of the iron and steel industry in developing countries. Whilst the applications of the latest technological innovations, automation and computerised operations in developing countries are rightful ambitions and objectives, nonetheless the applications of fully appropriate technology should be encouraged depending upon the conditions and environment in each case and country. To illustrate this subject, it is recommended that the use of charcoal for iron smelting in relatively small blast furnaces (less than 200 tpd capacity) should be fully supported in developing countries which have a good forest wealth and forestation programme. In a fast developing country like Brasil, for instance, some three million tons of pig iron is smelted in small blast furnaces using charcoal as the reductant and for heat input. In western Australia, at Wundowie, an iron smelting blast furnace complex using charcoal is in profitable operations for the last two decades. In another fast developing country, India, in the Mysore Iron and Steel Works at Bhadravati, charcoal blast furnace operations have advantageously been carried out for years. In Malaysia, at theplant of Malayawata steel, iron smelting has been successfully in operation for the last several years using charcoal made from rubber wood.

In concluding, therefore, it is recommended that African countries, having good forest wealth and forestation programme, should fully study the possibilities of using charcoal for iron smelting in small blast furnaces. These are pertinent fields of appropriate technology for applications in developing countries. One cannot claim the last words to have been said on these subjects; nevertheless, the subject is pregnant with interesting possibilities which the developing countries should examine on their own merits and the United Nations Industrial Development Organisation is at their disposal to assist them in doing so. Some of the areas in which coordinated action will be required by the African countries are the following:

i) Raw materials development
ii) Economic evaluation and strategy for development
iii) Infrastructure and manpower
iv) Market studies and projections including statistical data (home and export markets)
v) Techno-economic feasibility studies including site selection studies
vi) Detailed project reports covering project engineering

In planning, projection and installation, and operation of the steel industry not only massive capital investments are required but also equally massive efforts for the achievement of technological self-sufficiency promoted albeit by external technical assistance.

The above data on the raw materials have been furnished to highlight the resources of selected African countries which can be utilized by them for the development of their iron and steel industry.

Future Projections and Estimates of Steel Production in African Countries

Having furnished the basic data concerning raw materials and natural resources, let us attempt to project the future steel capacities of some of the African countries as realistically as possible;

The Recommended Projections for Future Steel Developments for African and Arab Countries

The attached comprehensive tabulations are self explanatory. They provide the projections for ingot steel production in African and most Arab countries for the years 1980, 1985 and 2000. The ingot steel production figures for the years 1973 and onward are also furnished along with per capita production and consumption figures for these two years. The raw materials resources covering iron ore, coal, oil and gas are also tabulated. The population figures for the African and most Arab countries in 1972/73 and their growth over the years 1985 and 2000 have been projected. The general perspective and prospects for the iron and steel industry by the year 2000 have been furnished in the appropriate columns. These data have been projected as realistically as possible. However, these recommended projections are not strictly speaking forecasts but hopefully what could possibly be achieved through maximum coordinated efforts of the developing countries and developed countries catalyzed by the promotion roles of the United Nations agencies including United Nations Industrial Development Organization.

Table No. 28

IRON AND STEEL INDUSTRY IN AFRICA [1]

No.	Countries	Population, years, rounded off figures x 1000: [illegible]	[illegible] UN	[illegible] MIS	Critical Raw Materials [3]: Iron ores, Reserves million tons	Percentage (Averages): Fe	Si	Mn	Others	Remarks	Coal [2]: Reserves million tons	[illegible]
1.	Nigeria	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	non bituminous
[illegible]	[illegible]	[illegible]	[illegible],500	[illegible]	[illegible]	36	[illegible]	[illegible]				
[illegible]	Ethiopia	[illegible]	[illegible],800	[illegible]		[illegible]	[illegible]	[illegible]				
[illegible]	Zaire	[illegible]	[illegible],800	34,000	[illegible]	[illegible] to [illegible]	[illegible]	[illegible]			[illegible]	[illegible] bituminous
[illegible]	Sudan	[illegible]	[illegible]	40,000	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	non bituminous anthracite
[illegible]	Morocco	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		1[illegible] Bao	[illegible]	
7.	Algeria	14,[illegible]	4,[illegible]	38,[illegible]	1,[illegible]	[illegible]	4.[illegible]	[illegible]	[illegible] Bao + [illegible] [illegible] + [illegible]		[illegible]	non bituminous
8.	Tanzania	14,[illegible]	[illegible],000	[illegible],000	1.[illegible]	[illegible]		up to 11	Ti [illegible]			
[illegible]	Kenya	[illegible]	18,[illegible]	[illegible]	[illegible]	[illegible]						
[illegible]	Uganda	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	1.1	[illegible]	Ti [illegible]-20			
11.	Ghana	[illegible]	[illegible]	[illegible]	425	[illegible]	[illegible]	1.[illegible]				
[illegible]	Mozambique	[illegible]	1[illegible],900	14,000	[illegible]61	[illegible] to [illegible]	1 to 4	.05			[illegible]	non bituminous
[illegible]	Malagasy Rep.	[illegible],400	1[illegible],800	1[illegible]	[illegible]	to 46	1	.1[illegible]				
[illegible]	Cameron	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]		[illegible]				
15.	Angola	5,[illegible]	8,100	1[illegible],000	1100	[illegible]	[illegible]	[illegible]	-1.0			
[illegible]	Upper Volta	5,600	7,700	[illegible]	[illegible]	[illegible]8	[illegible]	[illegible]	[illegible]	7-0.33		
17.	Ivory Coast	5,400	[illegible],5[illegible]	[illegible]	,400	[illegible]	[illegible]	[illegible]				
[illegible]	Tunisia	5,[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		Bao Bao		
[illegible]	Mali	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]						
[illegible]	Guinea	[illegible]	[illegible]	[illegible]	1544	[illegible]	[illegible]24	[illegible]				
[illegible]	Malawi	4,700	6,800	10,000								
[illegible]	Zambia	4,500	7,000	10,000	[illegible]	[illegible]	[illegible]	1.1			[illegible]	bituminous
[illegible]	Niger	4,300	6,200	9,500	680							
[illegible]	Senegal	4,[illegible]	[illegible]	1[illegible],000	100			[illegible]				
[illegible]	Rwanda	4,[illegible]	5,700	[illegible],800								
[illegible]	Chad	3,800	5,500	[illegible],000								
[illegible]	Burundi	3,[illegible]	5,300	8,300								
[illegible]	Somalia	3,000	4,300	6,500	170	[illegible]						
[illegible]	Dohomey	2,800	4,100	5,[illegible]	[illegible]	[illegible]50	[illegible]	[illegible]				
[illegible]	Sierra Leone	2,700	3,800	5,800	200	[illegible]	[illegible]16 [illegible]-13	[illegible]				
31.	Libya	[illegible],000	3,100	5,000	[illegible]	[illegible]	[illegible]	1.[illegible]				
32.	Togo	2,000	2,800	4,300	64[illegible]	[illegible]	[illegible]	[illegible]				
[illegible]	Central African Rep.	1,700	[illegible],100	3,[illegible]00								
[illegible]	Liberia	1,600	1,800	2,200	[illegible]	[illegible]	1.[illegible]	0.12				
[illegible]	Mauritania	1,200	1,700	[illegible],500	46[illegible]	[illegible]	4.[illegible]	[illegible]				
[illegible]	Congo Braz.	[illegible],200	1,350	1,600	[illegible]	4[illegible]	[illegible]					
[illegible]	Spanish Sahara	-	56	65	1[illegible]	[illegible]			Ti-14			
[illegible]	Gabon	[illegible]	[illegible]	800	1,1[illegible]	[illegible]	1.7	[illegible]	Bao [illegible]		[illegible]	non bituminous
[illegible]	Swaziland	4[illegible]	[illegible]80	[illegible]	[illegible]	61	4.[illegible]	[illegible] to [illegible]				
[illegible]	Gambria	380	514	750								
	Others	[illegible],200	3,500	5,[illegible]	600							
	TOTALS	347,[illegible]	[illegible]	[illegible]								

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[1] Excluding South Africa and Rhodesia

[2] There are no coking coal reserves in these African countries (excluding South Africa and Rhodesia) Resources of anthracite to sub-bituminous coals are [illegible] tons

[3] Total reserves of iron ores in Africa (30-67% Fe, proved = 6,800 m tons, Potential unproved reserves iron ores = [illegible] m tons; total = [illegible] m tons

[4] All Metric Tons

SECTION 1

[illegible]	[illegible]	[illegible] steel [illegible] x million t [illegible]		per year	Raw Materials					
		[illegible]			Poor (P)	Fair (F)		[illegible]	[illegible]	
	[illegible]	[illegible]	1936	[illegible]	Iron Ores	Coal Coking	Coal Non Coking	Charcoal	[illegible]	[illegible]
			1.		F		F			
				1.	F					
								F		
							F			
					F			F		
					F			F		
					F		F			
					F					
					P				P	P
					P					
			0.4	1.						
					F					
					F					
					F					
					F					
					P					
					P					
					P					
4,864	781		2.0	5.						
			0.5							
			1.		G					
			0.5	1.						
			.3	.4						
882 [illegible]5kg p.c.	915	[illegible] kg [illegible]	[illegible] kg p.c.	[illegible] 90 [illegible] 115 kg p.c.						

[illegible] bituminous coals are [illegible] m tons

[illegible] m tons

SECTION 2

Present Status [illegible]				Prospective Iron and Steel Industry in the Year 2000				Remarks
Poor P	Fair F	[illegible]	Excellent E	Poor (P)	Fair (F)	Good (G)	Excellent (E)	General Analyses based on resources (men and materials) for the Iron and Steel Industry: A to G represents the status of the Steel Industry of African Countries
						G		(G) Iron and steel industry will be expanded to make Nigeria **a leading steel production in Africa.**
	F					G		(G) Iron and steel industry is being expanded and ~~SRF~~ will be **a leading steel producer in Africa**
				P				Needs a small iron and steel industry
					F			" " " " " "
					F			
								Iron and steel industry needs top priority
						G		(F) Morocco should have a **medium** sized steel industry in Africa.
						G		(G) Iron and steel industry's expansion is being given a top priority and Algeria will lead the African countries in **steel production.**
					F			
					F			
				P				
				P				
				P				
				P				
P				P				
				P				
				P				
				P				**Tunisia will have a medium size steel industry in Africa**
				P				
				P				
				P				
				P				
				P				
					F			
				P				
				P				
					F			
				P				
				P				
				P				
								Iron and steel industry needs top priority. Libya will be a leading steel producer in Africa.
				P				
				P				
					F			Liberia will have a medium size steel industry amongst the **African countries.**
				P				
				P				
					F			
				P				
				P				

SECTION 3

Table No. 29

IRON AND STEEL INDUSTRY IN THE ARAB COUNTRIES

CRITICAL RAW MATERIALS

No.	Country	Population in million			IRON ORES									COAL	
					Reserves in million tonnes	PERCENTAGE							Ore Type	Reserves in million tonnes (proved in truck)	Qualit
		1975	1985	2000		Fe	SiO_2	Al_2O_3	Mn	S	P	Others			
1.	Algeria	16.8	23.5	36.7	1500 (586)	40 to 56	5 to 12	0.4 to 4.5	1.0 to 3.5	0.0[illegible] to 0.[illegible]	0.01 to 0.5	CaO 0.5/2.6 MgO 0.2/2.3	H/S/O/M	20 (9)	Non-bitumin
2.	Bahrain	0.26													
3.	Egypt	37.5	47.2	64.6	433	43 to 49	2.6 to 14		2.0 to 4.5	0.35 to 0.84	0.2 to 0.6	Al_2O_3 + CaO + MgO 3.1 to 4.4	H/O	25	
4.	Iraq	11.1	15.6	24.4											
5.	Jordan	2.68													
6.	Kuwait	1.1	1.8	3.2											
7.	Lebanon	2.87													
8.	Libyan Arab Republic	2.3	3.1	4.7	3524	29 to 50	16 to 46	4 to 5.5		0.[illegible] to 0.35	0.36 to 0.39		H		
9.	Mauritania	1.3	1.7	2.5	465	52 to 65	4.3 to 8.0	1.0 to 1.5	0.12 to 0.15	0.01	0.03 to 0.13	CaO 0.2	H/O/M		
10.	Morocco	17.5	23.8	35.9	149	43 to 60	7.0 to 10	1.0 to 6.0	0.2 to 2.3	0.03 to [illegible]	0.01 to 1.1	CaO 2.2 BaO 14.6	R/M/S/O/P/O	68 25	Non-bitumi anthracite
11.	Oman	0.77													
12.	Qatar	0.09													
13.	Saudi Arab Republic	9.0	12.1	18.6	403	35 to 65	2.2 to 18	3 to 8.4	0.1 to 0.6	0.02 to 0.4	0.16 to 0.6	TiO_2 0.1 to To 1.7	H/M		
14.	Sudan	18.3	25.1	39.0	61	37 to 61							H/M/O		
15.	Syrian Arab Republic	7.3	10.1	15.8											
16.	Tunisia	5.85	7.5	10.9	75	54 to 58	4	0.8 to 3.7	2		0.03 to 0.1	CaO 0.3 to 0.5	H/S/O	20	Lignite
17.	United Arab Emirates	0.23													
18.	Yemen Arab Republic	6.7													
19.	Yemen Democratic Republic	1.17													

Iron Ores

H = Hematite
M = Magnetite
O = Goethite
S = Siderite
P = Pyrite
O = Ochre

Summary

a) The population of the Arab world by the year 2000 may be from [illegible] - 230 millions.

b) Arab World's steel production by the year 2000 may be from [illegible] - 20 million tons and that 65 - 75% of it could be via the sponge iron electric arc steel making route and the product mix may be of the ratio of 50: [illegible] for the flat products and non-flat products; the ratio could however differ depending upon the national and regional market conditions.

c) Necessary machinery and equipment for the above steel projected growth may be of the order of 6 million tons.

d) Necessary structural work (shops, bays, etc.) for the above steel projected growth may be of the order of 3 million tons.

SECTION 1

[illegible] COUNTRIES

RAW MATERIALS									CRUDE STEEL				
ORES					COAL		OIL	GAS	1976			1985	
[illegible]	S	P	Others	Ore Type	Reserves in million tonnes (proved in brack)	Quality	in million tonnes	in billion m^3	Production million t	Production per capita kg	Consumption per capita kg	Production million t	Production per capita kg
[illegible]	.02 to .5	0.01 to 0.5	CaO 0.5/2.6 MgO 0.2/2.3	H/S/G/M	20 (9)	Non-bituminous	1158	2960	0.45	26	51	6.0	272
							34	51					
[illegible] to 4.[illegible]	.35 to .84	0.2 to 0.6	Al_2O_3 + CaO + MgO 3.1 to 4.4	H/G	25		386	142	0.40	11	27	5.3	112
							4724	778				2.4	153
							10469	1080					
	0.22 to 0.35	0.26 to 0.39		H			4864	800				2.0	644
0.12 to 0.15	0.01	0.03 to 0.13	CaO 0.2	H/G/M								1.0	572
[illegible] to 2.3	.03 to .5	0.01 to 1.1	CaO 2.2 BaO 14.6	H/M/S/G/P/O	68 25	Non-bituminous anthracite	160	40	0.0005	0		1.0	42
							450	68					
							720	221				2	
0.1 to 0.6	0.02 to 0.4	0.16 to 0.6	TiO_2 0.1 to To 1.7	H/M			14,780	1726				3.0	
				H/M/G									
							402	76				0.2	
[illegible]		0.03 to 0.1	CaO 0.3 to 0.5	H/S/G	20	Lignite	69	82	0.15	27		1.15	
							3397	768				3.0	

[illegible] may be from 260 - 280 millions.
[illegible] from 60 - 70 million tons
[illegible] electric arc steel making
[illegible] for the flat products
[illegible] ffer depending upon the

[illegible] ve steel projected growth may be

[illegible] for the above steel projected
tons.

SECTION 2

INDUSTRY IN ARAB COUNTRIES

DE STEEL

	1976		1985		2000			
n t	Production per capita kg	Consumption per capita kg	Production million t	Production per capita kg	Production million t	Production per capita kg	GDP per capita US$	Remarks
	26	51	6.0	272	15	408	477 (73)	A 1.2 mty sponge iron plant using gas is expected at Tindouf between 1981 - 1985
							935 (73)	
	11	27	5.3	112	15	231	260 (73)	A 0-mty gas based sponge iron plant at Dakbella expected between 1981 - 1985
			2,4	153	10	410	645 (73)	
							358 (74)	
							11,852 (74)	A 0-mty gas based sponge iron plant at Shuaiba expected between 1981 - 1985
							874 (73)	
			2.0	644	5.0	154	5,236 (74)	A 0-mty gas based sponge iron plant at Misurata expected between 1981 - 1985
			1.0	572	2.0	800	232 (73)	A 0-6 mty gas based sponge iron plant is expected
	0		1.0	42	2.0	55	362 (74)	1 pellet plant using more in 1972 of 0.85 m.t.y. at Sheferif Nador and a 0.4 mty gas based sponge iron plant
							492 (73)	
			2				5,938 (73)	A 0.4 mty sponge iron plant by Midrex process expected by 1977 (Midrex)
			3.0				3,237 (73)	A 2.4 mty gas based sponge iron plant expected between 1981 - 1985
							154 (73)	
			0.2				546 (74)	
	27		1.15				626 (74)	A gas based sponge iron plant of 0.8 mty capacity at Gabes expected by 1981 - 1985
			3.0				6,736 (73)	
							129 (73)	
							110 (73)	

SECTION 3

V. Foreign exchange savings[1] resulting from the establishment of domestic steel capacity in developing countries

The installation of iron and steel-making capacities by developing countries will yield some foreign exchange savings as locally produced iron and steel products are substituted for imports of similar goods. However, the savings are not automatic, particularly during the initial start-up and "learning" period, nor are they "one for one" in that the value of an item formerly imported is a measure of the foreign exchange saved. The amount of capital costs to be borne in foreign currency terms is an important variable that must be taken into consideration in any foreign exchange saving equation. These costs are a function of the degree of industrialization in the developing country in question. Thus, initially the foreign exchange component of the total expenditures will be very high, as most machinery and other items have to be imported. Once industrialization is well under way, however, the proportion of equipment that can be produced locally will rise.

In computing foreign exchange benefits, it is not unrealistic to assume that most developing countries which have developed, or are planning to develop, a steel industry possess iron ore and pay the greater part of their wage bills in domestic currency, consequently, these costs are not considered here. As far as other materials are concerned, however, almost any combination is possible, ranging from almost total self-sufficiency in, to heavy dependence on imports of such inputs as coke, coal, oil, limestone, gas, and hydro-electric power.

Table 31 sets out the foreign exchange benefits accruing from steel production in a blast furnace/basic oxygen system plant as computed for four "typical" cases, although a wider range of possibilities does exist. As can be seen, savings range from $161 to $196 per ton, depending on the various assumptions used. The foreign exchange benefits are likely to be much the same with the direct reduction/electric furnace technology.

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[1] Computed by UNCTAD, mid-1977

Table 30

Savings in foreign exchange from steel production*/

Case	Percentage of cost borne in foreign exchange		Foreign exchange cost in producing steel	Gross foreign exchange saving	Net foreign exchange saving
	Capital	Operating	(dollars per ton)	(dollars per ton)	(dollars per ton)
A	70	30	100	261	161
B	50	30	81	261	180
C	70	15	84	261	177
D	50	15	65	261	196

Source: UNCTAD secretariat estimates.

*/ Maximum capacity working and operating efficiency assumed throughout. These figures are derived from the following estimates of the costs and benefits of operating a five million tons per year integrated blast furnace/basic oxygen system plant: capital costs $639; production costs $206 (operating costs $110 *plus* capital costs $96); for a final cost per ton of $261. The figures include an allowance for scrap losses and credits. A capital charge of 15 per cent has been used, reflecting both interest and depreciation. For the purposes of these calculations, it is assumed that the cost of imported equipment is reflected in the proportion of the financing of any loan that has to be paid in foreign currency. For example, in case A, 70 per cent of the capital costs of $96 equalling $67.20 plus 30 per cent of the operating costs of $110 equalling $33 provide the $100 foreign exchange costs of producing a ton of steel. This figure subtracted from the assumed cost of a ton of imported steel of $261 yields the net foreign exchange savings of $161 per ton.

VI. Some examples of experience in the field of co-operation amongst developing countries and between developing and developed countries

The examples of co-operation given here correspond to actual co-operation, through participation and assistance as distinguished from business arrangements for the sale of equipment or services. They have been drawn from recent editions of technical journals and from the press and should not be regarded as exhaustive or fully up-to-date. Furthermore, since such co-operative efforts are subject to changes and modifications depending on the industrial policies of the countries and decisions of the Governments involved, the examples are meant merely to be indicative of the type of co-operation now being implemented or discussed.

Brazil

The CVRD - Cia. Vale do Rio Doce (Brazilian state-owned iron-ore company) has entered into agreement with a number of foreign organizations for the establishment of pelletizing plants in addition to the two already operated by CVRD. One 3-million-ton pelletizing plant has been established jointly with FINSIDER (Italy). Two pelletizing plants, with a total capacity of six million tons per year, will be established together with Japanese interests. One 3-million-ton pelletizing plant will be established in collaboration with Instituto Nacional de Industria (Spain). CVRD holds 51 per cent of the capital in all these ventures and will operate all plants. The pellets produced will be exported mainly to the countries concerned.

A large integrated iron and steel plant, producing 3 million tons per year in the first phase and 6 million tons per year in the second phase, is being constructed at Tubarão. It is a joint venture of CVRD (51 per cent of the capital) and Kawasaki Steel (Japan) and FINSIDER (Italy), each with 24.5 per cent participation. The first phase will involve an investment of some $US700 million, and the semis produced will be exported mainly to Japan and Italy.

Guaira S.A. Paran, will spend $90 million increasing steel production by 143,000 t/yr. Aconorte S.A. Pernambuco, will spend $30 million increasing steel production by 40,000 t/yr. Dufer S.A. Industria e Comercio de Ferro e Aco, S.Paulo, will up its capacity by 90,000 tons/yr. Simecs S.A. Santa Catarina will spend $4 million on increasing steel production.

Siderurgica Barra Mansa will spend $120 million expanding steel production. Industria Metalurgica Nossa Senhora de Aparecida S.A. Sorocaba, S. Paulo, will spend $60 million expanding production of steel alloys, cast iron and rolled products. Confab Industrial S.A. S. Caetano, S. Paulo, will spend $16 million expanding its production of castings. Niken Metalurgica, S. Paulo, will expand its stainless steel production capacity. Sumitomo Heavy Industries will supply two continuous pickling lines to CSN. Companhia Paraibuna de Metals will build a $51 million plant in Juiz de Fora with a production capacity of 31.000 tons of electrolytic zinc a year. Nippon Steel Corp. will help Siderurgica Mendes Jnr. S.A. draw up a master plan for building a steel mill with an annual capacity of 4.8 million tons. It will be located 220 km west of Rio de Janeiro.

Chile

Plans are under way for building the country's first iron ore pelletizing plant with a capacity of 4 million tons per year at Guasolda in the Huasco Valley. A new port will be constructed at Guacolda capable of handling ships of up to 250,000 tons and with a loading capacity of 8,000 tons per hour, using ores of the Algarrobo and Boqueron Chanar mines, which are also to be developed. These plans are under implementation on schedule.

Five Japanese steelmakers - NKK, Kawasaki, Nippon Steel Corp., Sumitomo and Kobe - having signed a preliminary agreement to buy 32.5 million tons of pellets between July 1978 and December 1985.

Paraguay

CONSIDER and ACEPAR of Brazil and Paraguay are cooperating respectively for the establishment of a 100,000 tpy integrated steel plant based on charcoal blast furnace for iron smelting of iron ore /pellets imported from Brazil, LD oxygen steelmaking and merchant steel rolling.

India

The Bokaro steel plant is in the final stages of commissioning. It is the second integrated steel complex to be set up with assistance from the USSR. Design and engineering work for Bokaro's first phase was shared by consultants from the USSR and India. Almost 75 per cent of the total plant equipment is being fabricated in India in the machinery and equipment complex of the Heavy Engineering Corporation At Ranchi, with assistance from the USSR and Czechoslovakia. The first phase of Bokaro has a capacity of 1.7 million tons per year of crude steel; the second phase, now under way, will raise the capacity to 4 million tons per year. A considerable and effective transfer of know-how and technology has taken place through the long standing cooperation between the two countries. India is now essentially self-sufficient in engineering services and the production of equipment for the iron and steel sector. The National Metallurgical Laboratory (India) and the Central Fuel Research Institute (India) undertook the entire programme of testing raw materials and investigations for the Bokaro steel complex. Kudremukh complex for the supply to Iran of high grade magnetite concentrate in India is under installation, with financial assistance from Iran - annual capacity 8 mty for supplying 150 mt of concentrate over twenty years - total project cost is 700 mUS$.

Indonesia

A direct reduction plant is planned for the production of two million tons per year of sponge iron to be used in electric arc furnaces. The process to be used will be the HyL direct reduction technology developed in Mexico, with know-how and engineering to be negotiated through Swindell-Dressler (United States of America).

P.T. Krakatau Steel recently ran successful trials of their newly installed bar mill at Cilegon, in North West Java, Indonesia. Commissioning is now nearing completion and firm orders are already being received.

The original mill, delivered by the USSR in 1960, was abandoned before erection could begin. Consulting engineers L.H. Manderstam and Partners, in association with Manderstam Associated Consultants SA. Geneva, were retained to revive the project and undertake such redesign as might be necessary, as well as supervising the reconstruction.

They advised the addition of a 500 mm section mill to the original design of the 120,000 t/y bar mill.

The original equipment has been utilised as far as possible, but a 40 t/h reheating furnace from Priest, oil and lubricating systems from Denco Farval, thickeners and filtration plant from Dorr Oliver, and a seven-stand roughing train from Danieli, with electronics by AEG, were also incorporated. Modification of the Soviet plant proved necessary to ensure compatibility with modern equipment and conformity to modern operating standards.

This major task was successful accomplished, and the section mill is scheduled to come on stream before the end of this year.

Iran

The second phase of the existing plant of Arya Mehr steel works in Isfahan is now being constructed with the cooperation of the USSR; it is due to be completed in 1976. Work on the third phase will probably begin in that year, so that capacity should reach 4 million tons by 1980.

NISIG and FINSIDER (Italy) have agreed to construct a steel direct-reduction plant in Bandar-Abass, with a capacity to produce 2 to 3 million tons per year of flat products for local and export markets. FINSIDER will provide assistance and will participate financially in the venture.

A company, Société Iranienne d'Aciers Especiaux, has been formed by Iranian organizations and Creusot-Loire (France) for the production of special steels. Initial capacity will be 80,000 tons per year.

An agreement has been reached between IDRO - Industrial Development and Renovation Organization (Iran) and Fried. Krupp (Federal Republic of Germany) to co-operate in a joint engineering services company to be set up on a fifty-fifty basis.

Iraq:

Plans are under way for the installation of a sponge iron and steel-making complex at Khor al Zubair with an annual capacity of about 1.2 million tons of sponge. It will employ the HyL process and use local natural gas. Agreement has reportedly been reached with the CVRD of Brazil for the supply of high-grade pellets for the sponge plant in Iraq.

Nigeria:

Plans are under way for the establishment of an integrated iron and steel plant, using the sponge iron electric furnace route. It would produce 500,000 tons per year of sponge iron for export and 500,000 tons per year of semis for home markets, using local natural gas. The project will have the co-operation of C. Itoh (Japan) for marketing and financing aspects and of Korf (Federal Republic of Germany) for technology.

Zaire

An agreement was signed recently with agencies of the Government of Zaire and FINSIDER (Italy) for the latter's assistance in the management of the steel works of the Société Nationale de Siderurgie at Maliku during the first ten years of operation. The plant, which is about to start operation, has a steel producing capacity of 120,000 tons per year.

Venezuela:

Venezuela has awarded a contract to Vöest of Austria for a 6m tpy pellet plant. Early 1976 Corporación Venezolana de Guyana (CVG) took over the US owned Amico and El Pao mines; CVG Ferrominera Orinoco has been set up to operate them.

[1]Developing countries have traditionally had to struggle to achieve a measure of industrialisation. Ironically, the newly found wealth of oil producing countries has not really lessened the problem, for inflation has followed swiftly. Simply stated, to achieve industrialisation a developing country must first seek the best advice on the path it should follow, and then make sure that it does follow it to its goal. In practice, however, both the choice and the realisation of industrial

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[1] MB - 26 July 1977

investments are often decided by commercial pressure, with political considerations often playing a part.

One striking example of a developing country which in the past has learned about steel the hard way, and is now using oil wealth to build up its steel industry, is Venezuela. A recent visit to the Sidor steelworks at Puerto Ordaz on the Orinoco showed that whatever problems may lie in the past, the massive expansion project now under way will entail problems of another sort in its realisation.

The Venezuelan steel industry has long espoused the cause of direct reduction. The first commercial example of the Strategic-Udy rotary kiln process was installed at Sidor in 1963, but was not successful. In 1968 construction was started on a plant using the HIB (high-iron briquette) fluidised bed process developed by US Steel Corp. The plant started up in 1973, but has not operated consistently at its design capacity.

By contrast the country's next venture into direct reduction was the application of two well-tried processes. Originally it was intended that the HyL and the Midrex plants at Sidor would be in operation in time to determine which process was most suited to Sidor's needs, to enable a choice to be made between them for the large Plant IV expansion which is now in progress. In the event, however, construction of these first two plants was delayed for a number of reasons, and operation started only within the past few months. In the meantime the orders for the Plan IV D-R plants had to be placed without the advantage of operating experience. Both HyL and Midrex were chosen for this scheme, which will increase raw steel capacity to 5m. tpy.

Also being commissioned in the Puerto Ordaz area is the first commercial example of another fluidised bed D-R process, Fior. This belongs to Fior de Venezuela, a private concern in which the Venezuelan mini steel works Sivensa has a shareholding.

Sidor itself suffered in its early stages from mis-timing. When the works was planned, priority had been given to serving the oil industry, and the main product was to be seamless pipes. In the first stage it was planned to begin making these from imported steel during 1958, but operation did not start until nearly the end of 1960. Delays caused Sidor to miss much of the local market, for from 1959 there was a decline in the granting of new oil drilling concessions, and the delay also encouraged the growth of a producer of welded pipes, by then finding acceptance for oil uses.

The iron and steelmaking route chosen for Sidor was also unorthodox, involving the use of electric pig iron furnaces based on hydro-electricity, and open hearth furnaces where electric arc furnaces might perhaps have been employed. Electric arcs will, however, be used in Sidor's build-up to 5m. tpy and perhaps beyond. Two melting shops, one with six 200-ton furnaces and the other with four 150-tonners, will create the largest electric steelworks in the world. It will be fed by the relatively new technology of direct reduction, and the steel produced will be processed entirely by continuous casting. Few electric arc furnaces of 200 tons are in operation anywhere in the world, and experience of continuous casting in Venezuela is very limited. Recognising the difficulties involved, Sidor has invited bids from steelmakers in industrialised countries to carry out the commissioning of the new plant, emphasising the difficulties a developing country faces in making a technological leap forward.

Venezuela is also considering another integrated steel plant in Zulia region based on blast furnace/LD steelmaking route.

Algeria:

Algeria possesses good resources of iron ore, oil and natural gas. Algeria's major two steelworks are located at Annaba and Oran. The expansion of El Hadjar plant at Annaba will be completed by 1978 based on raising the cold rolling mill capacity from 150,000 to 950,000 tpy and hot rolling mill from 450,000 to 1,800,000 tons with balancing increases in the iron and steelmaking capacities. Plans for setting up sponge iron plant based on gaseous direct reduction followed by electric steelmaking are under study.

Algeria is one of the most dynamic and fast developing countries with an outstanding rate of industrial/economic growth; the national plans call for a projected capacity of 12 mty of steel production by the year 1990. Algerian plans inter alia of steel industry are well balanced and good models indeed to follow.

Libya

Iron ore deposits located at Wadi Al-Shatti are estimated at 700 Mt with a 50% Fe content.

Libya has a mini steel works with a 21,000 tpy billet plant at Tripoli which is equipped with two 5-ton electric arc furnaces and a single-strand billet caster.

Plans for an integrated iron and steel complex at Misurata are under active implementation. Phase 1, with 500,000 to 1,000,000 tpy capacity is set for 1980. Detailed project studies by international consultants are being undertaken. Phase 2 is planned to have a 5 m tpy integrated iron and steel works at a greenfield site; considerable infrastructure will be established including port, power, gas pipeline, township, etc.

The first phase will be reportedly based on sponge production based on gaseous direct reduction process. Libyan steel plans and their execution are following bold, energetic and well balanced policies that will pay dividends.

Morocco

Société Nationale Sidérurgique has been created for the establishment of an integrated steelworks near Nador to be operational by 1979 with a crude steel capacity of 1 million tons, to be based mainly on Moroccan pellets. Blast furnace/LD steelmaking /continuous casting route will be followed in the integrated iron and steel works under establishment. Moroccan plans are well prepared for balanced execution.

Tunisia

Tunisia's steel industry, the El Fouladh Sté Tunisienne de Sidérurgie at Menzel-Bourguiba with a current capacity of 140,000 tons will be expanded to double the capacity.

A feasibility study is being undertaken for establishment of a DR plant at Gabes to produce sponge iron based on gaseous direct reduction.

Nepal:

A mini integrated steel plant based on charcoal/sub-merged arc electric smelting of iron using local iron ore is under study followed by LD steelmaking and rolling mill for light sections.

Mauritania:

Scrap-based mini steel works with 12,000 tpy melting capacity and 36,000 tpy bar mill are envisaged to start up in 1978 at Nonadhibon.

Qatar

Japan's Tasei Corporation and South Korea's Jung Woo Development Co. will jointly build a steel works for Qatar Steel Co. - a joint venture between Qatar Government, Kobe Steel and Tokyo Boeki.

Yugoslavia

Zenica commissioned a 1.3 m tpy LD converter and a new wire rod mill with start by the end of 1977. The country's first galvanizing line was commissioned at Skopje in March 1977. Phase 3 expansion at Sisak is aimed to bring raw steel capacity upto 1 m tpy and increase the tube-making capacity. Modernisation of Boris Kidric steel works got under way but the Smederevo project has been delayed.

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The above examples are merely illustrative of the general trends in developing countries vis-á-vis the iron and steel industry and they by no means do or can cover all the developing countries of the world; it is hardly possible to do so in this paper. Nevertheless, it is hoped that these examples will stimulate further studies and joint ventures amongst the developing countries and between developing and developed countries and particularly so in the African countries and those in the Arab world.

World Iron Ores Survey including Beneficiation, Sintering and Pelletizing

Iron Ore Minerals:

A large portion of the common ore and rock-forming minerals contain appreciable amounts of iron. But there are only six iron-bearing minerals containing sufficient and appreciable amounts of iron. These are available in sufficiently abundant quantities to be potential sources from which iron may be economically obtained. The six iron-bearing minerals are as follows with Fe content in pure mineral in each case:

i)	Hematite	Fe 69.9%
ii)	Magnetite	Fe 72.4%
iii)	Goethite	Fe 62.9%
iv)	Chamosite	Fe 42%
v)	Siderite	Fe 48.2%
vi)	Pyrite	Fe 46.6%

The wide variety of conditions under which iron is concentrated in the earth, the physical and chemical nature of these concentrations, their mineralogical and geological environment and the complex process which contributed to the concentration of iron in ore deposits, account for peculiar characteristics of each deposit.

Major Deposits:

The major iron ore producing regions of the world are USSR, Canada and West Indies; USA, Mexico and Central America; South America; Middle East, Asia and the Far East; Africa, Europe and Australia and New Zealand.

USSR

In USSR, the biggest deposits are in Ukrainian Republic (Krivoy Rog and Kursk magnetic anomaly) which are of Lake Superior type. Taberg type of deposits are found in the Eastern slopes of the Urals. Ores or Magritnaya type and those of Minette type are found in Turgay and Western Siberia areas. Large deposits are found in Kasakhstan, Siberia and Caucasus regions.

Canada and West Indies

The deposits of Canada and West Indies are located in Appalachian, Grenville, Labrador, Southwest and Northern Canada, Cuba and Dominican Republic. These are generally of Lake Superior, Magnitnaya and Taberg types and mostly contain hematite, magnetite and goethite. Siderite, pyrites and chamosites are also sometimes found associated.

USA and Mexico

The important deposits of USA occur in Mesabi, Cuyuna, Vernilion, Fillmore, Gogebic and Lake Superior regions. These are mostly of Lake Superior type but sometimes Kiruna, Taberg, Magnitnaya and Clinton types also occur. The principal minerals are hematite, magnetite and Siderite. The deposits of Central America and Mexico are generally of Kuruna and Magnituaya types and contain mostly magnetite, hematite and goethite.

South America

Argentina, Brasil, Chile, Colombia, Peru and Venesuela are the countries in this region where iron ore deposits are located. Deposits in Argentina are of Lake Superior and Minette types and contain hematite and magnetite. Bolivian deposits are of Lake Superior type containing hematite. The Brasilian deposits are mostly of Lake Superior type containing hematite. The deposits of Kiruna type are also found when hematite and magnetite are the principal iron-bearing minerals. The deposits of Chile are of Kiruna and Magnitnaya types containing magnetite and hematite as iron minerals. The deposits of Colombia contain goethite and are of Minette type. The deposits in Peru are mostly of Magnitnaya type containing magnetite. Lake Superior type of deposits are found in Venezuela containing hematite.

Middle East, Asia and Far East

Saudi Arabia, Israel, Turkey, Iran, Afghanistan and Pakistan comprising West Asia, have iron ore occurrences. The deposits of Saudi Arabia are mainly of Lake Superior type and contain mostly hematite with magnetite mineralisation sometimes. The deposits in Israel are of hematite and goethite. The Turkish deposits are mostly magnetite and are of Magnitnaya type. Similar type of deposits occur in Iran. The deposits of Afghanistan contain hematite and siderite. Magnitnaya type and bedded type of deposits are found in Pakistan with magnetite and hematite as principal iron bearing minerals.

Middle Asia constitutes India, Sri Lanka and Nepal. Indian iron ores are of Lake Superior type and also of Massive and Taberg types. The predominant iron-bearing mineral is hematite and sometimes goethite and magnetite. The Sri Lanka deposits are of residual lateritic type and mostly contain goethite and sometimes magnetite. Hematite is found in Nepal and the deposits are of bedded type.

The Eastern Asia consists of Burma, Thailand, Laos, Cambodia, North Viet-Nam, Malaysia, Indonesia, Philippines, China, Hong Kong, North Korea, South Korea and Japan. The deposits of Burma, Thailand, Laos, Cambodia, North Viet-Nam, Malaysia, Indonesia and Philippines are generally of Magnitnaya, residual lateritic and bedded iron sand types. These contain magnetite, goethite and hematite as iron minerals. Magnetite-hematite are the principal iron minerals of the Chinese deposits which are of Lake Superior, Minette and Magnitnaya types. The deposits of Korea are mainly Magnitnaya type containing mostly magnetite and sometimes hematite. The deposits in Japan are of residual bog and bedded iron sand types containing magnetite, ti-magnetite, goethite.

Africa

Deposits of Africa are of Minette, Lake Superior, Bilbao, Taberg and Magnitnaya types and mostly contain hematite-magnetite, hematite-goethite, hematite-pyrite (ochre) and siderite-goethite.

Europe

Portugal has Minette type of deposit consisting of hematite and magnetite and sometimes siderite and Chamosite. In Spain, Bilbao type of deposit is in predominance with hematite-goethite as iron minerals. French ores are of Minette type and contain siderite-goethite. The ores of United Kingdom are also of Minette type but contain chamosite-goethite-hematite. The deposits of Norway are of Lake Superior, Magnitnaya and Taberg types containing magnetite-hematite minerals. The Swedish ores are of Kiruna and Lake Superior types containing magnetite, magnetite-hematite minerals.

The ores of Federal Republic of Germany are of Minette type, mostly containing hematite-chamosite-siderite with occurrences of goethite also in some of the areas.

Ores of Austria are of Bilbao type containing mostly siderite. Ores of Italy and Yugoslavia are mainly of Bilbao, Minette and Magnitnaya types with magnetite, siderite, siderite-chamosite minerals.

Lateritic deposits are predominant in Greece with gothite as the principal economic mineral. East Germany and Czechoslovakia have Minette types of deposits. Poland and Romania, both have ferruginous carbonates containing siderite-magnetite-goethite. Bulgarian ores are of Bilbao type and contain hematite, siderite, goethite and magnetite.

Australia and New Zealand

The Australian deposits are of Lake Superior, Algoma and Clinton types with hematite, goethite, magnetite, hematite-magnitite-goethite and magnetite-pyrite minerals.

The deposits in New Zealand are of aluvial and sedimentary nature and contain magnetite and goethite as the iron minerals.

Production of iron ore in some of the countries is given in Table 1, and world distribution of reserves in Table 2.

Table 1

Iron Ore Production

country	1973 m. tonnes	1974 m. tonnes	1975 m. tonnes
Algeria	3.13	3.20	3.25
Angola	6.05	5.50	3.60
Australia	83.57	96.69	99.40
Austria	4.21	4.25	3.83
Brasil	55.02	79.97	69.64
Bulgaria	2.77	2.68	2.24
Canada	48.20	47.27	39.60
Chile	9.65	10.30	10.50
China	50.00	51.00	51.00
Czechoslovakia	1.67	1.69	1.80
Egypt	0.64	1.30	1.12
Finland	0.89	0.93	0.90
France	54.75	54.73	50.14
E. Germany	0.52	0.25	0.58
W. Germany	6.43	5.67	4.27
Hungary	0.68	0.60	0.64
India	34.43	34.23	40.27
Iran	0.60	0.62	0.65
Italy	0.68	0.80	0.74
Japan	1.01	0.78	0.90
North Korea	8.10	8.10	8.20
South Korea	0.47	0.49	0.53

Table 1 (Cont'd)

Iron Ore Production

Country	1973 m.tonnes	1974 m.tonnes	1975 m.tonnes
Liberia	34.62	36.00	36.50
Luxembourg	3.78	2.69	2.32
Malaysia	0.52	0.47	0.35
Mauritania	10.42	8.28	8.50
Mexico	5.74	4.90	5.55
Morocco	0.37	0.54	0.62
New Zealand	1.99	2.20	2.00
Norway	3.97	3.92	4.06
Peru	8.96	9.56	9.60
Philippines	2.26	1.62	1.24
Poland	1.41	1.24	1.25
Rhodesia	0.55	0.60	0.60
Romania	3.23	3.21	3.10
Sierra Leone	2.27	2.40	2.50
S. Africa	10.96	11.73	12.24
Spain	6.90	8.61	8.22
Swaziland	2.15	2.20	2.30
Sweden	34.73	36.15	32.64
Tunisia	0.81	0.82	0.68
Turkey	1.86	1.53	1.90
U.K.	7.11	3.60	4.49
USA	88.80	85.92	81.35
USSR	216.10	224.88	232.80
Venezuela	22.88	26.41	27.00
Yugoslavia	4.67	5.03	5.24
World	851.00	896.30	881.50

Table 2

GLOBAL DISTRIBUTION OF TOTAL RESOURCES & POTENTIAL RESERVES OF Fe ORE MINERALS.

	F	M	G	S	FM	FG	GS	FS	MP	MS	FMP	MSP	MG	SP	FMG	FMS	Not classified	
USSR	29,025 (20,975)	38,325 (21648)	106,363 (13,894)	1258 (1195)	36,255 (29,421)		522 (447)	9316 (9316)								300	82,937 (13,687)	
Australia New zealand Caledonia	(1630)	(660)	(5951)		(35)	(7953)		(322)	(144)		(2)				(120)			
U.S.A	3561 (396)	12,969 (789)	907 (745)		65,555 (3227)	6139 (7287)	343 (343)	50					313 (113)		1742 (272)	10,254 (4)	3 (3)	FMS 30(3[illegible]) FMGS 4428([illegible]3) others( )
Canada & W. India Dominican Republic.	12,235 (2025)	32,411 (8164)	- (1)		55,875 (20,898)	8370 (4320)		600	20 (10)	1000		1675 (40)		735 (420)		6020 (20)	1500	F(38), FI 1350(3[illegible], FMI 320, F.C 20 F.C 25, GSC 1500.
Middle East, Far East (includes India)	19,427 (8310)	7751 (2073)	3206 (655))	41	12,824 (4206)	566 (317)	2545 (508)	129 (29)					4 (2)		275 (108)		24,328 (85)	GSC (450
India	15,516 (6982)	2332 (620)			8547 (419)	52 (52)	2540 (508)								53 (53)		12 (12)	
Africa	17,056 (2405)	2718 (373)	1297 (262)	6 (6)	4254 (603)	1358 (127)	(92 (20)	168 (168)		55 (15)	41 (41)		46 (46)		1419 (1250)	1427 (432)	42 (42)	P 17, F.I (1) FMI 279, (2[illegible]) FMC 1000(1000)

Table 2 (Cont'd)

	F	M	G	S	FM	FG	GS	FS		MP	MS	SMP	MSP	MG	SP	FMG	FMS	Not classified	
[illegible]	84,900 (32,282)	788 (251)	1348 (301)		2610 (411)	2304 (929)								8					
Europe	777 (487)	3122 (3103)	1384 (794)	1900 (1880)	3408 (1378)	830 (130)	9430 (4840)	775 (675)	Europe	50 (10)	50 (80)					440 (100)	2240 (2120)	1110 (10)	MI 50 (50), GC 5148 (3048) SC 10,(?) FSC 50, (30) FSC 880(230), GSC 1883 (1048), FGMC 1740, (1640) NGS 38(38)
Sweden		2805			475														

Legend : i) F = Hematite, M = Magnetite, G = Goethite, S = Siderite , P = Pyrite, C = Chamosite
I = Ilmenite.

ii) Figures without bracket indicates total resources (million tonnes) (ie. reserve + potential ore) and those with bracket show reserve (million tonnes).

iii) The deposits of India and Sweden are shown exclusively along with the entire deposit of East Asia, Far East & Europe which include these.

The above brief description of world iron ore resources gives an indication about the varieties of iron ores found. Each of these deposits have their own characteristic features, variations in iron content, mineralogical assemblage, particle size of iron minerals and those of associated economic and gangue minerals, etc.

The world over, higher grades of ores are gradually getting depleted due to some type of selective mining or the other. During mining of these high grade ores, low grade ores, which may be present as overburden and capping or occuring in situ along with good grade ore, get admixed. This admixture becomes inevitable where large scale mechanised mining is resorted to.

Thus, in most cases, some kind or the other beneficiation of the run-of-mine ore has to be adopted to ensure an accepted and consistent quality of iron ore of desired chemistry for iron smelting. Prepared burden for iron smelting is of paramount importance, necessitating size reduction, screening into size grading and improving the chemical composition of the ore by employing beneficiation techniques.

Beneficiation

Depending upon the mineralogical and petrological characteristics, different methods of beneficiation are employed to suit a particular ore. The methods include crushing, grading, sizing, washing and wet screening, gravity treatment, magnetic separation, froth flotation, reduction roasting, thickening and drying. The overall beneficiation flowsheet may comprise the use of one or more of the different methods. The criteria for determining and finalisation of treatment flowsheet, are the cost economics of the process, requirement of the quality of end product and the possibilities of finding use of waste products; these are primarily governed by the mineralogical characteristics of the ore under study.

The various beneficiation methods are briefly outlined below:

i) Crushing: The ore as mined, is generally of 300-400 mm in size. Requirement of size of ore for use in blast furnaces are that the ore should be of over 10 mm size, with the top size of 50 to 30 mm. Crushing is done employing jaw and/or gyratory crushers.

For some types of ore, such as the Indian iron ores, wet screening at 10 mm size, has to be adopted due to the sticky nature of the ore and presence of clayey matter with the mined ore. The screen undersize, namely -10 mm fraction is dewatered and slime removed in spiral or rake classifier.

ii) Grinding: In some cases, such as with magnetite ores and taconites, the ore is ground, either wet or dry in ball and/or rod mills, with a view to liberating iron bearing minerals from gangue minerals.

iii) Washing: Lateritic ores and the ores admixed with aluminous clayey matter, are scrubbed with water in log-washers or cylindral washers fitted with lifters, for loosening the adhering fines. The scrubbed ore is then wet screened on a double-deck wet vibrating screen to separate clean lumpy ore free from adhered fines for direct use in blast furnace and free flowing fines for use in sinter plant.

iv) Gravity methods:

a) Heavy media separation: Aqueous suspension of ferro-silicon or magnetite, finely ground, is used to separate hematite, goethite or siderite from lighter gangue minerals. The size of ore treated is normally -30 mm + 4 mm. However, finer size can be treated in heavy media cyclones.

b) Jigging: Harz or Renier types of jigs are used for ore in the size range of -25 mm to 0.5 mm.

c) Humphreys' Spiral: The size range of feed to spiral is generally -1.5 mm to 0.1 mm. Sometimes specular hematite of as fine a size as 65% passing 150 microns, has been successfully treated on spirals.

d) Shaking tables: The size of feed is almost same as used for spirals. Tables are generally employed for re-cleaning of fine gravity rougher concentrates.

e) Cyclones: Cyclones are used for recovering heavy minerals from fine gangue particles from slimes.

v) Magnetic Separation:

a) Low intensity wet magnetic minerals like magnetite from non-magnetic minerals. The separation is often preceded by desliming the feed for better efficiency.

b) Low intensity dry magnetic separation: This is used for pre-concentration of strongly magnetic minerals and for treatment of beach sands for recovering ilmenite and other magnetic minerals.

c) High intensity magnetic separation: This is used for feebly magnetic minerals like limonite, specularite, goethite, etc. and can be wet or dry. In case dry separation is employed, the ground ore should be almost free from adhering gangue minerals like clays.

vi) Froth flotation: Flotation is employed for fine grained low grade non-magnetic ores such as siderite-hematite ores, and specular hematitic ores. pH of the flotation pulp could be weakly acidic or alkaline depending upon the minerals to be floated and reagents used. Tall oil, alkyl sulphonates, sodium fluosilicic acid, ligneous tar, fish fats, etc. are the common flotation reagents.

vii) Electrostatic/high tension separation: This method is used for further upgrading fine gravity concentrates, and helps in removal of undesirable minerals like apatite, micas, hypersthenes, etc. from iron-bearing minerals.

viii) Low temperature Magnetic roasting: The method is employed for fine grained, non-magnetic or feebly magnetic low grade ores containing hydrated oxides and sometimes siderite. The roasted ore is then passed through magnetic separators to separate magnetics from non-magnetic gangue minerals.

ix) Dewatering and drying: Fine concentrates are thickened in thickeners, filtered and dried for use. Drying could be partial depending upon the end use of fine concentrate.

Beneficiation practices in some of the countries

1. USA

i) Brown Iron Ore: After crushing to the required size, the ore is scrubbed and wet screened to obtain clean sized lumpy ore and free flowing fines for use in sinter plant or for pelletization.

ii) Oxidised ores: Generally, after washing, the washed lumps and fines are subjected to gravity methods of beneficiation namely, heavy media separation, jigging, Humphrey's spiral treatment and hydrosising. Sometimes, flotation is adopted to recover iron values from fine grained tailings from heavy media circuit.

iii) Teconites: The ore, after crushing, is stage-ground using rod and ball mills in closed circuit. After rod milling, the pulp is passed through wet magnetic separator to recover magnetic iron oxide got liberated in primary grinding. The classifier overflow from ball mill circuit is deslimed in cyclones and sand fraction subjected to amonic flotation to remove siliceous gangue minerals.

iv) Specularite: After stage grinding in open circuit rod mill and closed circuit secondary ball mill followed by desliming, the underflow is subjected to flotation. The rougher flotation concentrate after regrinding and hot conditioning, is refloated to yield a final concentrate analysing 67% Fe.

v) Oolitic hematite and calcareous ore: The run-of-mine ore analysing 36% Fe is ground to a course size and after hydraulic classification, treated in heavy media separators and jigs to produce high grade concentrates.

vi) Complex magnetite, hematite and martite: The ore is stage crushed and passed through magnetic separators to recover magnetic iron oxides. The non-magnetic iron ore is recovered by froth floration after grinding.

The ores from Benson mines containing magnetite, martite and hematite, are mined selectively and crushed separately. The magnetite ore is beneficiated by magnetic separation after stage crushing and jigging. The non-magnetic tailings are further ground fine in ball mill and passed through a set of magnetic separators to recover magnetics.

Martite is upgraded in humphrey's spiral after size reduction. The spiral tailings are subjected to flotation for recovery of hematite ore.

vi) Magnetic ore from Meramec Mining Co: After stage crushing and magnetic cobbing, the magnetics are ground in ball mill and subjected to magnetic separation. The non-magnetic portion after desliming, is floated for differential separation of pyrite, phosphates and specular hematite. The sequence of recovery of different minerals is - first xanthate flotation for recovery of pyrite, then fatty acid flotation for apatite and finally, flotation of hematite using sulphonates.

2. Sweden

i) Magnetite ores: These types of ores found in Kiruna, Malmberget, Graugesberg are upgraded by repeated magnetic separations. If hematite is also present, then the non-magnetic tailings are treated in jigs/shaking tables for its recovery. The concentrate analyse over 60% Fe and are generally fine requiring agglomeration.

ii) Hematite ore: The ore after coarse crushing is subjected to Stripa process or heavy media separation using ferro-silicon as medium for the latter. The finer fractions of ore are treated in shaking tables and humphrey's spirals.

Sometimes flotation is adopted to recover associated economic minerals like apatite. Emulsified tall oil is the reagent used at a pH of 8.5 to recover apatite. Hematite is floated after lowering the pH to about 6. The raw ore analysing 35% Fe and 0.02% P, is upgraded to 65% Fe and 0.01% P. The apatite float analyses 0.3% P.

Skarn and other types of ore such as those found in Bodas, are first subjected to dry magnetic separation at about 20 mm size, followed by ball milling and flotation of pyrite. The flotation tailing after high intensity wet magnetic seperation, yields magnetite concentrate separately.

2. Canada

i) Specular hematite: These are low grade and friable occuring in southern parts of Labrador - Quebec district. Generally, after autogenous grinding, the ground ore is treated on spirals. If, however, super high grade concentrate is needed, then magnetic separation and flotation are sometimes employed.

For specular-hematite-magnetite quartsites of Lake Carol and Lake Wabush regions, Humphrey's spiral treatment is adopted to produce concentrates analysing 60 - 66% Fe.

ii) Hematite-Siderite: These ores of Algoma, Wabana and Steep Rock are subjected to washing, gravity treatment such as heavy media separation (cyclones/drums) and jigging.

iii) Magnetite: Ores from Moose mountains, Marmora, Ontario, etc. are concentrated by low intensity magnetic separation.

3. USSR

Magnetite ores are mainly exploited as there are considerable reserves of these ores. Besides this, these ores are easier to beneficiate. However, purely magnetic separation treatment becomes economical if the proportion of magnetite in the ore exceeds 70-80% and the loss of iron in magnetic tailings does not exceed 12-14%.

The beneficiation plants at Olenyogorsk and Krivoi Rog employing a combination of magnetic separation, and gravity methods such as spirals, heavy media separation and jigging, treat 20 m.tpy. For flotation, the ore is subsequently ground to a fineness of about 90% passing through 200 mesh screen.

4. India:

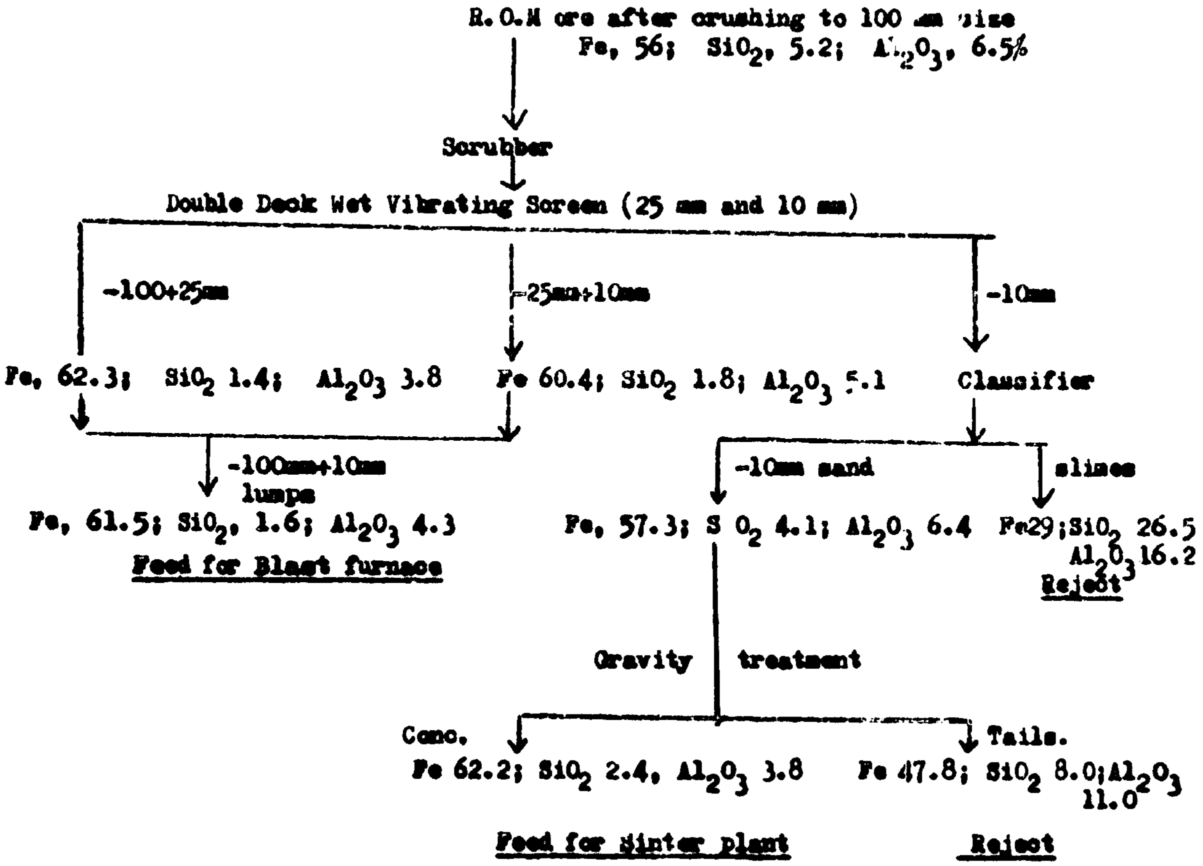
Indian iron ores, though generally of high iron content, are characterised by their high alumina content and presence of clayey matter. This makes the ore sticky, particularly in rainy season with the result that the ore crushing and handling plants come to a stand still during the wet weather. All the crushers, bins and bunkers, conveyors and chutes, get choked making screens completely blocked.

i) The treatment for these types of ores (hematites), is scrubbing with water to loosen the clay and then wet screening with powerful jets of water. The screen under size containing almost all the water and slimy matter, is treated in classifier. The classifier overflow carries away the slime which is generally a waste product. This is sent to water reclamation system. In case the slimes contain higher percentages of iron values, the slimes are treated in cyclones. Cyclone underflow after thickening and filtering, is sent to agglomeration plant.

The classifier sand portion is then a free-flowing material and can be used for agglomeration directly or after beneficiation by gravity methods. The washed lumps are clean, free from adhered fines. Nearly 30-40% of the total silica in the ore is thus eliminated as slime along with about 20-30% of alumina.

ii) Magnetite-hematite ores: These ores are found in Kudremukh and Ongole areas in southern parts of the country. Magnetic separation after grinding yields a high grade concentrate analysing over 60% Fe. The non-magnetic tailings containing hematite, are treated in humphrey's spirals for its recovery.

A typical flowsheet for hematitic ores is given on page 15:


R.O.M ore after crushing to 100 mm size
Fe, 56; SiO_2, 5.2; Al_2O_3, 6.5%
Scrubber
Double Deck Wet Vibrating Screen (25 mm and 10 mm)
-100+25mm
-25mm+10mm
-10mm
Fe, 62.3; SiO_2 1.4; Al_2O_3 3.8
Fe 60.4; SiO_2 1.8; Al_2O_3 5.1
Classifier
-100mm+10mm lumps
Fe, 61.5; SiO_2, 1.6; Al_2O_3 4.3
Feed for Blast furnace
-10mm sand
slimes
Fe, 57.3; SiO_2 4.1; Al_2O_3 6.4
Fe29; SiO_2 26.5 Al_2O_3 16.2
Reject
Gravity treatment
Conc.
Fe 62.2; SiO_2 2.4, Al_2O_3 3.8
Tails.
Fe 47.8; SiO_2 8.0; Al_2O_3 11.0
Feed for Sinter plant
Reject

Agglomeration

Mechanized mining, crushing and screening adopted to meet ever increasing demands of iron ores and subsequent beneficiation in many cases, necessarily produce large proportions of fines ranging from 25% to over 50% by weight. In case of magnetic ores, the entire concentrate quantity is in the form of fines.

These fines are utilised for ironmaking after sintering or pelletising.

Sintering: Sintering plants in an iron and steel plant acts as a scavenger of the plant, which makes useful agglomerate - sinter utilising a wide variety of wastes such as coke breeze, mill scale, limestone and dolomite dust, lime fines, and blue dust. This process has a greater flexibility to agglomerate raw materials with different physical properties and mineralogical compositions.

The self-fluxed and super-fluxed sinter has same or even superior metallurgical, physical and chemical properties to that of pellet.

Pelletising: Pelletization is often adopted where the ore particles are in very fine form either as a beneficiated product or naturally occuring mineral like blue dust. For making pellets of good green strength and subsequently the indurated pellets, choice of type of grind assumes importance. The size to which the ore should be ground and the specific surface area of the ground material, the schedule of pre-heating, firing and cooling are other equally important parameters which are to be controlled carefully.

Grinding could be wet or dry, in open or closed circuit with the mill. With requisite quantities of water and binders, pellets of good quality are made in disc, drum or cone types of pelletisers. Usually three types of indurating furnaces are employed.

The following tables give brief summary of a few pelletization plants of the world. Table 3 gives data for shaft kilns, table 4 for travelling grate and table 5 for Grate-Kiln installations.

GLOBAL LOCATION & DESCRIPTION OF SOME PELLETIZING PLANTS :

Table 3

(a) Shaft Kiln.

Plant	Company	Material type.	Start up year	Capacity Mt/y.	No.of kiln	Capacity/ kiln tpd.	Kiln Geometry(M) L	W	L/W	C.S. (M^2)	Sp.capacity T/M^2 area.day.	Balling installation.	Constructor.
1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWEDEN:													
1.Dodas	Sandvikens Jernwerks .	M	1952	0.04	1	121	1.19	1.07	1.11	1.27	95.4	D,1200 x 5000	Sala
2.Soderfors	Stora Kopper bergs, Bergslog AB.	M	1952	0.015	1	45.5	1.62	dia		2.065	22.0	-	-
3.Falun	" " "	M	1954	0.05	1	151.5	1.7	dia		2.3	71.4	D,2133x5000	Sala
4.Hellefors	Hellefors,Bru. oke.	M	1953	0.015	1	45.5	2.22	dia		3.8	11.7	-	-
5.Hofors	SKS	M	1954	0.06	1	182.0	2.5	12.5 (2 shafts)		2.5	72.8	D,975x5000	Sala
6. Persberg	Udeholms AB	M(64	1960-3	0.07	2	10 6	2.2	die		3.81	27.8	D,1200x5000	Sala
7.[illegible]	Reymersholms Garula Industri AB	Roasted Pyrite (P,M)	1963	0.03	-	-	-	-		-	-	-	-
8.Strassa	Grangesberg	M(66)	1963-5	0.05	2	757	6	1.8	3.33	10.8	70.0	D(2)1830 x 5000	Surfece Combuston.
9.LKAB	Malmberget	M(66/ 71.5)	1955-65	0.8	4	608	6	1.8	3.33	10.8	56.11	(85) D (2)	Sala
CANADA: ONTARIO													
10. Marmora	Bethlehem Steal	M(66.5)	1955-7	0.45	4	340	4.26	1.75	2.44	7.45	45.6	(60/65) D(4),2133 x 4724.	Surface Combuston.
11.Hilton	Pickland Mather.	M(68)	1958-60	0.90	3	910	1.83	4.27	2.4	8.64	104	,75)D-	"
12.Moose MT	Hanna Mining.	M(63/64)	1963	0.70	2	1080	4.42	2.29	1.33	10.1	105	(85/90)D	-
13.Griffith	Pickland Mather.	M	1968	1.5	3	1515	6.4	2.44	2.62	15.6	97	-	-
USA:													
14.Grace, Penn.	Bethlehem Steal.	M(65)	1960	1.35	5	820	4.57	1.98	3.31	9.05	90.6	(65) Cones	Surface Combuston.
15.Corvel, Penn.	"	M	1962	1.75	3	757	4.57	1.88	2.31	0.05	83.6	"	"
16.Hoytlakes, Minn.	Eria Mining Co.	M(64.1)	1956-7	10.50	27	1180	5.64	1.83	3.08	10.3	114.5	(91/92) D, 2744 x 620	"
17.Pee Ridge Mo	Merramec Mining Co.	M(66/70)	1964	2.0	5	1210	4.57	1.98	2.31	9.05	133.8	D(5) 3048 x 6705	-
AUSTRALIA:													
18.PortLatta, Tessmania.	Savage River Mines(Pickland Mather)	M	1967	2.25	5	1200	-	-	-	-	-	-	Surface Combuston.
FINLAND:													
19.Otanmaki	Otanmaki oy	M(67)	1956	0.15	2	227	2.72	dia		5.8	39.1	- (85) D(?) 1830 x 5000	Sala.
FRANCE:													
20.Segre	Forges et Ac du Nord etole l' Est.	M	1961	0.04	1	121	2.2	dia		3.82	31.6	D,1830 x 5000	"

Table 3 (Cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
ITALY :													
21. Ferromin	Elba	F	1955	-	1	-	2.01	dia		3.18	-	-	-
JAPAN :													
22. Chiba	Kawasaki Steel Co.	M (some F)	1950-62	1.30	17	232	-					-	Kawasaki
23. Hachinde	Nisso Steel Mfg.		1960-2	0.25	-	-				-			-
24. Tobata	Kowa Seiko	Chlorinated Roasting of Pyrite.	1963	0.15	-	-					-		-
PHILLIPINES :													
25. Pellet Corpn. of Phill. (Kawasaki)	Larap	M/F	1966	0.75	3	787	-				-		A.G. McKee,
JUGOSLOVIA :													
26. Skopje Maceloine Rudnici Leb-zarnica	Melezari Skopje.	M (some F)	1968	0.15	1	455	6.1	1.2	5.08	7.3	62.2	D(?)1830x5000	Sala
MOROCCO :													
27. Sheferif Nador.	-	M	1972	0.85	-	-					-	-	-
U S S R :													
28. Krivoi Rog		M					1.8	2.4					

Legend : M (64) = Magnetite (64% Fe)

F = Hematite.

(85) D(2) = 85- -325 mesh conc. Drum, 2 nos.

- - - -

Table 4

(b) TRAVELLING GRATE (CONTINUOUS GRATE OR STRAIGHT GRATE)

Plant	Company	Material type.	Start up year.	Capacity Mt/y.	No. of units.	Capacity/ unit tpd.	Grate size(m) Width	Area	Sp. capacity t/ M²/day	Wind boxes per grade	Balling installation.	Constructor.
1	2	3	4	5	6	7	8	9	10	11	12	13
CANADA :												
1.Copper cliff	International Ni	M (Pyrite)) (artificial) (67/68)	1956-61	0.86	1	1290	2.44	117.6	11.02	24	(75)D1(4) 5.49ø	Lurgi./ Dravo.
Sudbury (Ont.)					1		2.44	160	8.063	32		
2.Colard (Ont.)	Island steel	F	1966	1.0	1	3030	3.05	229.8	13.19	38	D1(5),5.49ø/	Dravo.
3.Steep Rock (Ont.)	Steep Rock	F/G (53.4)	1967	1.0	1	3030	3.05	302	10.03	50	D1(5) 5.49ø	Dravo
4.Wabush Mines(Que)	Pickland Mather.	Specular F(66)	1966	4.3	3	4950	3.05	229.9	21.54	38	90.0 D	Dravo.
5. "	"	F	1968	1.1	-	3340					D, 3.05 x 9.45 m	Dravo.
6.Carol New Foundland, Canada	Iron Ore co.	Specular F(66) M	1963-8	9.5	4 2	- -	3.05 3.05	205.5 278.8	- -	34 46	(90)D 3.005 x 9.15 m	Dravo.
BRAZIL :												
7.Tubarao	CVRD I	F	1969	2.0	1	12,120	3.43	278.5	43.52	27	-	-
	CVRD II	F	1973	3.0								
NETHERLAND :												
8.Ijmuiden	Hoogovens	F/M	1970	2.5	1	7580	3.43	425.5	17.81	41	-	Lurgi/Dravo
AUSTRALIA :												
9.Dampier (W.A.)	Hammersley RTZ	F/L.	1968	2.0	1	6060	3.36	402.0	15.08	60	D1(6)6.04ø	Dravo
10.Robe River	-	L	1972	4.0								Lurgi.
INDIA :												
11.Chowgule (Goa)	-	F/L (63.5)	1967	0.5	1	1670	2.5	109.7	15.23	-	D, 3.05 x 9.15 m	Lurgi
U S A :												
12.Silver Bay (Minn)	Reserve Mining.	M (65.5) M	1956 1960	37.5 5.5 (10.0)	6 2	- -	1.83 2.44	94 172.2	-	28 27	(88.0) D(3)AG D(3)	Mckee
13.Eagle Mills (Mich)	Cleveland Cliffs.	F(64/66)	1965 1962	0.80 1.5	1	2424	1.83	125.0	19.37	28	(80.0)D1(4)	McDowel
14.Groveland (Mich)	Hanna Mining.	F/M(60)	1963	2.0	1	6278.0	3.06	209.0	25.25	34	(75.80) D(4) 3.05x9.45 m	Dravo
15. Atlantic city(Wyo)	U.S.Steel	M(65)	1962	1.50	2	2272.5	1.83	94.0	21.25	32	D(6)2.74 x 9.45 m	A G Mckee.

Table 4 (Cont'd)

1	2	3	4	5	6	7	8	9	10	11	12	13
16.Eagle Mount (Calif)	Kaiser Steel	F.M.	1965	2.2	1	6667	3.05	272	24.54	45	-	Dravo
17.Pilot Knob (Mo)	Hanna Mining.	M	1968	1.2	1	3637	3.05	114.3	31.66	19		
18.Black River Falls (Wis) HYL	Inland Steel		1969	0.75	1							
USSR :												
19.Sokolovsk	-	M	1964-7	6.3	7	2850	-	108.8	26.2			
20. Krivoi Rog	-	M(64)	1965-8	7.4	4 2	- -	- -	108.8 108.8				
21.Krivoi Rog	-	M	1972	4 0	-	-	-	-				
22.Kechkanar	-	M(63)	1965-7	2.7	4	2046	-	6.5				
SWEDEN :												
23.Kiruna	LKAB	M	1965	1.5	1	4545	2.44	178.3	25.49	28	D(6)2.74x9.15m	Head Wrightson Mckee.
NORWAY :												
24.Mo-I-Rane	Norsk Jernverk	M(67)	1964	0.6	1	1820	-	145.9	12.38		D(3)3.05 x 7.95	Simon Engg.
25.Liberia Buchanon	Lamco	F/L	1967	2.0	1	6060	3.36	3555	17.07	53	- -	Dravo
PERU :												
26.Marcona	Marcone Mining.	M M	1963-6	3	2 1	-	2.44 3.05	130 238		25 44		Lurgi/ Dravo
27.Hierro Perr-u	-	M/F	1963	1.2								
28.San Ni-cholas		M/F	1966	2.8								
CHINA												
29.P.R.China Tech.Import.		F/M	1968	1.1								
MEXICO :												
30.Hoyolata y	Lamma	M	1970	1.1	1	[illegible]	3.06	180	18.56	20	- -	M Cree.
31.Pena Colarede		M	1974	1.5								
32.Man Zenillo												
33.HyLSA colima		M/F	1970	1.5								
ITALY :												
34.Follonice	Montecatini	M (Artificiel)	1964	0.33	1	1000	1.8	50.4	19.85	-	-	Head Wrightson- Mckee

Legend : Di = Disc, D = Drum pelletizer

(75) D(6) 2.74 x 9.45 m means

75% -325 mesh Drums, 6 nos, 2.74 m dia x 9.45 m long

F = Hem, M = Magnetite, L - Limonite

M(64) = Magnetite (64% Fe).

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Table 5 - Grate Kiln

Plant	Company	Material type	Start up year.	Capacity mt/y.	No. of kilns.	Capacity unit t/d.	Grate W	Grate Area	Kiln dia	C.S. area	Vol.	L	L/D	Sp. Capacity t/m³/day	Cooler Mean dia	Cooler Area	Balling installation	Constructor.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
USA :																		
1.Butler (Minn)	Hanna Mining	M	1967	2.6	1	7070	4.87	144	6.1	29.4	1068	34.5	5.96	7.37	17.08	108.5	-	-
2.National (Minn)	"	M	1969	2.2	1	6480	4.57	144	6.1	29.4	1060	34.3	5.96	7.04	17.08	108.5	-	-
3.Minntac (Minn)	UssTEEL	M	1967	5.6	5	5790	5.03	107.2	5.04	26.6	772.5	30.2	5.48	7.06	15.25	90.7	D(2) 5.75 x 9.45 m	-
4. "	"	M	1972	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-
5.Eveleth (Minn)	Eveleth(Taconite)	M	1968	1.5	1	5480	5.06	107.2	5.04	26.0	772.5	30.9	5.48	7.05	15.25	90.7	D(5) 5.72 x 6.45 m	-
6.Empire (Mich)	Cleveland Cliffs.	M(65.6)	1964-66	2.4	1 1	8130	5.92 5.66	90.3 96.5	5.18	21.16	615	30.5	5.64	6.36	12.5	65.7	(96) D	
7.Pioneer (Mich)	"	F(Natural) fines.	1965	1.4	1	4940	5.06	179	4.80	18.77	588	28.7	5.88	7.88	13.5	68.7	D1(6) 5.48φ	
8.Republic (Mich)	"	F (Conc) (60)	1962	2.25	2	3410	2.64	125.5	4.57	16.8	462	26	6.12	7.28	13.5	65.7	(80) D	-
9.Humboldt (Mich)	"	F (62-5)	1960	0.8	2	1210	2.64	45.4	3.05	7.3	290	29.5	13.06	4.17	7.7	26.5	(78) D(4) 5.74x9.15 m	Allis Chalmers/Makee.
10.Keewatin	National Steel Corpn.	M	1967	2.4	-	3640	belt drying furnaces (2) Rotary hearth furnaces(2 Shaft Stoves (8)		-	-	-	-	-	-	-	-	D(8) 5.06 x 9.15 m	Mid Land Ross.
CANADA :																		
11.Adams (Ont.)	Jones Laughlin	M(66)	1964	1.26	1	3780	3.06	71.2	[illegible]	21.16	615	30.3	5.64	6.15	12.0	65.7	-	-
12.Sherman	Cleveland Cliffs	M	1968	1.2	1	3640	3.05	62.5	4.57	16.6	462.5	28.0	6.12	7.87	12.5	65.7	-	-
13.Knob Lake	-	F	1973	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
JAPAN :																		
14.Kobe Steel.	Nadahama	F(natural fines)	1968	1.2	1	3640	5.06	125.4	5.18	21.16	62.6	29.5	5.64	6.2	12.5	87.4	-	-
15. "	Kakagawa	"	1970	3.0	1	9160	4.57	27d.5	6.61	34.4	1880	46.5	6.04	5.76	17.08	160.8	-	-
16.Hirohata	-	Mixed ore	1972	5.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWEDEN :																		
17.LKAB	Svappavaara	M	1969	1.6	1	5450	4.57	144	6.1	29.4	1060	34.3	5.96	6.1	17.08	108.5	-	-
NORWAY :																		
18.Sydvaranger	-	M	1969	1.2	1	3640	3.06	71.5	4.88	18.77	588	28.7	5.80	6.76	12.5	65.7	-	-
AUSTRALIA:																		
19.Broken Hill	-	F(natural fines)	1968	1.5	1	5450	5.03	160.3	5.44	26.0	764	30.0	5.42	7.13	15.25	90.7	-	-
LIBERIA :																		
20.Bong Range	-	M/F	1971	2.0	1	6060	4.57	155.5	6.1	29.4	1060	34.3	5.96	6.67	17.08	108.5	-	-
INDIA :																		
21.Noamundi	TISCO	F	1972	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BELGIUM :																		
22.Clabecq	-	Mixed ore	1970	2.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

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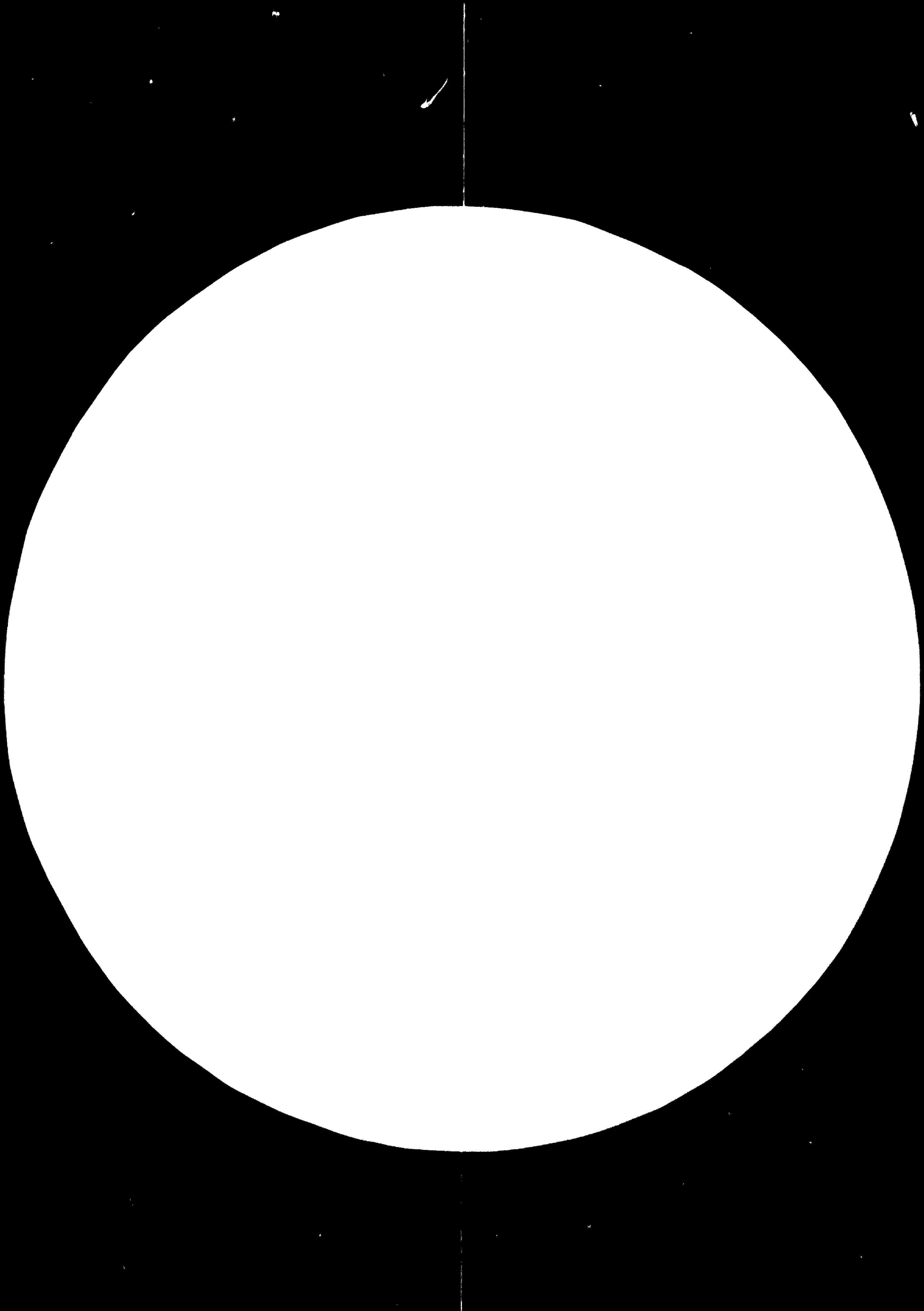

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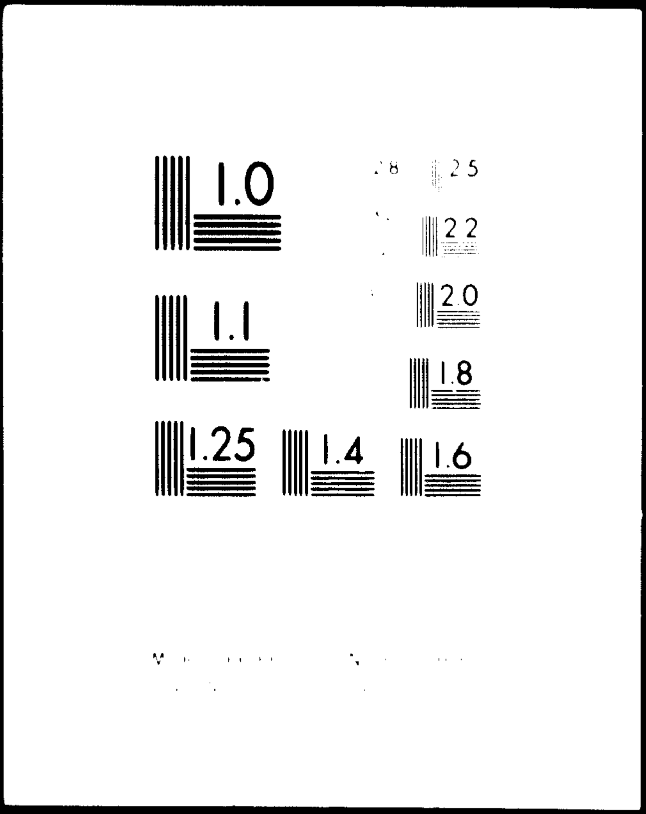

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ANNEXURE "B"

SOME ASPECTS OF RECENT ADVANCES IN THE FIELD OF SPONGE IRON PRODUCTION PROCESSES

1. Introduction

Direct reduction for the production of sponge iron can now reasonably claim a breakthrough so far as the gaseous direct reduction processes are concerned such as the HYL, Midrex, Purofer, Exxon-Fior, NU Iron, HIB, Armco, etc. In examining the direct reduction processes, the following factors are important:

a) Direct reduction processes and their contributions to the growth of the world's steel industry should be viewed in a proper perspective and further that these processes do not offer a universal panacea for all ills retarding the growth of the steel industry, particularly in developing countries.

b) Some of the direct reduction processes are still cutting their teeth and remain techno-economically unproven despite contrary claims particularly those based on solid reductants (non-coking coals and fossil fuels) although there are some exceptions. Utmost caution is required in advocating their applications, inter alia, in developing countries some of which have already paid a heavy price in such processes and plant installations having been scrapped within a year or two of their commissioning.

c) Direct reduction per se should be considered on the basis of offering possibility of relatively minor complementary growth to the conventional iron and steelmaking processes; the latter undoubtedly provide the main sinews of the steel industry's current status and future growth and will continue to do so in the decades to come.

d) Direct reduction processes will in the foreseeable future not be able to displace the blast furnace technology and any such talk on technical platforms tends to mislead many in the developing countries.

e) Direct reduction processes should be considered for supply of sponge for steelmaking to feed the merchant mills in view of the limitations of the module sizes inherent in direct reduction processes (much lower in solid reductant based processes than for gas based direct reduction processes).

f) The choice of technology (direct reduction processes and/or conventional iron and steelmaking) should be related to the scale of operations of the steel industry and the markets it seeks to serve (home and export markets).

A comprehensive 1973 study[1] had indicated that global scrap supply would balance the demand upto the mid-1980s, although regional

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[1] Battelle Institute Frankfurt, Reduction Processes Outside the Blast Furnace and Their Impact on Future Iron and Steel Production in the World, Special Report 1973

shortages would be seriously met with periodically; at the same time, scrap quality would deteriorate requiring better preparation facilities and higher prices for high grade pedigree scrap.

Due to the relatively low levels of steel consumption and engineering activity in developing countries, the quantities of all scrap generated - circulating, process and capital scrap - are small while the arrangements for collection and preparation are generally inadequate.

Mid 1974 imported steelmelting quality scrap cost over 200 US$ per ton c.i.f., in many developing countries. During early 1975 scrap prices dropped to almost half due to the world-wide recession, but have somewhat risen since. Steelmaking from scrap requires much less energy than from iron ore via pig iron or highly metallized sponge iron in arc furnaces. Scrap is normally a preferred feed material. But due to increasing use of continuous casting the world over, internally generated plant circulating scrap is decreasing. Viewed in the above context, sponge production for steelmaking quality in particular, has assumed considerable importance and received impetus during the last decade.

2. Direct Reduction of Iron Ores and Sponge Production

In examining the developments in the field of direct reduction processes, a clear distinction must be made of direct reduction sponge for (a) blast furnace charge and (b) for direct steelmaking in the electric steelmaking; the former is not so susceptible to operational variables and difficulties since the blast furnace stack can digest a variety of burden feeds (partially or highly metallized), provided their physical strength is assured. Such a favourable criterion would apply in the case of the new sponge iron plant commissioned in November 1974 - Nippon Kokan KK direct reduction plant at Fukuyama (Japan) whose rotary kilns are fed, inter alia, with all the mill residues/waste products of the steel plant (flue dusts, coke breeze, LD fines, mill scale, ore/pellet/sinter fines and steel plant wastes, sludges, etc.); this plant effectively reduces the environmental pollution, utilizes the plant wastes and residues and provides a well metallized blast furnace feed for iron smelting. Some of the fines used are below -325 mesh and are pelletized along with other fines prior to charging in the rotary kiln, The technology employed at this plant is based on a grate type preheater and rotary kiln operations. The largest of its type; this plant has a daily rated capacity of 1,100 tons of sponge. The plant uses ore fines and particulates, mill residues and scale; these are mixed with iron ore, crushed, ground and pelletized into green balls of about 13 mm diameter. These balls are heat hardened in the preheater and charged into the rotary kiln along with coal. Air tubes installed inside the kiln wall heat the air which in turn heats up the coal. The CH_4, C_mH_n and CO are combusted to provide the temperatures to effect the reduction in the range of 1200°C. The reduced pellets have a metallization of over 90% and are used as the feed for the blast furnace. Basic operational results that are significant to adjudge its performance are, however, not available about this plant.

It is reiterated that direct reduction processes that yield a well metallized sponge for the iron blast furnace are not operationally so critical; the determining factors in such processes are the costs and overall economics in balancing the total cost of the metallized burden with the savings in the coke rate and increased productivity (hot metal) and ensuring overall favourable economic results:

The new plants based on solid reductants rotary kiln operation that have gone on stream during 1974 and whose operational data have not so far been adjudged, however present interesting potentialities, these are the Fukuyama plant of Nippon Kokan (Japan) referred to above and the Griffith Mine SL/RN plant rotary kiln plant in Canada with the production capacity of 350,000 tpy of prereduced pellets. Both these plants will prepare the prereduced pellets for ironmaking in the blast furnace and their operational results and performance will be watched with great interest.

Thus, it is highly important to understand the differences between a highly metallized product (sponge) for direct steelmaking in the electric arc steelmelting furnace and partly metallized product for ironmaking in an electric submerged arc ironsmelting furnace; the two products are different from one another chiefly in respect of the degree of metallization and the end products they directly produce, viz. steel and pig iron respectively. This distinction is to be clearly understood in view of the anomalous claims made in respect of their success and failures vis-á-vis the metallization technology. Direct reduction represents almost the complete solid state reduction of the oxides of iron in the ore: the directly reduced sponge iron is suitable for charging to a steelmaking furnace for melting and refining to steel. The prereduction is the partial reduction of iron ore in the solid state; the prereduced sponge is suitable inter alia for ironmaking. Although prereduction has received less publicity than the direct reduction processes, steady progress has been made and industrial prereduction plants have well been operating successfully on a commercial scale for years now. In the ferro-alloy industry for example, pre-reduction in rotary kilns prior to electric smelting of the ferro-alloy in the sub-merged arc electric furnace, has been successfully employed for both manganese and chrome ores primarily in Japan. Pre-reduction of lateritic nickeliferous ores in rotary kilns has been carried out in New Caledonia and also in Greece for years now. Pre-reduction of the same ores is currently being done in shaft furnaces in the Dominican Republic.

In the case of the iron blast furnace, considerable pre-reduction takes place in the shaft of the blast furnace itself and so the advantages of a pre-reduced charge are not so marked as in the case of electric sub-merged arc furnace for ironsmelting where the shaft height and effects are minor. The charge of a fully and directly reduced sponge to the blast furnace is another question which needs a separate techno-economic study and appraisal.

In the case of iron smelting in a sub-merged arc electric smelting furnace, which is employed in the process flowsheet to produce ferro-vanadium via the vanadium enriched slag or ferro-nickel, the intermediate product pig iron can be used for steelmaking such as by the LD oxygen steelmaking process. In all these cases, the degree of metallization of the metallized product/sponge could differ either by design or attainability, depending upon different process variables; in both cases, sometimes a virtue is made of a necessity and vice-versa. It also needs due emphasis that since contaminants are not physically removed in the direct reduction processes, it is important that a high grade, uncontaminated, low gangue raw material (lumpy high grade iron ore and/or pellets) is used for direct reduction to yield acceptable quality sponge. These criteria would preclude the use of iron ores or pellets which contained high gangue despite their high Fe content. The costs of producing such low gangue feed and of prior beneficiation of the ore fines to yield the requisite low gangue concentrate (capital and production costs) must be fully taken into account by those claiming to offer a process that can use any type of low or high grade iron ores and reductant (non-coking coal, lignite, anthracite, etc.) for the production of directly reduced sponge and its conversion into steel in the electric arc furnace. Such unqualified statements and business claims are highly misleading specially for developing countries. In this connexion1/ the following general technical data for some typical specifications for the iron ore/pellet feed available from different countries, for sponge production to produce steel in the electric furnace, are furnished herewith; relaxations of the specifications vis-à-vis the price structure are, however, possible and have to be mutually negotiated between the supplier and the purchaser.

1/ Compiled from different commercial sources

Case A

Iron oxide pellets

Size - +1/8" to -7/8" = 98%

Compressive strength — Range - 150 - 950 pounds
Average-350 - 500 pounds

- Total iron - at least 66%
- Oxide content - hematite 95%
- Sulphur - as low as possible - less than 0.03%
- Phosphorous - as low as possible - less than 0.08%

Volumetric weight- 1.8 to 2.3 ton/cu m.

Iron oxide Pellets' chemical analyses % (Range)

Fe - 65 - 67
SiO_2 - 3 - 4
Al_2O_3 - 0.05 - 1.0
S - 0.01 - 0.03
) - trace- 0.01
CaO + MgO - 0.5 - 1.0
Cu - trace 0.01
As - trace
Moisture - 0.1%
Size - +3/8"to -5/8"

Case B

Average analysis - Iron Oxide Pellets - %

Fe - 67.3
SiO_2 - 1.6
Al_2O_3 - 0.3
CaO + MgO - 1.9
P - 0.05
S - 0.01
Estimated Basicity - 1.0

Case D (Cont'd)

As - 0.001
Cr - 0.013
Moisture - 2.0
Bulk Density - 1.9 - 2.0 g/cm^3
Tumbler test - T: 92% + 6.3 mm
Compressive strength - 300 kg

Case E

Iron oxide pellets

Chemical Analysis (Dry basis) % Average	Pellet High quality	Pellet Lower quality
Fe	65.5	64.00
SiO_2+Al_2O_3	3.0	6.00
S	0.0005	0.0005
P	0.03	0.03
Moisture	0.05	1.00
CaO	2.00	2.00
Alkalis	0.05	0.05
Physical size	90% - 18mm 5% - 5 mm	90% - 18 mm 5% - 5 mm
Compressive Strength	500 pounds	500 pounds

Case F

Iron oxide pellets

Average chemical analysis	%
Fe	67.2
P	0.05
S	0.01
CaO	1.79
MgO	0.75
Al_2O_3	1.03
SiO_2	1.28
Basicity $\frac{Cao + Mgo}{Al_2O_3 + SiO_2}$	1.1
Porosity	24.92

Physical properties

size distribution

+7/8" - 1%
+5/8" - 17%
+3/8" - 97%
+1/8" - 100%
-1/8" - 0%

Case G

Iron oxide pellets

Average chemical analysis		% (oven dried - 100 mesh sample)
Fe	-	66.88
FeO	-	1.18
Fe_2O_3	-	91.67 1/
Fe_3O_4	-	3.81 2/
SiO_2	-	2.23
S	-	0.004
P_2O_5	-	0.19
Al_2O_3	-	2.10

Case H

for

Pellets specifications/sponge production to produce steel in electric arc furnace

The column "A" shows the purchaser's specifications and column "B" shows what one iron ore/pellet supplier is offering; the price ranges (premium and penalty clauses) have to be negotiated in each case. In furnishing these general technical data, it is pointed out that the latter could vary from one case to the other depending upon many factors including the sources of pellets' supplies;

	"A"	"B"
I. Chemical (Dry)		
(a) Iron (Fe)	65.5% min.base 66.0% Fe hematite 95% min. hematite	65-66% base 65.5% Fe (95% of total iron will be in the form of hematite)
(b) Silica + Alumina ($SiO_2 + Al_2O_3$)	4% max.average subject to note below.	4% average subject to note below.
(c) Sulphur (S)	0.03% max.	0.04% max.
(d) Phosphorus (P)	0.08% max.	0.08% max.
(e) Pb, Zn, Cu, Sn, Cr and As	Combined total 0.01%	Combined total 0.01% max.

1/ Hematite does not include the Fe_2O_3 tied up with FeO in the magnetite.

2/ Calculated assuming that FeO is unstable and that each FeO mole would tie with it Fe_2O_3 mole to form Fe_3O_4.

		"A"	"B"
(f)	Moisture i) during fair season	2% max.	2% max.
	ii) during rainy weather	6% max.	3% max.
(g)	Basicity CaO+MgO	0.5 to 1.2 (0.5 minimum)	0.5 to 1.2
II.	Physical and Metallurgical		
(a)	Size	+21 mm:1% max. -21 mm+5mm 94% min. -5 mm: 1% max. (at port of unloading -5mm size: 5% max.)	+21 mm:1% max. -21 mm+5 mm 94% max. - 5 mm: 5% target +21 mm and -5 mm not to exceed 6%
(b)	Compression Strength	210 kg/pellet average min. below 80 kg not to exceed 5%.	210 kg/pellet av. min. below 80 kg/pellet not to exceed 5%.
(c)	Reducibility (Cakustin method)	55% min.	55% min.
(d)	Swelling index (Cakustin)	15% max.	15% max.
(e)	Compression strength (after reduction) (Cakustin)	35 kg/pellet min.	35 kg/pellet min.
(f)	Bulk density	1.9-2.3 gms/cc.	1.9 to 2.3 gms/cc.

Note:

a) The max. average for silica plus alumina shall not exceed [illegible]% per batch of 125,000 tonnes.

Cont'd

Note:

a) Total silica plus alumina content shall not exceed 4% average for a batch 500,000 tonnes.

Cont'd

b) Rejection limit is 4.5% (silica plus alumina) max. for each shipment. However, supplies between 4.5 to 4.75% (silica plus alumina) will be allowed for the first 2.5 million tonnes supply, provided that the tonnage with 4.5 to 4.75% ($SiO_2+Al_2O_3$) shall not exceed 10% of the quantity to be supplied, and also provided tat the average of SiO_2 + alumina for each batch of 125,000 tonnes is maintained at 4%. The main factors are a) Iron (Fe) content 65.5% min. b) max. of $SiO_2+Al_2O_3$ combined on a batch of 125,000 MT is 4% and c) basicity 0.5 min. Any other stipulation contradicting these three main factors are to be ignored.

b) Rejection limit is 4.5% (SiO_2+alumina) of each shipment. However, supplies between 4.5 and 4.75% (silica plus alumina) will also be allowed during supply of first 2.5 million tonnes provided that such quantity shall not exceed 10% and provided that average for batch is maintained at 4%.

Case I

A typical metallised sponge iron pellets specification for use in electric arc furnace

Size	-	+1/8" to -7/8" = 90%
Compressive strength	-	above 35 kg
Metallisation	-	84 to 92%
Total Fe	-	over 87%
Metallic Fe (Fe+Fe from Fe_3C)	-	over 73%
Gangue + lime added	-	less than 7.0%
Gangue basicity	-	0.5 to 1.3
Carbon	-	1.3 to 2.5
S	-	As low as possible - less than 0.03%
P	-	As low as possible - less than 0.08%

Some of the recent developments in the field of sponge production processes

The sponge production processes are to-day literally offered by the dozens to meet any situation (types and grades of raw material, fuels available, etc.

A relatively new entrant amongst the direct reduction processes is the Kinglor Metor Direct Reduction process; ILTA - Tubificio Arvedi, Italy, has placed an order with Kinglor Metor (joint venture between Danieli and Monteforno for a direct reduction plant, comprising two basic modules, each of 40,000 tpy sponge capacity) depending upon the quality of the raw materials. The iron ore charge will be either Italian or imported lumpy ore/pellets and the coal will be European based. The direct reduction sponge is expected to feed the two 50-ton electric arc furnaces at Cremona to produce steel for black and galvanized steel tubes.

At a recent Direct Reduction Seminar organized by ILAFA at Porto Elégre in May 1975, latest developments in some of the Latin American countries were highlighted. An attempt is made here to outline some of their salient points albeit with no claims made about their veracity by the writer. How far and to what extent the planned sponge capacity figures would actually be achieved can only be conjectured albeit optimistically.

Argentina

There is no direct reduction plant currently in operation; one Midrex plant of 300,000 tpy capacity is under construction and is likely to start in 1976. An identical HYL plant is reportedly under negotiation. Another plant (ACINDA) will have a crude steel capacity of 600,000 tpy with a captive Midrex sponge based capacity of 450,000 tpy. It is expected that a total of two million tpy steel capacity will be based on sponge/scrap charge by 1979/80.

Mexico

There are currently five sponge plants (HYLSA) in operation based on the HYL process aggregating about 1.5 million tpy capacity. Another HYL plant of 700,000 tpy of sponge capacity is under construction at present which will take the HYL sponge capacity to over 2.2 million tpy by the end of 1976. Another sponge plant (HYL-TAMSA) is planned with a capacity of 300,000 tpy. It is expected that by 1982, about 5.1 million tpy sponge capacity would be set up based on the HYL process in the country.

Venezuela

A 400,000 tpy sponge plant recently taken over by the Government (HIB plant of U.S. Steel) is currently in operation to provide blast furnace feed for iron smelting; data about its techno-economic performance/success are lacking. One HYL plant with a sponge capacity of 450,000 tpy and one Midrex plant of 400,000 tpy sponge capacity are scheduled to start end 1976. A 400,000 tpy sponge capacity is expected to be on stream by end of 1975 based on the EXXON/FIOR process. It is planned by the Government that by 1978 end, a sponge capacity of 3.1 million tpy would be established. The capacity figures for 1980 and 1985 are projected at six million tpy and 8.25 million tpy respectively.

Chile

There is no direct reduction plant planned or currently in operation. Some gas reserves have been located on the extreme south over 3,000 km away from the iron ore deposits in the country. Some off-shore oil drilling operations are under way.

Colombia

There is no direct reduction plant currently operating in the country. Some thoughts are being given to solid reductant based direct reduction capacity (0.4 to 0.5 million tpy) considering that the country has over 60 billion tons of proved coal reserves. Colombian iron ores, however, are highly phosphoric and unsuitable for direct reduction; mineral beneficiation to get low phosphoric concentrate/pellets is most difficult in view of the complex mineralogical association of the phosphorous in the metrix. Gas reserves are reported at 2×10^{12} cu.ft. A comprehensive UNIDO sponsored study of Colombian steel industry including sponge capability is currently under way.

Brasil

CONSIDER is reportedly providing the following guidelines for direct reduction in the country:-

(a) Use of coke oven gas and blast furnace synthetic gas mixtures for reforming and sponge production - Midrex is conducting a feasibility study thereon for USIMINAS;

(b) Gasification of Brazilian non-coking coals for direct reduction;

(c) Gasification of reportedly surplus heavy oil for direct reduction (Cosigua plant based on Purofer, 300,000 tpy capacity);

(d) Natural gas piped from Bolivia or transported through LPG for direct reduction;

(c) Use of low shaft furnace gas for direct reduction.

- The current capacity (SL/RN) of Acos Finos Piratini is around 67,000 tpy; the capacity actually achieved is, however, reportedly less at present· doubling/tripling of this capacity is reportedly planned by Piratini (SL/RN).

- USIBA plant (HYL)with 250,000 tpy sponge production achieved its rated capacity 2-3 weeks after starting in March 1974 - a commendable performance.

- COSIGUA plant based on Purofer process with a sponge capacity of 300,000 tpy using surplus heavy oil should go on stream end 1975; a second unit is planned for start up 1978 of equivalent sponge capacity.

- A Midrex sponge plant of 400,000 tpy is planned near Sao Paulo.

Brazil is actively planning to increase its raw steelmaking capacity to about 25 million tpy by 1978. The original programme formulated by CONSIDER (Conselho Nacional de Industria Siderurgica, now changed to Conselho de Nao Ferrosos e de Siderurgia with the same acronym) has been accelerated and includes simultaneous expansion of Government owned steel plants, USIMINAS (Usiminas Siderurgicas de Minas Gerais), COSIPA (Companhia Siderurgicas Paulista) and CSN (Companhia Siderurgicas Nacional). Brazil is today the largest steel producer in South America and will be, before long, one of the leading in the world.

Midrex Corp.[1] announced recently that it has received a letter of intent from USIMINAS (Usinas Siderurgicas de Minas Gerais S.A.) of Belo Horizonte, Brazil, confirming the commitment of USIMINAS to enter into a series of agreements with Midrex including a construction contract for two 400,000 tonne/year modules using the MIDREX Direct Reduction Process.

The two modules to be constructed at Ipatinga, Brazil, will apply coke-oven gas as a process gas substitute for natural gas. Operations of the direct reduction facility is expected to begin in 1978, when Phase III of the USIMINAS expansion plan is complete.

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[1] Iron and Steel Engineer - November 1975 -p. MM-19

The MIDREX Direct Reduction Process as used by USIMINAS will be the first commercial installation of its kind in the world. USIMINAS is studying the feasibility of using direct reduction in integrated steel mills. Savings in metallurgical coal consumption by more effective use of coke oven and blast furnace gases could be substantial.

USIMINAS will use the highly metallized iron in blast furnaces and LD converters for the production of high quality steel. Through use of iron produced by this process, USIMINAS will be able to increase steel production by as much as 20% in the range of US$50 million/year.

Under the agreement, Midrex will provide USIMINAS with engineering, plant equipment and personnel for supervision of erection, start-up and training of USIMINAS employees Technological process developments related to the utilization of coke-oven gas in the MIDREX Direct Reduction Process will be applied at USIMINAS plants in a joint undertaking by Midrex and USIMINAS. Know-how relating to the use of iron in the blast furnace will be a part of this collaboration. Technology developed will be available to other steel plants in Brazil and throughout the world following refinement of this developmental programme.

Besides coke-oven gas, Midrex scientists and engineers are currently conducting pre-engineering studies for modules using the MIDREX Direct Reduction Process based on coal, off-gas from electric iron smelting furnaces and naphtha. Other fuels the MIDREX Direct Reduction Process claim to utilize include heavy oil, propane and off-gas from refineries.

Peru

There is no direct reduction capacity in the country today. Results of oil and gas surveys and exploration are awaited. Meanwhile, one direct reduction plant based on solid reductant rotary kiln operations is planned using high grade (67% Fe) Marcona pellets and coke breeze stocked at Chimbote.

Bolivia

There is no direct reduction capacity at present in the country. A feasibility study of gaseous sponge plant based on Mutun iron ore and local natural gas is reportedly under way.

Solid reductant rotary kiln based direct reduction processes claim the use of iron-bearing steel plant sludges and wastes and further that their processes are cheaper than projected coal gasification direct reduction processes currently under development; however, there are heavy heat losses and adverse heat balance and considerable Research and Development work are needed to develop recuperation systems to improve the overall heat balance of rotary kiln operations.

- Sponsors of Purofer process claim the use of coke oven gas at their direct reduction facility at Oberhaussen (FRG); Purofer fuel oil, electric pig-iron submerged arc furnace gas for direct reduction. Purofer sponge, it is claimed, could be used in a hot blast cupola; it could also be hot-briquetted to reduce its reoxidation.

Sponsors of Midrex process claim over eleven million tpy current capacity (planned and installed) and that Midrex could use gasified coal gas, naphtha, etc. R and D work is under way in collaboration with CVRD on raw materials processing, hot briquetting of coal fines and sponge.

Sponsors of HYL process claim modules of 700,000 tpy sponge capacity and an almost equivalent planned and installed sponge capacity as of Midrex. HYL's R and D teams are working on twenty research and development projects aiming at reducing the fuel/energy consumption figures, computerization of HYL plant operations.

EXXON-FIOR Sponsors trace their development from a pilot plant of five tpd capacity on to a demonstration plant of 100,000 tpy capacity, claim the use of iron ore fines for fluidised bed direct reduction and refer to their 400,000 tpy sponge plant under installation in Venezuela; they claim that a 14 million tpy capacity could be harnessed by EXXON-FIOR in the years to come.

Claims[2] concerning the gasification of coal (mostly non-cooking) to produce synthetic natural gas have to be viewed with caution. It has recently been reported by M.I.T. and Union Carbide studies that synthetic natural gas of pipeline quality will cost seven times more than natural gas (3.60 US$/million BTU for synthetic natural gas compared to 0.5 US$ per million BTU for natural gas). El Pasa Natural Gas Company's Four Corner operations in New Mexico state that their original capital cost estimates at 209 million US$ have now escalated to cost 1 to 1.2 billion US$.

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[2] Industry Week - 1 September 1975 - p.46

Following the triple increase in the oil prices during the last couple of years, interest in coal as a source of energy for iron- and steelmaking and direct reduction has been greatly aroused. The gasification of coal to yield a high calorific value gas for use in the iron and steel industry and methanation of the gasified coal gas to yield a substitute natural gas suitable for reforming and eventual use for gaseous direct reduction, have led to potentially interesting developments equally to a plethora of claims; many of the latter have still, however, to be proved on a commercial scale. Thus coal gasification appears to offer special promise as a long range measure for supplemental gas supply. Countries such as USA, India and others have vast reserves of coal; in the case of India, however, these resources are mostly of non-coking coals. One is faced with serious problems, ranging from heavy capital finances and investments needed to establish coal gasification on a commercially acceptable scale, to the lack of sufficient water resources in all areas where coal gasification plants could be advantageously located. A co-operative agreement between the gas industry and the US Department of Interior was initiated in 1971 at a cost of 30 million US$ annually for four years with the objective of developing a process for producing high BTU value pipeline quality gas on a demonstration phase basis. At present, two pilot plants are operating. It is expected that a typical commercial plant which will produce 250 million cu ft of high BTU gas per day from 16,000 tons of coal, will cost a billion US$. Twelve such plants will produce one trillion cu ft of gas annually which will, however, equate to hardly 5% of the current US natural gas consumption annually.

Meanwhile, some coal gasification plants are planned to start up by 1980 based on the Lurgi process to convert sub-bituminous non-coking coal into a low BTU gas which will be enriched in its heat content through the application of a new methanation process, to yield a pipeline quality SNG (substitute natural gas). About eighteen such coal gasification plants are being planned, some of which will use the Lurgi process. However, the heavy capital investment needed is the primary limiting factor. The Synthane process (coal to SNG) is being developed at the Pittsburgh Energy Centre (PERC) of the US Energy Research and Development Administration. A 75 ton/day synthane plant has been designed by the Lummus Co. and constructed by Rust Engineering Co. at Bruceton[1] and is getting ready to go into operation currently.

Reliable capital and operating costs for SNG production are, at present, not available. The estimated order of magnitude[2] [3] of capital cost for a 7×10^6 m^3/day SNG plant is of the order of 250 million US$. The SNG product is estimated to cost 5 to 7.5US$/$10^6$ kcal; which is about thrice the current price of natural gas

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[1] Akhtar, Sayeed, Nestor J. Mazzocco, Murray Weintraub and Paul M. Yavorski-Synthol process for converting coal to non-polluting fuels presented at the 4th "Synthetic fuels from Coal" Conference of the Oklahoma State University, Stillwater, Oklahoma, May 6-7, 1974.

[2] S. Bresler and J. Ireland, Chem. Eng. 16 October 1972, 79.

[3] D. Jackson. Engineering and Min. Journal March 1974, 175.

in the USA. The direct reduction sponge costs are extremely sensitive to the cost of gaseous reductants. The growth of economic coal gasification plants (small or medium size) could include low energy gas processes only for power/steam and heating purposes. The low-methane-yield gasification processes will need expensive methanation treatments for use in gaseous direct reduction. It is, therefore, necessary that claims for SNG processes and plants for direct reduction should be comprehensively techno-economically and commercially evaluated before wholesale acceptance.

A comparison of some leading direct reduction processes is compiled[4] in the attached tabulation (charge, energy, consumption, type of reduction reactor, etc., raw materials consumption and utilities). It must be accepted that gaseous direct reduction processes mainly hold the fields for sponge production today and hold equally good promise of future growth and planned developments.

Characteristics of coal gasification processes[5] are also tabulated in view of their recent potentialities for direct reduction of iron ores.

4/ 5/ Compiled from technical literature (different journals and magazines).

COMPARISON OF DIRECT REDUCTION PROCESSES

No.	Item	Processes using gaseous reductant				Solid reductant rotary kiln	
		HyL	Midrex	Purofer	FIOR	SL/RN	Krupp
1.	2.	3.	4.	5.	6.	7.	8.
1.	Raw materials	Lump ore/pellets	Lump ore/pellets	Lump ore/pellets	Ore fines	Ore fines, lumps and pellets	Ore fines, lumps and pellets
2.	Desired analysis of raw materials:						
	% Fe	64 min.	64 min.	High iron contents preferred	64 min.	64 min.	64 min.
	Total gangue % (SiO_2+Al_2O_3)	4 max. preferred	4 max. preferred	Low gangue content preferred	-	4 max. preferred	4 max. preferred
	% SiO_2	-	-	-	2.0 - 2.5		
	% Al_2O_3	-	-	-	0.5 - 1.5		
	% S	-	0.015 max.	No restriction on sulphur claimed			
	% P	0.05 max.	0.05 max.	As low as possible	0.01-0.03	As low as possible	As low as possible
3.	Size range of iron bearing materials, mm	12-50 (lump ore) 9-16 (pellets)	6-30 (lump ore) 6-30 (pellets)	6-25 (lump ore) 8-20 (pellets)	0.044-12.7 (minus 0.04mm. should not exceed 20%)	wide size range acceptable	wide size range acceptable
4.	Reductant used	Reformed natural gas	Reformed natural gas	Reformed natural gas or gas from liquid hydrocarbons	High hydrogen content gas from hydrocarbon feed stock such as heavy crude oils, fuel oils, naphtha, LPG and natural gas	Non-coking coals and fossil fuels	Non-coking coals and fossil fuels

COMPARISON OF DIRECT REDUCTION PROCESSES (Cont'd)

No.	Item	Processes using gaseous reductant				Solid reductant rotary kiln	
		Hyl	Midrex	Purofer	FIOR	SL/RN	Krupp
1.	2.	3.	4.	5.	6.	7.	8.
5.	Desirable properties of the reductant	Low sulphur	Low sulphur	Low sulphur	Low sulphur	Low sulphur	Low sulphur
6.	Gas reformer	Ni-catalytic recuperative type	Ni-catalytic recuperative type	Catalytic regenerative type	Ni-catalytic	-	-
7.	Reforming agent	Steam	Recycled top gas	Air or recycled top gas	Steam/partial oxidation	-	
8.	Reducing gas analysis:			Reforming with air Reforming with top gas	Essentially hydrogen		
	% CO	14	24-36	21 43			
	% H_2	75	40-60	39 49			
	% N_2	-	12-15	38 3			
9.	Type of reduction reactor	Static bed	Countercurrent moving bed (shaft furnace)	Countercurrent moving bed (shaft furnace)	Fluidised bed	Rotary kiln	Rotary kiln
10.	Specific consumptions (approx.) per tonne of Fe total in sponge iron:						
	Natural gas	4.4-5.7x10^6 kcal	3.4-3.5x10^6 kcal	3.3x10^6 kcal	4.10x10^6 kcal	3.5-4.8 x10^6 kcal/ton (95% metallization)	3.5-4 x10^6 kcal/ton (95% metallization)
	Electric power	9-13 kWh	130-136 kWh	100 kWh	40 kWh	55 - 65 kWh	55 - 65 kWh
	Water (make-up)	3-4 m^3	1.6-1.7 m^3	1.5 m^3	4-35 m^3	-	-
	Catalysts and chemicals	0.04-0.05 kg	0.02 kg	0.01 kg	$ 0.75 (U.S.)	-	-
	Refractories	1.10-1.40 kg	0.55-0.57 kg	1.00 kg	-	High Actual figure NA	High Actual figure NA

Main characteristics of selected coal gasification processes

Process	Koppers - Totzek	Lurgi	Winkler	Texaco
Developer	Krupp Koppers GmbH, Essen, Federal Republic of Germany	Lurgi Mineralöltechnik GmbH Frankfurt/Main	Bamag Verfahrenstechnik GmbH	Olin Mathieson Chemical Corporation
Feedstock	Bituminous and lignite, mazout, shale, domestic waste, ash content to 40 per cent	Bituminous or lignite in narrow grain sizes, high ash fusion point	Bituminous or lignite up to 8 mm, ash up to 40 per cent	Lignite and bituminous (probably with a high volatile content), dust
Type of gasification, conversion conditions	Oxygen-steam or air-steam coal dust gasification, atmospheric pressure, temperature 1 500-1 900° C	Oxygen-steam or air-steam gasification, pressure 10-40 atm, temperature 760-900° C	Pressureless fluidised bed gasification, temperature 850-1 100° C	Pressure gasification of coal dust (70 per cent less than 0.075 mm), pressure 15-85 atm
Reactor	Twin or four-burner jet reactor, up to 50 000 Nm^3 gas	Gasifier with rotary grate, diameter up to 4 m, capacities up to 35 000 Nm^3, planned 5 m diameter (75 000 Nm^3)	Shaft reactor with section area up to 25 m^2, up to 20 m high, capacity up to 3 500 Nm^3/h	Chamber reactor with removal of molten ash
Feedstock consumption per Nm^3 gas	Coal 0.6 kg Steam 0.143 kg Oxygen 0.325 Nm^3 (98 per cent) Water 1.7 l including 0.7 for ash transport, closing of water circuit possible	Coal 0.64 kg Steam 0.65 kg Oxygen 0.19 kg	Coal 0.6 kg Steam 0.55 kg Oxygen 0.25 Nm^3 Water more than 1 l Electrical energy about 30 MWh/Gcal	Coal 0.5 kg Steam 0.4 kg No further data
Product yields (dry)	CO 55-66 per cent CO_2 7-12 per cent H_2 21-32 per cent N_2 1 per cent CH_4 0.1 per cent H_2S 0.5-1 per cent Calorific value 2 600 kcal/kg	CO 18-20 per cent CO_2 27-31 per cent H_2 38-40 per cent CH_4 9-10 per cent N_2 1 per cent H_2S 0.5-1 per cent Calorific value 2 800 kcal/kg	CO 30-50 per cent CO_2 15-25 per cent H_2 35-45 per cent CH_4 1-2 per cent N_2 0.5-1.5 per cent Calorific value 2 200-3 100 kcal/Nm^3	CO 38 per cent CO_2 46 per cent H_2 13 per cent CH_4 1 per cent N_2 1.5 per cent H_2S 0.5 per cent Calorific value 2 650 kcal/Nm^3
Remarks	Molten slag, considerable part of ash with hot gases; purification by normal industrial methods, thermal efficiency 75-80 per cent	Owing to pressure, a relatively high CH_4 content of raw gas, thermal efficiency 75 per cent	From existing industrial plants single reactors are in operation; the development is directed to pressure method	Applied in 1956 to get 6 500 Nm^3/h in Morgantown plants, Virginia, United States of America
Development status	16 plants in operation; recently erected: Korba Plant, India (1972); AE and CI, Ltd., Modderfontein Kafue, Zambia (1974)	14 plants were erected; inter alia, in Sasolburg, Republic of South Africa, 4 plants are under project for synthesis gas (SNG)	Commercial scale; 16 plants were erected (at present, the plants are in liquidation)	Commercial scale, but without a wider application

Process	Rummel - Otto	Ruhrgas	Babcock and Wilcox du Pont	Pintsch - Hillebrand
Developer	Union Rheinische Braunkohlen Kraftstoff AG	Ruhrgas AG, Essen, Federal Republic of Germany Gibbon Brothers, Dudley, England	Babcock and Wilcox Co.	Julius Pintsch AG
Feedstock	Lignite and bituminous 0-3 mm	Lignite and bituminous 0-0.6 mm (90 per cent)	Gas coal	Lignite, peat briquettes
Type of gasification, conversion conditions	Pressureless process, temperature up to 1 800 ° C (temperature of flowing slag)	Pressureless process, temperatures below the ash fusion temperature (1 000-1 300 ° C)	Coal dust gasification, pressureless	Gasification of briquettes at a slight overpressure temperature 1 300 ° C
Reactor	Fluidised-bed reactor, revolving bottom, [illegible]; in project up to 1 600 Nm^3/h, actually 4 000 Nm^3/h	Emulated bed reactor, 16 000 Nm^3/h	Chamber-shaft reactor, removal of molten slag, production of 2 600 Nm^3/h	Gasification in the space between the conical jackets, production of one reactor 5 500 Nm^3/h
Feedstock consumption per Nm^3 gas	Coal 0.55 kg Oxygen 0.2 Nm^3 Steam 0.6 kg	Coal 0.26 kg Steam 0.57 kg Gasification with air	Coal 0.5 kg Steam 0.14 kg Oxygen 0.27 Nm^3	Coal briquettes 0.56 kg Steam 0.78 kg
Product yields (dry)	CO 35-50 per cent CO_2 4-75 per cent H_2 9-40 per cent CH_4 0.1-0.5 per cent N_2 1.0-1.5 per cent H_2S 0.5-1.0 per cent Calorific value 2 500-2 700 kcal/Nm^3	CO 22.8 per cent CO_2 5.1 per cent H_2 8.0 per cent N_2 60.1 per cent Calorific value 950 kcal/Nm^3	CO 40.2 per cent CO_2 16.2 per cent H_2 39.4 per cent CH_4 + C_nH_m 1.1 per cent N_2 2.9 per cent Calorific value 2 580 kcal/Nm^3	CO 28 per cent CO_2 14 per cent H_2 56 per cent CH_4 1 per cent N_2 1 per cent Calorific value 2 700 kcal/Nm^3
Remarks	Industrial plant producing 16 000 Nm^3/h in Wesseling (thermal efficiency 66-82 per cent); in air gasification 1 000-1 350 kcal/h gas is obtained	Pilot plants close to existing plants; thermal efficiency 84 per cent	One plant was erected at Belle, W. Virginia, USA, E.I. Du Pont; thermal efficiency 85 per cent	Liquid products occur
Development status	Commercial scale	Commercial scale	Commercial scale, gasifier 28 000 Nm^3/h	Before the Second World War two plants were erected (Hamburg and Wesseling)

Source: Central Mining Institute, Katowice, Poland.

The following tabulation provides technical data and relevant particulars on the status of coal gasification processes:

CHARACTERISTICS OF ADVANCED COAL GASIFICATION PROCESSES*

Process	Lurgi	Koppers-Totzek	Hygas	Biggs	CSG	Synthane	Atgas	Kellogg
Type	Fixed Bed	Injection Chamber	Fluid Bed	Entrained Bed (2-Stage)	Fluid Bed Acceptor	Fluid Bed	Molten Iron Bath	Molten Salt Bath
Heat Source	Oxygen	Oxygen	Oxygen	Oxygen	Air	Oxygen	Oxygen/Air	Oxygen/Air
Temperature °C	870	1,480-1,815	980	1,650	860	980	1,375	950
Pressure, Bar	20-35	Atmospheric	70-83	70-105	10	70	Atmospheric	28-83
Input, Metric tons per day	16,300	-	12,400	12,400	27,000	13,600	-	12,700
Output								
Low Energy								
million cu m	-	-	-	-	4.25	54	35	-
kcal per cu m	890-1,780	2,560	4,000	-	3,350	4,450	1,700	-
High Energy								
million cu m	6.9	-	7	7	7	7	7	7.4
kcal per cu m	8,900	-	8,100-8,900	8,900	8,900	8,000	8,360	8,550
Comments	Some coking coal not suitable. Basic process commercial. Requires sized coal	Basic process commercial. Coal size not limiting. Low pressure.	Uses all types of coal. Relatively high methane yield.	Uses all types of coal. Relatively high methane yield.	Uses lignite. Only methanation required for SNG. Oxygen not required.	Utilizes fluid bed technology. Wide range of coals, including lignite. Minimum oxygen requirement.	Uses steel-making technology. Uses all types of coal.	Reduced temperature. Uses all types of coal. Clean CO-rich gas.

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* Based on commercial or projected commercial plants of indicated high energy capacity.

An updated list of direct reduction plants (operating, under installation, under negotiations and contracting) in different parts of the world is given below: (Compiled from technical journals - June 1977)

D-R plants in operation

As at January 1, 1977

Start-up	Company	Country	Process	Reductant	DRI capacity (tpy)
1954	Hoganas/Granges*	Sweden	Hoganas	Coke breeze	170,000
1954	Hoganas Corp.	USA	Hoganes	Coke breeze	70,000
1954	SKF/etc.†	Sweden	Wiberg	Coke breeze	90,000
1957	Tohoku-Satetsu	Japan	Rotary kiln	Coal	24,000
1957	Hylsa-Monterrey I	Mexico	HyL	Natural gas	100,000
1960	Hylsa-Monterrey II	Mexico	HyL	Natural gas	270,000
1964	Hitachi Metals	Japan	Wiberg	Coke breeze	10,000
1967	Tamsa	Mexico	HyL	Natural gas	280,000
1968	Anglo-American Corp.	S. Africa	Highveld kiln	Coal	1,000,000
1969	Hyisa-Pueble I	Mexico	HyL	Natural gas	315,000
1969	Oregon Steel Mills	USA	Midrex	Natural gas	300,000
1969	Kawasaki Steel	Japan	Kawasaki	Coke breeze	72,000
1970	New Zealand Steel	New Zealand	SL/RN	Coal	120,000
1970	Thyssen-Purofer	W. Germany	Purofer	Nat. Gas/Coke oven gas	150,000
1971	Georgetown Steel	USA	Midrex	Natural gas	400,000
1971	Nippon Steel	Japan	Koho	Coke breeze	48,000
1972	Kawasaki Steel	Japan	Kewasaki	Coke breeze	240,000
1972	Hamburger Stahlwerke	W. Germany	Midrex	Natural gas	400,000
1972	Armco Steel	USA	Armco	Natural gas	330,000
1973	Aços Finos Piratini	Brazil	SL/RN	Coal	60,000
1973	Dunswert Iron & Steel	S. Africa	Krupp	Coal	150,000
1973	Sidbec-Dosco	Canada	Midrex	Natural gas	400,000
1973	Minorca	Venezuela	HIB	Natural gas	650,000
1974	Usiba	Brazil	Hyl	Natural gas	250,000
1974	Hylsa-Monterrey III	Mexico	Hyl	Natural gas	475,000
1974	NKK	Japan	SL/RN	Coal	350,000
1975	Steel Co. of Canada	Canada	SL/RN	Coal	360,000
1975	Hecle Mining	USA	SL/RN	Coal	60,000
1975	Sumitomo Metal	Japan	Sumitomo	Coal	240,000
1975	Sumitomo Metal	Japan	Kubota	Coal	210,000
1975	Allis-Chalmers	Canada	Accar	Coal/oil/gas	550,000
1976	Dalmine-Siderca	Argentina	Midrex	Natural gas	330,000
1976	Sudbury Metals‡	Canada	Accar	Nat. gas oil	240,000
1976	Fior de Venezuela	Venezuela	Fior	Natural gas	400,000
1976	Nippon Steel	Japan	NSC	Oil	150,000
1976	Ferriere di Arvedi	Italy	Kinglor-Metor	Coal	40,000
				TOTAL	8,804,000

2 plants, at Hoganas and Oxelosund. †3 plants, at Hofors (SKF), Sandvik (Sandvik), and Uddeholm (Uddeholm). ‡The Accar plant at Sudbury uses a mixture of natural gas & oil, approx. 75%/25% in summer and 40%/60% in winter. On Jan. 1, 1977, this unit was down for structural repairs.

D-R under contract at start of 1977

Under contract at start of 1977 and scheduled for completion by 1980

Start-up	Company	Country	Process	Reductant	DRI capacity (tpy)
1977	Sidbec-Dosco II	Canada	Midrex	Natural gas	625,000
1977	Sidor III	Venezuela	Midrex	Natural gas	360,000
1977	Sidor III	Venezuela	HyL	Natural gas	360,000
1977	Cosigua	Brazil	Purofer	Gasified oil	350,000
1977	Nisic	Iran	Purofer	Natural gas	330,000
1977	Hylsa-Puebla II	Mexico	HyL	Natural gas	625,000
1977	Nisic	Iran	Midrex	Natural gas	1,200,000
1977	Iraq Iron & Steel	Iraq	HyL	Natural gas	1,485,000
1977	Anglo-American Corp.	S. Africa	Highveld Kiln	Coal	300,000
1977	Consolidated Gold Fields	USA	SL/RN	Coal	100,000
1977	Kawasaki Steel	Japan	Kawasaki	Coke breeze	250,000
1977	Nippon Steel	Japan	NSC	Oil	240,000
1978	Siderperu	Peru	SL/RN	Coal	100,000
1978	Tika	Zambia	HyL	Natural gas	250,000
1978	Nisic	Iran	HyL	Natural gas	1,000,000
1978	Acindar	Argentina	Midrex	Natural gas	420,000
1978	BSC Hunterston	UK	Midrex	Natural gas	800,000
1978	Qatar Steel	Qatar	Midrex	Natural gas	400,000
1978	PT Krakatau	Indonesia	HyL	Natural gas	575,000
1979	PT Krakatau	Indonesia	HyL	Natural gas	1,725,000
1979	Sidor IV	Venezuela	Midrex	Natural gas	1,200,000
1979	Sidor IV	Venezuela	HyL	Natural gas	2,100,000
1979	Kursk	USSR	Midrex	Natural gas	2,500,000
1980	North Sea Iron	UK	—	Natural gas	800,000
1980	Norddeutsche Ferrowerke	W. Germany	Midrex	Natural gas	1,200,000
1980	Kursk	USSR	Midrex	Natural gas	2,500,000
1980	Iscott	Trinidad-Tobago	Midrex	Natural gas	420,000
				TOTAL	22,215,000

D-R projects planned for operation 1981-1985.

Country	*Company &* *(Location)*	*Probable reductant*	*DRI capacity (tpy)*
USA	Texas Farreduction*	Natural gas	900,000
USA	Gulf Coast consortium†	Natural gas	1,500,000
Canada	Interprovincial Iron	Coal	400,000
Argantina	Gurmendi	Natural gas	400,000
Bolivia	Sidersa (Santa Cruz)	Natural gas	200,000
Brazil	Cosigua II	Gasified oil	350,000
Brazil	Cofavi	Gasified oil	350,000
Brazil	Usiba II	Natural gas	300,000
Brazil	Imbituba (Sta. Catarina)	Gasifiad coal	400,000
Brazil	Piratini II	Coal	200,000
Mexico	Tamsa II	Natural gas	300,000
Venezuala	Fior de Vanezuela	Natural gas	2,000,000
Italy	Adriatic consortium	Natural gas	800,000
Spain	Sid. Gibraltar	LNG	450,000
Spain	Prenosa (Bilbao)	LNG	500,000
Algeria	SNS (Jijal)	Natural gas	1,200,000
Egypt	Govt. (Helwan)	Natural gas	400,000
Tunisia	Govt. (Gabes)	Natural gas	800,000
Turkey	Edas	Coal or natural gas	400,000
Iran	Nisic (Bandar Abbas)	Natural gas	2,800,000
Iran	Nisic (Isfahan)	Natural gas	1,200,000
South Africa	Scaw & Anglo-Amarican	Coal	200,000
New Zealand	New Zealand Stael II	Coal	200,000
USA	Republic Steel (Massillon)	Coal	360,000
USA	Rapublic Steal (Gadsen)	Coal	360,000
El Salvador	Govt. (Acajutla)	Coal	160,000
Argentina	Hipasam (Punta Colorado)	Natural gas	400,000
Argentina	Lucini	Natural gas	400,000
Brazil	Dedini	Coal	400,000
Brazil	Ikosa-Pains	By-product gas	160,000
Brazil	Mendes Junior	By-product gas	350,000
Brazil	Mannesmann	By-product gas	400,000
Colombia	Acanor (Barranquilla)	Natural gas	200,000
Ecuador	Ecuasidor	—	400,000
Greece	Siderhellas	Natural gas	300,000
Abu Dhabi	Government	Natural gas	400,000
Libya	Govt. (Misurata)	Natural gas	500,000
Morocco	Govt.	Natural gas	300,000
Saudi Arabia	Govt. (Al Jubail)	Natural gas	1,600,000
India	Govt. (Andhra Pradesh)	Coal	60,000
Australia	Hamersley Iron	Natural gas	1,200,000
		TOTAL	24,200,000

**Sponsored by Midrex.* *†Supported by Fior. Consortium includes B & W, Conners, Keystone Steel & Wire, North Star, Penn-Dixie, and Timken.*

Table 2: Other D-R projects under study

Early decision allowing startup befora 1985 unlikely

Country	*Company &* *(Location)*	*Probabla Reductant*	*Probable DRI (tpy) capacity*
USA	Sovereign Industries (Arizona)*	Coal	400,000
Canada	Lasco	Natural gas	300,000
Argantina	Somisa	Natural gss	600,000
Brazil	Acesita	Coal/charcoal	300,000
Brazil	Cosipa	Coke ovan gas	400,000
Brazil	CSN	Coka ovan gas	800,000
Brazil	Tasa	Natural gas	400,000
Brazil	Cosim	By-product gas	600,000
Brazil	(Urucum)	Natural gas	400,000
Brazil	Usiminas	Coka ovan gas	400,000
Brazil	Villares	Gasified oil	350,000
Colombia	Acenor (Cali)	Natural gas	400,000
Chile	(Magallanes)	By-product gas	400,000
Mexico	Govt.	Natural gss	1,000,000
Venezuala	Acelcar	Natural gss	400,000
W. Garmany	(Duisburg)†	Coka braaza	200,000
W. Germany	Mannesmann‡	Coal	200,000
Italy	Solmine	—	400,000
Spain	Pradacasa (Barcelona)	LNG	400,000
USSR	Govt. (Kaliningrad)	Natural gas	3,000,000
Bulgaria	Govt. (Kramikovtsi)	Coal	800,000
Egypt	Govt. (Alexandria)	Natural gas	1,600,000
Nigeria	Govt. (Pt. Harcourt)	—	1,200,000
Kuwait	Govt. (Shuaiba)	Natural gas	400,000
Iran	Nisic (Bushehr/Kangan)	Natural gas	2,500,000
Iran	Nisic (Mashad)	Natural gas	400,000
Iraq	Govt. (Al Zubair)-II	Natural gas	800,000
South Africa	Scaw & Anglo-American	Coal	800,000
South Africa	Iscor	Gasified coal	800,000
Mauritius	Govt.	Natural gas	600,000
Singapora	Nism	—	400,000
Thailand	Consortium (Sattahip)	Natural gas	400,000
Malaysia	Govt. (Kuantan)	Natural gas	400,000
India	Tamil Nadu (Salem)	—	400,000
India	Gujarat (Ahmedabad)	—	200,000
Bangladesh	Govt.	Natural gas	400,000
Pakistan	Govt. (Punjab)	Natural gas	400,000
Japan	Nisshin Steel (Kure)	Gasified oil	1,200,000
South Korea	(Inchon)**	—	160,000
Taiwan	Tang Eng. Iron Works	Coal	200,000
China	China Nat. Tech. Import	—	1,000,000
		TOTAL	26,410,000

**Kiln using iron sands.* *†Kiln using wasta oxides.* *‡Kiln using lignite.*
***Redesign and modification of existing kiln.*

REGIONAL DISTRIBUTION OF DR INSTALLATIONS: 1954 to 1980
(Percentage at yearend)

Region	1954-1976		1977		1978		1979		1980	
	Capac.	No.	Capac.	No.	Capac.	No.	Capac.	No.	Capac.	No.
	%		%		%		%		%	
Latin America	35.5	25.6	32.1	27.4	28.8	27.6	33.1	29.0	29.2	28.8
North America	25.1	23.1	19.5	21.6	15.8	19.0	11.3	17.7	9.4	16.7
West Europe	9.6	20.5	5.7	15.7	8.9	15.5	6.3	14.5	11.7	16.7
East Europe	-	-	-	-	-	-	9.6	1.6	16.1	3.0
Middle East	-	-	20.1	5.9	23.8	8.6	16.9	8.1	14.2	7.6
Africa	13.1	5.1	9.6	5.9	9.1	6.9	6.5	6.5	5.5	6.0
Asia	15.3	23.1	12.2	21.6	13.0	20.7	15.8	21.0	13.5	19.7
Oceania	1.4	2.6	.8	1.9	.6	1.7	.5	1.6	.4	1.5

DISTRIBUTION BY CAPACITY AND PLANTS
(Annual Capacity in Millions of Metric Tons, and Number of Plants

Region	MT	No.	MT	No.	MT	No.	MT	No.	MT	No.
Latin America	3.13	10	4.83	14	5.34	16	8.65	18	9.07	19
North America	2.21	9	2.93	11	2.93	11	2.93	11	2.93	11
West Europe	.85	8	.85	8	1.65	9	1.65	9	3.65	11
East Europe	-	0	-	0	-	0	2.50	1	5.00	2
Middle East	-	0	3.02	3	4.42	5	4.42	5	4.42	5
Africa	1.15	2	1.45	3	1.70	4	1.70	4	1.70	4
Asia	1.34	9	1.83	11	2.41	12	4.13	13	4.13	13
Oceania	.12	1	.12	1	.12	1	.12	1	.12	1
WORLD	8.80	39	15.03	51	18.57	58	26.10	62	31.02	66

List of World Direct Reduction Plants Based on Gas and Solid Reductants1/

1. Commercial interest in direct reduction has quickened recently, due to a combination of factors. The technology has reached a stage where there is ample evidence that a number of processes are now both economically and technically efficient. In addition, direct reduction seems eminently suitable for use in the energy-rich developing countries such as the oil producers which possess natural gas deposits. Those nations now also command the funds to develop large-scale industries, and appear to be willing to take the plunge with a relatively new ironmaking technology.

2. In the industrialized countries direct reduction has played a necessarily more muted role, given the existence of established iron and steelmaking. The proposed BSC plant at Hunterston and the Spanish projects for example, are primarily aimed at covering actual or predicted scrap deficits. It remains to be seen whether the Spanish plants, if approved, can operate economically given the necessarily higher cost of imported natural gas on which they will have to run.

3. It can be expected that merchant direct reduction plants will be of growing importance and that traditional iron ore exporters may prefer to build such plants to add value to their exports. The effect this development has on the untreated iron ore and scrap markets may be considerable.

Alphabetical Order

Country, Company	Location	Process	Capacity (tpy)	Start-up date	Status
ABU DHABI **Government/** **Kawasaki Steel**		**Midrex**	1,000,000	1978-9	**agreed in principle**
ARGENTINA **Dalmine** **Siderca**	**Campana**	**Midrex**	330,000	1976	
BANGLADESH		**Hyl**	**250,000 tpy**		**under feasibility stage**
BOLIVIA **Sidersa**	**Mutún**				**envisaged**

1/ Based on the list compiled from technical journals and Metal Bulletin Monthly, June 1977 and updated to August 1977.

Country, Company	Location	Process	Capacity (tpy)	Start-up date	Status
BRAZIL Aços Finos Piratini	Charqueadas	SLRN	67,000	1973	operating
		SLRN	250,000	1976	planned
Construtora José Mendes Jr.	Juiz do Fora				envisaged
Cosigua	Santa Cruz	Purofer	300,000	1976	
			300,000	1978	
Fi-El Korf SA	São José dos Campos	Midrex	400,000	1978	planned
Usiba	Bahia	Hyl	185,000	1974	operating
CANADA Falconbridge Nickel Mines	Sudbury	SLRN	300,000	1971	closed down 1972
Sidbec-Dosco	Contrecoeur	Midrex	400,000	1973	operating
		Midrex	600,000	1976	plant ordered
Stelco	Griffith Mine, Ontario	SLRN	545,000	1975	
EGYPT Government in joint co.	Dakhella	Midrex	1,600,000	1977	agreed in principle
		Midrex	3,400,000	1982	envisaged
FRANCE	Toulouse	Novalfer	18,000	1968	pilot plant
GREECE	Kabella	Hyl	500,000		under negotiation
WEST GERMANY August Thyssen Hütte	Oberhausen	Purofer	300,000	1972	pilot plant
Hamburger Stahlwerke	Hamburg	Midrex	400,000	1971	operating
INDIA	Guijrat	Hyl	500,000		feasibility stage
	Andhra Pradesh	Rotary kiln	30,000	1975	pilot plant (UNIDO proj.)

Country, Company	Location	Process	Capacity (tpy)	Start-up date	Status
INDONESIA PT Krakatau Ferrostaal	Anyer-Lor	Hyl	1,000,000	1976	plant ordered
IRAN	Ahwaz	Purofer	330,000	1975-6	
National Iranian Steel	Ahwaz	Midrex	1,200,000	1976	under constr.
Industries	Isfahan	Hyl	1,000,000	1976	plant ordered
	Bandar (Abbas	Midrex	2,000,000 3,000,000		agreed in principle
IRA	Khor Al Zubeir	Hyl	1,150,000		agreement signed October 1974
ITALY					
Siderurgica Monfalcone	Monfalcone	Kinglor Metor	30,000	1973	pilot plant
JAPAN					
Chiba			250,000		partial reduction
NKK	Fukuyama	SLRN	500,000	1974	
Hitachi Metals Ltd.	Tokyo	Wiberg-Söderfors			
Kawasaki Steel	Mizushima				rotary kiln: operating
Nippon Steel Corp.	Hirohata	(NSC process)		end 1974	planned for commercial operation
KUWAIT					
Kuwait Iron and Steel Co.	Shuaiba		400,000		at tender stage
MEXICO					
Hylsa	Monterrey	Hyl	85,000	1957	operating
		Hyl	185,000	1960	operating
		Hyl	365,000	1974	operating
Hylsa de Mexico SA	Pueblo	Hyl	250,000	1970	operating
Siderúrgica Tamsa	Vera Cruz	Hyl	170,000	1967	operating

Country, Company	Location	Process	Capacity (tpy)	Start-up date	Status
NEW ZEALAND					
New Zealand Steel	Glenbrook	SLRN	150,000	1970	operating at reduced capacity; serious troubles encountered in plant operations
PERU					
Siderperu	--- details are not available ---				Re-use of 3 cement kilns planned
QATAR					
Government in joint venture			350,000	1977	agreed in principle
SAUDI ARABIA					
Petromin in joint venture			3,500,000		agreed in principle
SOUTH AFRICA					
Dunswart Iron and Steel	Benoni	Krupp-Renn	150,000	1972	operating
Highveld Steel and Vanadium	Witbank	Lurgi/Elkem	440,000	1968/72	partial reduct.
		Lurgi/Elkem	250,000	1974	partial reduct.
SOUTH KOREA					
Inchon Steelworks	Inchon	SLRN	150,000	1970	partial reduct.; closed down 1971
SPAIN					
Prenosa	Prat de Llobregat Barcelona		500,000		subject to government approval
Prenosa	Bilbao		800,000		"

Country, Company	Location	Process	Capacity (t/y)	Start-up date	Status
Predecasa	Barcelona		300,000		subject to government approval
Siderúrgica de Gibraltar	Algeciras	Midrex	400,000		subject to government approval
SWEDEN					
Gränges Steel	Oxelosund	Hoeganaes	40,000		operating
Hoeganaes AB	Hoeganaes	Hoeganaes	130,000	1911	for iron powder prod.
Sandvik AB	Sandvik		65,000		
SKF Steel Div.	Hofors		30,000		
TAIWAN					
Tang Eng Iron Works in joint co.			1,000,000		
THAILAND					
C.S. Steel	Kaohsiung	Midrex	420,000		planned
TRINIDAD					
Government in joint co.		Midrex	800,000		agreed in principle
TUNISIA					
Government in joint co.		Midrex	1,000,000	1976	"
TURKEY					
Edas	Izmir		250,000	1976	planned
UK					
Ferrofeed Ltd.	Hunterston		800,000	1977	agreed in principle
BSC	Hunterston	Midrex	400,000	1977	envisaged

Country, Company	Location	Process	Capacity (tpy)	Start-up date	Status
USA					
Armco Steel	Houston	Armco	350,000	1973	operating
Georgetown Steel Corp.	Georgetown	Midrex	400,000	1971	operating
Georgetown Texas Steel Corp.	Beaumont or Georgetown	Midrex	400,000		planned
Hecla Mining	Casa Grande	SLRN	95,000	1975	plant ordered
Niagara Metal		(Allied-Chalmers)	300,000		semi-commercial operation (rotary kiln)
Oregon Steel Mills	Portland, Ore.	Midrex	2x 150,000	1969	operating
Republic Steel	Arizona		400,000		at feasibility stage
USSR					
National Steel Ind.	Kursk	Midrex	2.4 m.	1978	1st stage agreed in principle
	Stariy Oskol	Midrex	2.4 m.		2nd stage under constr.
VENEZUELA					
Aceria Electrica del Caroní	Matanzas		500,000		at feasibility stage
Fior de Venezuela	Guyana	Fior	400,000	1975	plant ordered
Orinoco Mining	Puerto Ordas	HIB	1,000,000	1973	partial reduct. (initially), operat.
Sidor	Matanzas	Midrex	400,000	1976	plant ordered
Sidor	Puerto Ordas	Hyl	365,000	1976	" "
YUGOSLAVIA					
Radnici-i-Zelezara Skopje	Skopje	Elkem	500,000		partial reduct closed 1971
ZAMBIA					
Tika Ltd.	Lusaka	Hyl	250,000	1976	plant ordered

Economic aspects of Direct Reduction

There are no universal yardsticks to assess the economics and production costs of direct reduction including capital and operational costs; these will again differ in the case of gaseous direct reduction processes, vis-á-vis solid reductant based rotary kiln direct reduction processes; the following Tables No. 19 and 20 depict the general indications of the cost data respectively:

Table 19

Cost of production of sponge iron

Gaseous Direct Reduction Plant at 100%
Capacity utilization in US dollars

Serial No.		Cost element	Unit	Rate	Specific Consumption	Cost per ton of sponge iron
I.	1.	Pellet[1]	tonnes	24.77	1.4	34.678
	2.	Natural gas	Nm^3	0.0125	460	5.750
		Total Materials				40.428
II.		Cost above Material				
	1.	Labour and Supervision Services				0.450
	2.	Power	KWH	0.0206	30	0.618
		- others excl. transport				0.30
		Total services				1.368
	3.	Operating supplies				0.4
	4.	Repair and Maintenance				0.75
		Total cost above Material			=	2.518
III.		Overheads				0.60
		Total cost of production excl. capital depreciation and overheads				44.914
					or say	45 US$
					per ton sponge	

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[1] F.O.B. cost excluding ocean and rail transport

It would not be out of place to refer to the most leading direct reduction processes and their capacities (in operation and under construction) as of 1975 based on gaseous direct reduction technology.

Process	Direct reduction and electric furnace plants	DR plant operational	units under construction	Rated capacity tpy
HYL	10	6	7	8,000,000
Midrex	8	5	5	6,500,000
Purofer	2	-	2	700,000
Armco	2	1	-	330,000

Agreement has been reached between the Saudi Arabian Basic Industries Corp (Sabio) and Korf-Stahl AG, West Germany, to form a joint venture company to construct and operate a Midrex direct reduction plant in Saudi Arabia, The plant, which is intended to be built at Al-Jubail in the country's Eastern Province, will have an initial output of 800,000 t/y, most of which will be used by the domestic steel industry. Any surplus during the first years of operation will go to export.

The direct reduction facilities, originally comprising two Midrex modules, are expected to be expanded later to meet a growing local and international market.

(Excerpt from "Iron and Steel International" August 1977)

The name "North Sea Iron Company" might suggest that another mineral resource had been discovered in that useful body of water, it is, in fact, the name under which a plant producing 800,000 t of iron ore briquettes, using North Sea gas as the reducing agent, will operate at Jarrow Slake, near Newcastle.

The plant will be owned by a consortium of Consolidated Gold Fields, the Sheerness Steel Company (who between them willhold 60-70% interest), Fiat Teksid Turin, the Manchester Steel Company, and Tube investments Ltd. Construction will be carried by GutehoffnungshUtte Sterkrade Aktiengesellschaft (GHH), and a letter of intent has just been signed by the participants. The Purofer process will be employed in this plant, which is similar to those operating at Oberhausen in Germany and Cosigua in Brazil and to that nearly ready for commission at Ahwas in Iran. It will be the largest Puroder plant yet built, will cost £ 90m, and snould be completed in 1979.

Much of the equipment will be made in Britain, although GHH will act as designers and primary contractors. That part of the production not consumed by the participants will be marketed by Tennant Trading Ltd. a subsidiary of Consolidated Gold Fields. Mr. L.W. Palmer, at present Technical Director of Sheerness Steel, has been appointed Managing Director of North Sea Iron, and Mr. C.C. Schueppert, Chairman of Sheerness Steel, will be its non-executive Chairman.

When the plant is completed, 150 people will be employed. The project will be eligible for regional development grants, and the consortium is at present having discussions with the Department of Industry about selective financial assistance under the Industry Act.

(Excerpt from "Ironmaking and Steelmaking, 1977 No. 4)

In concluding this paper, it is stated that the approach of UNIDO to new technological developments, inter alia, direct reduction fields is one of enlightened technical and practical interests particularly in relation to their possible applications in developing countries. It must be appreciated that developing countries with their meagre resources financial and technological, do have a valid case when they feel and rightly so that they should not be used as the base for commercializing technically and industrially unproven processes and technologies. UNIDO in its dedication to assist the developing countries endeavours to meet these requirements and build up technical linkages between the advanced and the developing countries in the fields of metallurgical industries including iron and steel industry and direct reduction sponge technology.

It is stressed that dogmatic approaches should be avoided in the establishment of the iron and steel industry in developing countries. Whilst the applications of the latest technological innovations, automation and computerized operations in developing countries are rightful ambitions and objectives, nonetheless the applications of fully appropriate technology should be encouraged depending upon the conditions and environments in each case and country. To illustrate this subject, it is recommended that the use of charcoal for iron smelting in relatively small blast furnaces (less than 200 tpd capacity) should be fully supported in developing countries which have a good forest wealth and forestation programme. In a fast developing country like Brazil, for instance, some three million tons of pig iron is smelted in small blast furnaces using charcoal as the reductant and for heat input. In western Australia, at Wundowie, an iron smelting blast furnace complex using charcoal is in profitable operations for the last two decades. In another fast developing country, India, in the Mysore Iron and Steel Works at Bhadravati, charcoal blast furnace operations have advantageously been carried out for years. In Malaysia, at the plant of Malayawata steel, iron smelting has been successfully in operation for the last several years using charcoal made from rubber wood.

ANNEXURE "C"

WORLD'S COAL INDUSTRY AND WORLD'S ENERGY RESOURCES

I. WORLD COAL PRODUCTION RISING SLOWING BUT SURELY

(European Coal Information Agency, Brussels, July 19, 1977)
The trend of the last few years of a slow but sure increase in world coal production continued in 1976. Provisional figures put world production of bituminous coal and anthracite in 1976 at 2,468,551,000 tons or 2.3% higher than the estimated 2,412,125,000 tons produced in 1975. Output by major geographic regions was as follows:

WORLD COAL PRODUCTION

	1976	
	Production in millions of tons	**Share of World Production in percentage**
North America	602.95	24.4
South America	8.62	0.3
Europe (excl. U.S.S.R.)	471.48	19.1
U.S.S.R.	546.00	22.1
Asia	684.49	27.7
Africa	78.89	3.2
Oceania	76.13	3.1
WORLD TOTAL	**2,468.55**	**100.0**

II. THE STATUS OF THE COAL INDUSTRY

A. World coal resources and their exploitation

1. The global picture

7. The world's coal resources are not adequately known and the available estimates are highly uncertain. This is partly because the various estimates are based on different geological concepts of measurement, calculations and forecasting methods. Moreover, the classification of coal resources is not yet universally standardized. In the World Energy Conference Survey of Energy Resources, for example, it was indicated that the world coal reserves that were sufficiently known and recoverable under present technological and economic conditions could be estimated at 600 billion metric tons. 2/ It should be noted that the Survey took into account only seams over 0.3 metres thick within 1,200 metres of the surface, and brown coal and lignite seams more than 0.3 metres thick within 500 metres of the surface. While this may be reasonable from an economic point of view, the selected limits of measurement produced a low estimate of geological resources of coal compared with other calculations. 3/ As long as the accuracy of the available data on world coal resources cannot be evaluated, comparison of different figures is neither feasible nor useful.

8. The Institute of Foreign Geology of the Union of Soviet Socialist Republics, using its previous work on the systemization and analysis of information on world coal resources by continents and countries, prepared in 1976 a comprehensive study, entitled "World coal resources and a detailed bilingual map of world coal deposits with a colour code which has been used to designate the spectrum of coal rankings, i.e., hard coal and anthracite; brown coal and lignite; and coals of all types. 4/

2/ This amounts to only a small portion of the total geological coal resources, which vary between 11×10^{12} tons and 23×10^{12} tons according to various sources. Yet according to the Survey, even recoverable coal reserves are still four times as abundant as oil and approximately eight times as abundant as natural gas, in comparable terms (see World Energy Conference Survey of Energy Resources (New York, United States National Committee of the World Energy Conference, 1974)).

3/ Lardinois, "Les réserves mondiales de combustibles minéraux solides", Annales des mines: Belgique, 1958, No. 2: A. Parker, "World energy prospects", Fuel (1970), No. 49, p. 3; N. G. Zelesnova and R. K. Matreev, "World coal resources", The Soviet Geology, 1973, No. 1.

9. Coal resources in the study are divided into three categories: measured, indicated and inferred; 5/ they add up to 14 trillion (10^{12}) tons, of which 64 per cent is hard coal, the remainder consisting of brown coal and lignite. Although the economic parameter is important, the available knowledge and the subjectivity of notions of profitability, especially in the current fluid situation, did not permit this factor to be taken into account in a universally acceptable fashion. 6/ The production basis of the coal industry today, i.e., that portion of total resources which provide its current output and enters its planning, is measured coal resources of about 1 trillion, which constitute only about 7 per cent of total world coal resources (see table 1, where all measurements are in metric tons). Measured resources are only partly economically recoverable, however, for example, in the World Energy Conference's Survey the economically recoverable portion is estimated at about 50 per cent and such an approach can be followed when more accurate estimates are not available.

10. Although coal resources in 60 of the 70 coal-possessing countries amount to less than one tenth of the world total, actual quantities in many of them may be very significant in relation to current energy demands and projected long-term needs. As was pointed out earlier, information on geological conditions and resources is incomplete, especially in developing countries, since in most of them comprehensive surveys have yet to be undertaken; therefore, the present estimates provide only a rough order of magnitude of coal resources. For example, the average density of coal occurrence per square kilometre for well explored continents and large areas is about 100,000 tons. Taking that as a control figure we could expect substantial increase of coal discoveries in Africa, Latin America, and Asia and in North America. On this basis, it can be calculated that, theoretically speaking, total world geological coal estimates could be doubled at 30 trillion tons in the future.

5/ "Measured resources" are those for which the tonnage is computed from dimensions revealed in outcrops, trenches, workings and drill holes, and for which the grade is estimated from the results of detailed samplings, generally allowing for deviations of 20 per cent. "Indicated resources" are those for which the tonnage and grade are computed partly from specific measurements, samples, or production data, as well as from projections based on geological evidence. "Inferred resources" are those for which quantitative estimates are based largely on the general knowledge of the geological characteristics of deposits and for which there are few, if any, samples or measurements. In some cases, the estimate of this class was obtained as a residual, subtracting "indicated" plus "measured resources from total resources. "Total", shown separately on the map, refers to all estimated resources, computed in accordance with the standards and methodology of the International Geology Congress, which include the sum of the above three categories, as well as any additional known resources.

6/ See, for example, Proceedings of the Conference on Methods of Assessing Energy Resources, May 1975 (International Institute for Applied Systems Analysis, Laxenburg, Austria, 1975).

Table 1. World coal resources by types of coal

Continent	Type of coal a/	Resources (10^9 metric tons unless otherwise indicated)				Percentage
		Measured	Indicated	Inferred	Total	
Europe	H and A	222	232	118	572	
	B and L	101	29	56	186	
	All	323	261	174	758	5.4
of which:						
Western Europe		269.3	210.2	35.6	515	
Eastern Europe		53.7	50.8	138.4	243	
Distribution		42.6 per cent	34.4 per cent	23 per cent	100 per cent	
Asia	H and A	254	538	4 736	5 528	
	B and L	121	156	2 758	3 035	
	All	375	694	7 494	8 563	60.7
of which:						
USSR		256	171	6 373	6 800	
China		80	420	1 000	1 500	
India		25.2	73.2	26.6	125	
Distribution		4.4 per cent	8.1 per cent	87.5 per cent	100 per cent	
North America	H and A	244	880	1 406	2 530	
	B and L	26	394	1 363	1 783	
	All	270	1 274	2 769	4 313	30.6
of which:						
United States		214.7	1 200.1	1 496.2	2 911	
Distribution		6.2 per cent	29.5 per cent	64.3 per cent	100 per cent	
South America	H and A	4	25	8	37	
	B and L	-	10	28	38	
	All	4	35	36	75	0.5
Distribution		5.3 per cent	46.7 per cent	48 per cent	100 per cent	
Africa	H and A	30	61	138	229	
	B and L	-	1	-	1	
	All	30	62	138	230	1.6
Distribution		13 per cent	27 per cent	60 per cent	100 per cent	
Oceania	H and A	5	21	49	75	
	B and L	48	47	2	97	
	All	53	68	51	172	1.2
Distribution		30.7 per cent	39.6 per cent	29.7 per cent	100 per cent	
World	H and A	759	1 757	6 455	8 971	63.6
	B and L	296	637	4 207	5 140	36.4
	All	1 055	2 394	10 662	14 111	100
Distribution		7.4 per cent	17 per cent	75.6 per cent	100 per cent	

Sources: Nilzarubezhgeologiya (Institute of Foreign Geology), Ministry of Geology of the USSR; World Energy Conference Survey of Energy Resources (New York, United States National Committee of the World Energy Conference, 1974).

a/ H and A - Hard coal (bituminous, high-calorie sub-bituminous) and anthracite.
B and L - Brown coal and lignite.

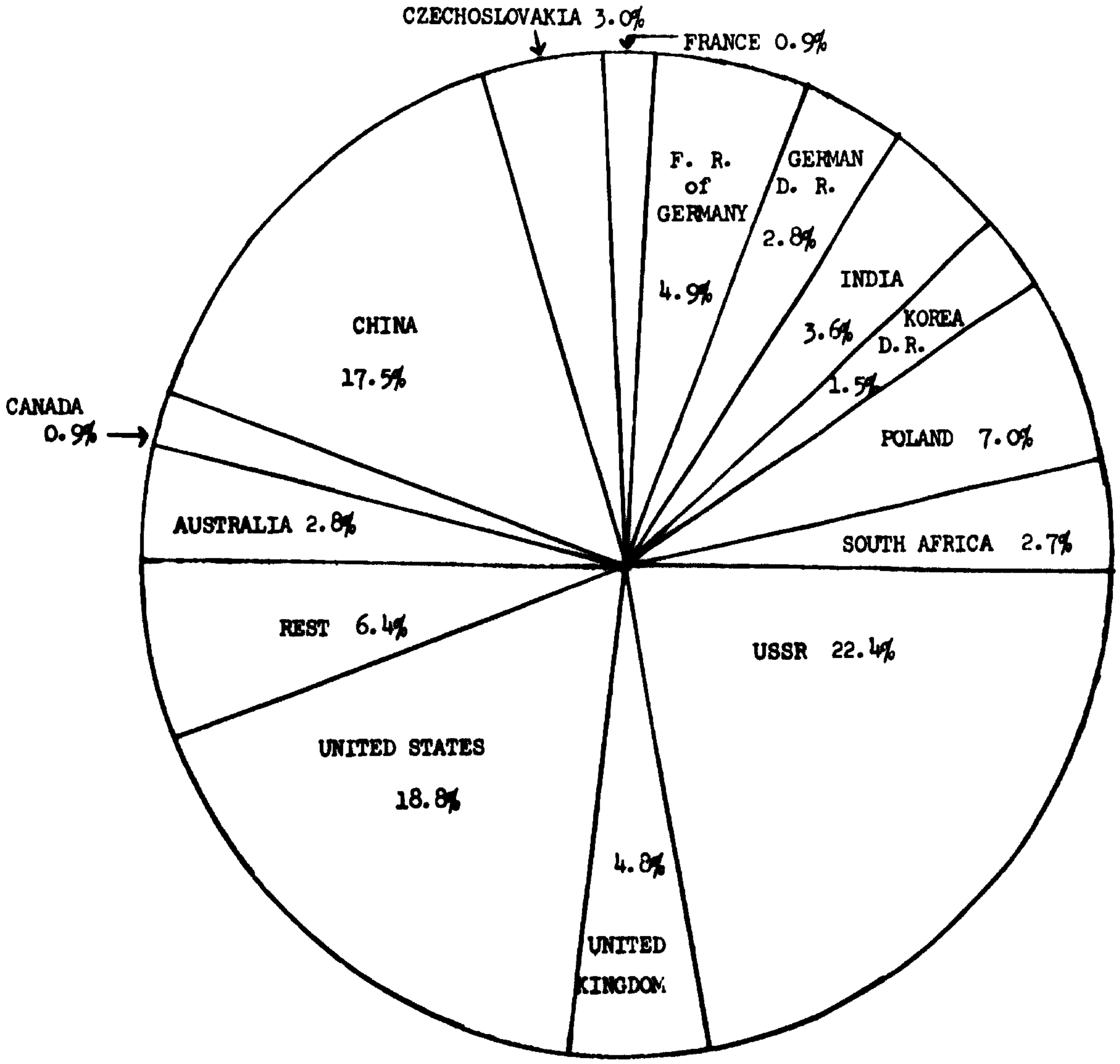
11. The long-term trend in world coal production in the modern era is one of continuous growth but at very different rates in the various regions and countries. Production expanded at a rate of 2.1 per cent between 1950 and 1975. 1975 marked above-average increases for nearly all regions, with production in North America, for example, increasing by almost 9 per cent after practically stagnating in 1972-1974.

12. The distribution of world coal production by socio-economic groups is uneven: centrally planned economies account for 52.4 per cent, developed market economies for 42.1 per cent and developing countries for only 5.5 per cent. Within each socio-economic group, however, there are several countries with a significant potential for the expansion of coal production, not only for internal use but also, in some cases, for export. These comprise developing countries such as Botswana, Brazil, Colombia, India, Indonesia, Mozambique, Mexico, Peru, Turkey and Venezuela, developed countries such as Australia, Canada, the Federal Republic of Germany, South Africa, Spain, the United States of America and the United Kingdom, and countries with centrally planned economies such as China, the Democratic People's Republic of Korea, Poland, the USSR and the Socialist Republic of Viet Nam. The potential in the developing countries will be highlighted in greater detail in the next section.

13. At present, nearly 90 per cent of the world's total coal output (measured in coal equivalent) is produced in only 15 countries, the most important of which are China, the Federal Republic of Germany, India, Poland, the USSR, the United Kingdom and the United States of America (see figure). The largest producing countries are also the biggest consumers of coal. International trade in coal is, therefore, relatively insignificant. Less than 10 per cent of the world's coal production flows into international trade, compared to 50 per cent for world crude oil production. Most of this world coal trade is intracontinental; trade between continents amounts to about one third of the total and consists mainly of trade in coking coal. Among the factors limiting the expansion of coal trade are the relatively high cost of coal transportation, the long-term character of contracts for coal supply, leading to little room for variation in the exportable surplus, and export and import restrictions imposed for a variety of reasons. Nevertheless, international coal trade has shown a substantial growth - 3.4 per cent per year - in the period 1950-1974. Since 1973, the five main coal exporters, which account for about 85 per cent of world coal trade, have increased their shipments as follows: the United States by 12.2 per cent, the USSR by 5.1 per cent, Poland by 10.3 per cent, the Federal Republic of Germany by 19.4 per cent and Australia by 3.1 per cent.

2. The potential of the developing countries

14. Many developing countries have not been explored geologically for coal. Until recently, the availability of inexpensive oil and natural gas discouraged expenditure on coal exploration. However, with the large increases in energy prices and with advances in drilling and geophysical exploration techniques the prospects of discovering and developing new coal resources in the developing



MAJOR COAL PRODUCING COUNTRIES, 1975

Source: United Nations World Energy Supplies 1950-1974, Series J, No. 19, New York, 1976, Sales No. E. 76. XVII. 5.

countries have improved considerably. 7/ Available information reveals that more than 30 developing countries have known coal resources.

15. The developing countries with known coal resources can be grouped into five categories. First, among the major oil-exporting countries, Algeria, Indonesia, Iran, Nigeria and Venezuela have fairly large coal potentials. Indonesia has already started to increase its coal production substantially to satisfy local needs, including the supply of coking coal to its metallurgical industry and for export. Nigeria possesses large deposits of sub-bituminous coal; however, the lack of adequate transport capacity has restricted their development. A newly discovered deposit at Lafia is stated to be of coking quality and consideration is being given to exploiting it to supply the planned iron and steel works. Algeria possesses several coal-bearing basins, particularly in the south Oran region, where the coal is of coking quality. Iran's coal reserves are large - the most important deposit being at Kerman; it is already exploiting its reserves of coking coal for its steel works. To sum up, the above oil-exporting countries have the capacity to increase their internal use of coal, thus releasing more oil for export. Their oil revenues could be used to develop coal production, which can provide additional and useful local employment.

16. The second group of countries consists of those with a significant oil industry and in addition, a sizable coal-production capacity. This group includes Argentina, Colombia, Egypt, Mexico and Peru. Argentina can become substantially self-sufficient in coal provided adequate transport facilities are developed to carry the southern coals to the industries in the north. Colombia, given its large coal resources, may be able to build up a major export trade of both thermal and coking coals; the problem, however, is in getting the coal from the mines to the coast. Egypt's known coal reserves are all in the Sinai Peninsula and as such have not been of benefit since 1967. Long-term efforts may result in the opening of new mines which would enable Egypt not only to become self-sufficient in coal but also to export some to other countries in the Middle East. Mexico appears to have enough resources to minimize its reliance on imports. Peru possesses resources of moderate coking quality, which are now under investigation; it has the resource base to become self-sufficient in coal. In the longer term, exports of coking and anthracite coals are possible, although there are considerable transport problems, in addition to difficult geological conditions.

17. The third group consists of oil-importing countries with a substantial coal-producing capacity, enough not only to meet their growing energy needs but in a few cases to be able to export. This group includes Brazil, Chile, India, the Republic of Korea, the Socialist Republic of Viet Nam and Turkey. Brazil, which is believed

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7/ It is possible that the extensive drilling carried out by the oil companies in the sedimentary basins may have indicated considerable resources of coal, although these may not have been reported. Therefore, the results of petroleum exploration efforts in developing countries should be carefully studied for any indications of the existence of coal resources.

possess important coal resources, at present produces only about one half of coal requirements: about one third is coking quality and the balance is steam coal. Coal exploration and development are being accelerated, since coking coal is very much in demand to match the expanding steel industry. In the case of Chile it may be feasible to supply the country's needs from its own resources. The Democratic People's Republic of Korea, the Republic of Korea and the Socialist Republic of Viet Nam have comparatively large resources of coal. Turkey possesses important coking-coal deposits and large lignite reserves, which are scattered across the country.

18. India is the largest producer of all the developing countries under consideration. Coal production has already exceeded the 100-million-ton level and is expected to increase by 50 per cent by 1980. India nationalized the coal-mining sector in the early 1970s and since then coal production has expanded considerably and coal exploration has also accelerated. It is estimated that the reserves of non-coking coal in India are adequate for at least 100-150 years and the coking coal reserves are enough to meet the metallurgical needs for the next 40 years. The expansion of coal production capacity would require large investments in coal-mining and in railways. [8] Nuclear power is being developed in the western and southern parts of the country where there are no significant coal resources and hydropower potentials have been practically exhausted. India is planning to increase its coal exports considerably, mainly to Europe and Japan. [9]

19. Fourthly, there are a number of countries which, while they do not possess a major coal industry, have significant coal potential. Botswana and Swaziland have limited internal markets for coal and, therefore, could export their coal or electricity generated from coal. Morocco's coal reserves are anthracites in fine form, which could be used for power generation and in the form of briquettes as a smokeless fuel for domestic (and industrial) purposes. Except for South Africa and Southern Rhodesia, Mozambique possesses the only hard coking-coal resource in southern Africa with an export potential. Very large coal resources are reported to exist in Zaire; however, their exploitation is limited because of location. Zambia's present reserves are sufficient to meet domestic requirements; the country is well-endowed with hydropower potential, which may reduce the opportunities for coal use in electricity generation. Pakistan's resources are basically of low-grade coal. Thailand's resources are of lignite and can be used for thermal power generation and fertilizer production.

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[8] It has been estimated that the total investments required for coal to the year 1985 would come to over $1.5 billion. The investment needs for creating the capacity to transport coal could come to almost as much as the investment required for increasing coal-production capacity, unless energetic efforts are made to move coal by inland waterways and coastal shipping. The investment needed for coal-fired electricity generation and transmission is much larger than that needed for producing and transporting coal.

[9] Information on India is mainly based on Kirit S. Parikh, Energy, Second India Studies, (New Delhi, 1976).

20. The fifth group of countries are those without known oil resources and without a coal industry at the present time but which are known to have coal resources. Madagascar has large resources of high-ash thermal coal which require investigation as to the economic feasibility of their exploitation. Malawi, a land-locked oil-importing country, could increase indigenous fuel supplies by exploiting its coal resources in the south of the country. There are believed to be large coal reserves in Namibia and, when the country becomes independent, there will be a strong incentive for it to develop its own fossil fuel supply and even a potential export industry. The coal resources of Bangladesh, Burma and the United Republic of Tanzania happen to be in somewhat remote areas and efforts will have to be made to supply the small local markets. Though some coal is mined in the Philippines, the quantities are modest and the mines are hand-worked. To sum up, in all the above countries, with the possible exception of Namibia, any increased coal production is likely to be mainly limited to meeting local demand. The emphasis, therefore, is likely to be on establishing a simple, low-capital-cost industry with minimum mechanization. Domestic coals could be substituted for imported oil wherever feasible.

21. In conclusion, more than 30 developing countries have either existing or promising coal potential. But the exploitation of this potential requires serious efforts in exploration and development and the linking of technologies, markets, finance and transport facilities through national planning, supported, as necessary, by international co-operation.

WORLD FOSSIL FUEL RESOURCES

According to a recently completed study by the Federal Institute for Geosciences and Natural Resources, Federal Republic of Germany,[1] total world fossil fuel resources, including those not yet identified but expected to exist, amount to 12,500 billion tons coal equivalent (t.c.e.), of which 890 billion t.c.e., or 7 per cent, are considered economically recoverable under present conditions and can be classified as reserves. (See table 1.) Additional reserves of 260 billion t.c.e. exist in the form of radioactive energy sources, bringing the total fuel reserves to 1,150 billion t.c.e..

Table 1 World energy resources (fossil fuels)
(Billions of tons, except natural gas, 1,000 billion Nm^3)

Energy source	Total resources			Technically exploitable resources			Reserves		
		coal equivalent	percentage		coal equivalent	percentage		coal equivalent	percentage
Bituminous coal	7,900	7,900	63.5	1,425	1,425	42.9	420	420	47.4
Lignite	3,570	1,900	15.3	605	333	10.0	230	125	14.1
Peat	210	90	0.7	210	90	2.7			
Coal (including peat)		9,890	79.5		1,848	55.6		545	61.5
Oil	725[a]	1,044	8.4	290	418	12.7	98	141	15.9
Natural gas	235	313	2.5	235	313	9.4	72	96	10.8
Oil sand[b]	340	490	3.9	270[d]	392	11.7	40	57	6.5
Oil shale[b/c]	490	705	5.7	245[e]	353	10.6	33	47	5.3
Hydrocarbons		2,552	20.5		1,476	44.4		341	38.5
Fossil fuels		12,442	100.0		3,324	100.0		886	100.0

Source: Federal Institute for Geosciences and Natural Resources, Federal Republic of Germany.

a/ Oil in place; b/ Contained oil; c/ Oil shale with over 40 litres oil per ton of rock; d/ Recovery 80 per cent; e/ Recovery 50 per cent.

The distribution of world reserves by economic group is shown in table 2. The developed market economies and the centrally planned countries each account for more than one third of the total reserves, and the developing countries possess slightly more than 20 per cent. According to the same study, of world resources, not shown in the table, 88 per cent are found in the developed market economies and centrally planned countries, and 12 per cent in the developing world. Uranium reserves, too, are concentrated in the industrialized countries, which are estimated to possess nearly 90 per cent of the total.

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[1] Federal Republic of Germany, Federal Institute for Geosciences and Natural Resources, Die künftige Entwicklung der Energienachfrage und deren Deckung - Perspektiven bis zum Jahr 2000 - Abschnitt III, Das Angebot von Energie-Rohstoffen, Hanover, 1976, 339 pp.

Table 2 Regional distribution of fossil fuel reserves
(Billions of tons; percentage)

Energy source	Developed market economy countries (OECD)		Centrally planned economy countries		Developing countries		World	
	coal equivalent	percentage	coal equivalent	percentage	coal equivalent	percentage	coal equivalent	percentage
Bituminous coal	140	15.8	250	28.2	30	3.4	420	47.4
Lignite	74	8.3	50	5.7	1	0.1	125	14.1
Total coal	214	24.1	300	33.9	31	3.5	545	61.5
Oil	14	1.6	22	2.5	105	11.9	141	15.9
Natural gas	20	2.3	31	3.5	45	5.1	96	10.8
Oil sand[a/]	57	6.4					57	6.5
Oil shale[a/, b/]	26	2.9	11	1.2	10	1.1	47	5.3
Total Hydrocarbons	117	13.2	64	7.2	160	18.1	341	38.5
Fossil fuels	331	37.3	364	41.1	191	21.6	886	100.0

Source: Federal Institute for Geoscience and Natural Resources, Federal Republic of Germany.

a/ Contained oil; b/ Oil shale with more than 40 litres oil per ton of rock.

Bituminous coal and lignite reserves are estimated by the Institute to total 545 billions of tons coal equivalent, or less than 6 per cent of total resources. Coal reserves are heavily concentrated in a few regions and countries. The centrally planned economies and North America together account for over 80 per cent, Western Europe, Asia and Africa between 3 and 6 per cent each, and Latin America less than 1 per cent. The developing countries as a group have less than 6 per cent.

The favourable reserve situation for both coal and lignite allows considerable production increases. The report states that various countries have already announced plans for significant expansion. Among these are the United States which intends to nearly double its production by 1985, and the USSR and China which plan to double production by 1990.

Technically recoverable petroleum resources amount to 290 billion tons, a third of which are "identified reserves". Twenty-two per cent of the reserves are offshore. The Near Eastern countries possess 56 per cent of the reserves and 37 per cent of the resources. Further identified reserves exist in Africa (9 billion tons), North and South America (12 billion tons) and Socialist countries (15 billion tons). The distribution of reserves between other groups of countries is very imbalanced: 68 per cent are in member countries of the Organization of Petroleum Exporting Countries (OPEC) and only about 10 per cent in members of the Organization for Economic Co-operation and Development (OECD).

Identified natural gas reserves amount to 72,000 billion cubic metres (20 per cent of them offshore) which is equivalent to 31 per cent of estimated resources. The regional distribution of natural gas reserves is less skewed than that of coal and oil: 41 per cent are in OPEC countries, 33 per cent in Socialist countries, and 21 per cent in OECD countries.

Present reserves of oil and natural gas allow production, at today's rate, for 34 and 54 years respectively; at a hypothetical 6 per cent growth rate, these life indices are reduced to 18 and 33 years, respectively. According to a scenario by the Federal Institute for Geosciences and Natural Resources, annual production could increase from approximately 3 billion tons at present to 3.9 billion tons oil by 1980, 5.2 billion tons by 1985, 5.4 billion tons by 1990 and 5.0 billion tons by 2000. Large-scale extraction of oil from oil shale and oil sand could provide additional supplies.

Oil shale and oil sand resources total over 800 billion tons (contained oil) of which 34 billion tons (7 per cent) are considered economically recoverable from oil shale and 40 billion tons (12 per cent) from oil sand, according to the report. Most of the oil shale and oil sand resources lie in North and South America (United States, Canada, Brazil, Venezuela, Colombia) with additional quantities in the USSR and China.

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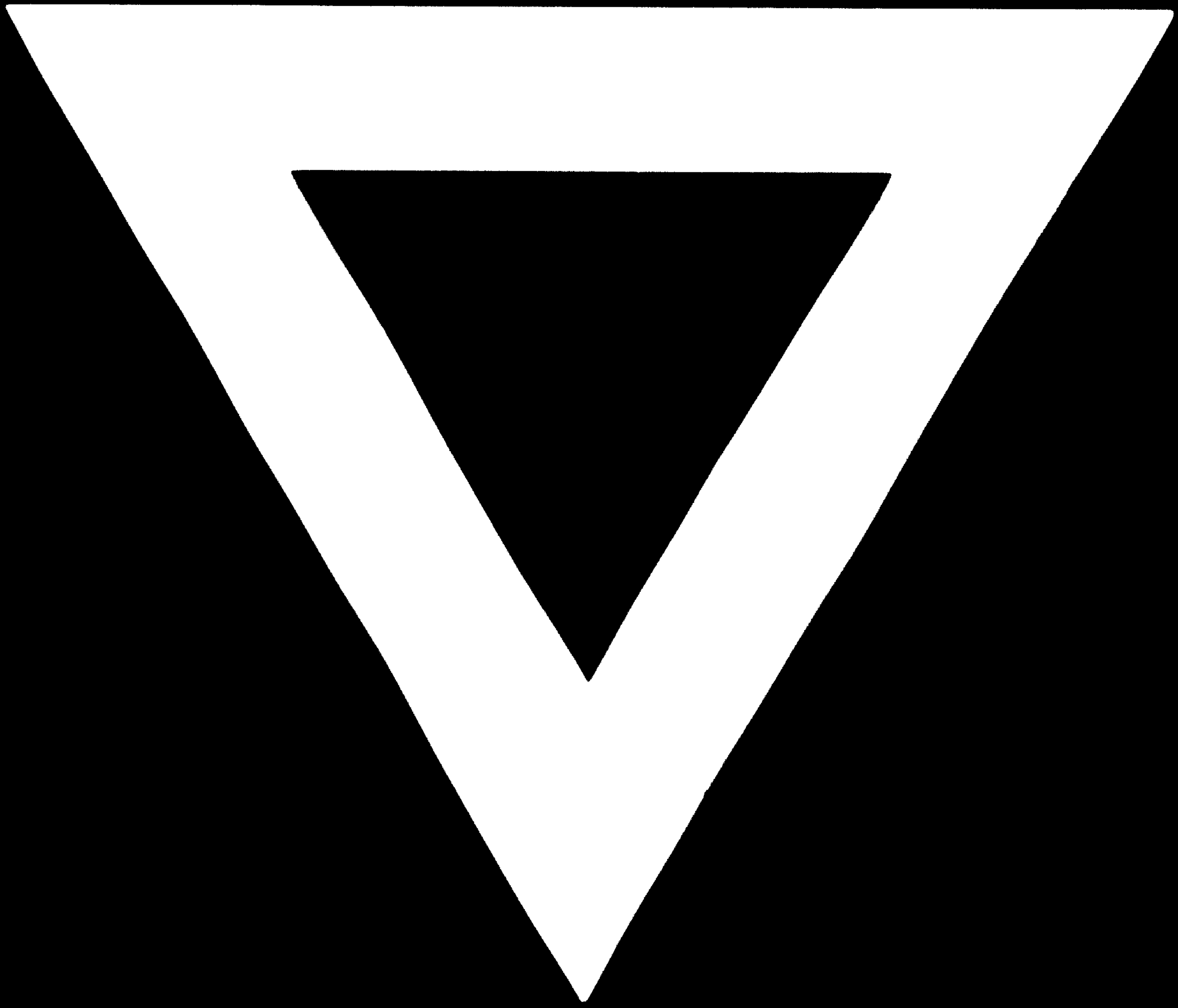

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