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TECHNOLOGY PROFILE ON MINI STEEL PLANTS*

Prepared for
INTIB - THE INDUSTRIAL AND TECHNOLOGICAL INFORMATION BANK

by

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PART I: ITS POSITION IN THE STEEL INDUSTRY

PART II: TECHNOLOGICAL APPROACH OF THE MINI-STEEL PLANT ALTERNATIVE ROUTES

PART I: Its position in the steel industry

Introduction

Steelmaking is today a very broad area of competition. Crude steel production of the world in 1985 amounted to 717.407 million tons and steel consumption per capita to 150 kg in the same year.

The world recovery in steel production was particularly marked in developing countries. These were since 1974 the only area where growth in steel intensity has continued to take place. Developing countries produced 130 million metric tons in 1985 and further increase of their production is expected (by 30% over the 1985 level) after for many of them the iron and steel industry is extremely vital in the industrialization process, not only as a supplier of steel products, but also as a mean to reach a self-sustained and comprehensive economic and social development due to its strong linkages with other parts of industry.

Also in international steel trade the producers from developing countries have increased their share of exports considerably at the expenses of the traditional exporting countries. The share of developing countries in world export of steel products increased from 2.4 to 11.7 % between 1975 and 1984.

Iron and steel can be produced in several different ways according to the size of production scale, kind of raw materials to be used and the type of products to be made. It is important to select a production system which serves the intended purpose.

Most of the world's steel is produced in large-scale "integrated" iron and steel works, which include production units for pre-treatment of raw materials, iron-making, steelmaking, steel casting and rolling. As a consequence of the cost and complexity of an integrated steelworks, it is vital to ensure that it operates at a production rate close to its design capacity for most of its working life to obtain a satisfactory return on the investment.

The sharp increase in energy costs in past resulted in a slow down of world steel production. As a result traditional markets shares in steel have been shifting and the industrial policy has been toward to decentrelization. Non-integrated producers and specially steelmakers occupy market niches for which the benefits of large-scale operations are less important. This had led to an impressive growth of mini-mills worldwide, as illustrated in the Table below:

TABLE

MINI MILL CAPACITY
(million metric tons)

	1970	(%)	1985	(%)
Mini:	35	7	106	19
Western[1] world total:	525	100	560	100

[1] means market-economy countries

In developing countries the role of mini-mill production is also impressive. Developing countries contribute 28.3 % of the western world capacity of "mini-steel".
As regards the least developed countries, one can also note the development of the mini-mill capacity.

However, developing countries and especially newcomers to the iron and steel sector face problems encountered in mini-mills related mainly to raw materials, energy, technology and financial aspects.

Hence part of the INTIB work programme of 1986 was the preparation and presentation of this technology profile with the purpose to make available to developing countries the necessary technological, economic and other information about the "mini-steel" route. This will facilitate planning the development of the iron and steel industry integrated with other sectors of the economy and the selection of suitable technological options that will permit this type of development.

Acknowledgements

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1. Iron and steel production methods

Iron and steel production methods currently practiced are roughly divided into three categories; the production process with blast furnace and basic oxygen converter (BF - BOF), the direct reduction system with direct reduction facility and electric furnace (DRI - EAF) and the electric furnace steelmaking by using scrap as raw material. Each sytem is in generally equipped with rolling facilities.

1.1 Types of plants

From the above roughly discussed categories three types of steel plants can be obtained: Integrated steelworks, integrated mini-mills and mini-mills.

a) Integrated steelworks is defined as the process which comprises the following stages:
Blast furnace → LD converter (BOF) route → rolling mills.

b) Integrated mini-mill is defined as the process which has the following stages:
DRI → EAF route → rolling mills.

c) Mini-mill is defined as the process which involves the following stages:
Scrap → EAF route → rolling mills.

This classification enables a distinction to be made among different routes of producing steel products, rather than by capacity size usually adapted to differentiate mini-mills from traditional large integrated steelworks. The mini-mill concept is based essentially on a small-scale entreprise philosophy, but the concept can be and has been applied in very different circumstances. Main facilities of the processes mentioned above are summarized in Table 1 and schematically depicted in Figure 1.

Table 1

Main steel production facility by process

Facility	Integrated steelworks (BF - BOF)	Integrated mini-mill (DRI - EAF)	mini-mill
Power plant [1)]	X	X	
Coke oven	X		
Sintering plant	X		
Pelletizer [2)]	X	X	
BF	X		
DRI plant		X	
BOF	X		
EAF		X	X
CCM	X	X	X
Rolling mill	X	X	X

(Source: Reference Nr. 34)

1) It is desired to own a power plant inside the steel works as one of energy saving measures

2) BF-BOF process does not necessarily own a pelletizer

Abbreviations:

BF - Blast Furnace
BOF - Basic Osygen Furnace
EAF - Electric Arc Furnace
CCM - Continuous Casting Machine
DRI - Directly Reduced Iron

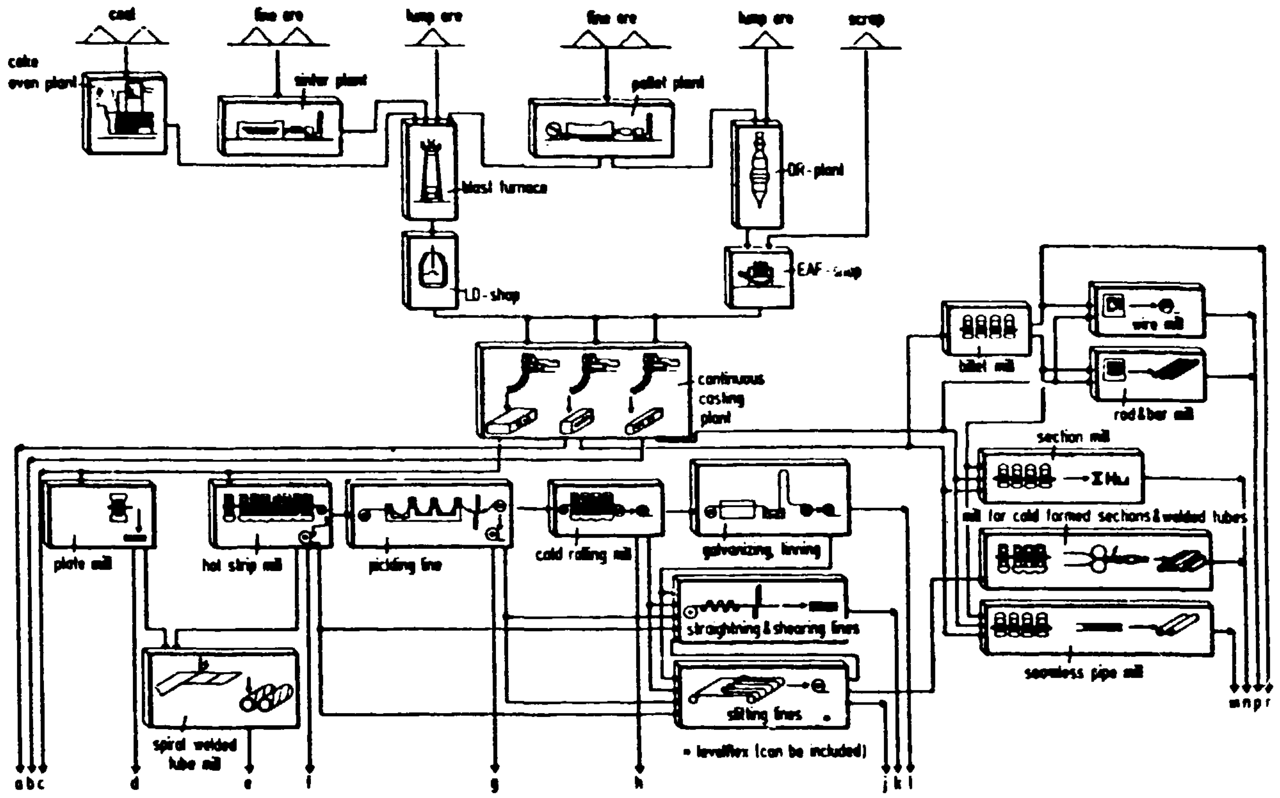
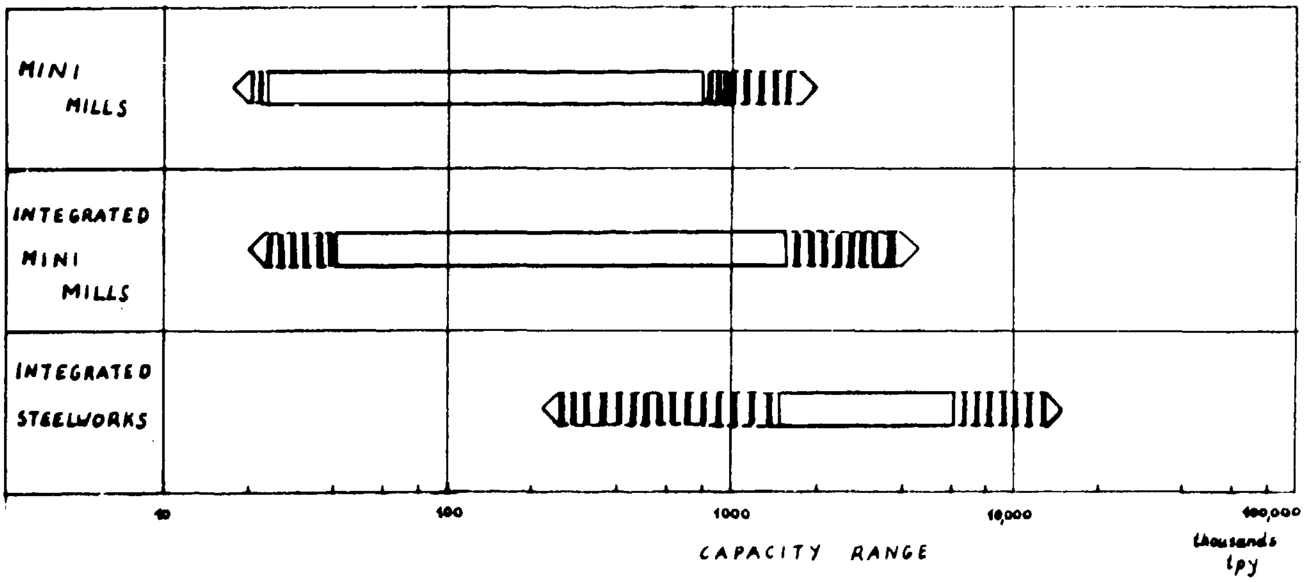


Figure 1. Main process steps for the different steel products;

- A – Blooms
- B – Billets
- C – Slabs
- D – Heavy plates
- E – Spiral welded tubes
- F – Hot rolled coils
- G – Pickled coils
- H – Cold rolled coils
- J – Strips; pickled, cold rolled, galvanized
- K – Sheets; hot rolled, pickled, cold rolled, galvanized
- L – Galvanized coils, tinned coils
- M – Pipes; seamless, butt-welded
- N – Sections
- P – Wire, rod and bar
- R – Billets

(Source: Reference Nr. 18)

Figure 2:



(Source: Based on references 4,5,10,18,24,25,26,27,28,34,40,41,45)

1.2 Capacity ranges

The BF-BOF system requires raw material handling facilities, coke plant, main and auxiliary facilities of blast furnace. This system with such heavy structures is fit for large scale production.

Although it is possible to have more than 2 BFs in an integrated steelworks, the maximum scale of such a steelworks is considered 15 million tons a year because there are limits to the capacity of unloading and storing faclities of raw materials. The scale of the integrated mini-mills varies according to the type of production method it uses. Production of 20,000 to 60,000 tpy is possible if solid reductant is used. In general, the production scale of 300,000 tpy is considered minimum from the point of economical use of gaseous reductant. Scale-up of the production capacity is easily made in both cases by adding modules. However, the scale of 2 millions tpy is generally considered maximum because if it becomes too large, integrated mini-mill (DRI-EAF) will be less economical than integrated steelworks (BF-BOF). Figure 2 illustrates the usual capacity ranges of the three types of plants above described.

Tables 2a & 2b show examples of functions relating costs for the limiting case (capacity=2 million tons).

Table 2a Capital cost in relation to plant size for the limiting capacity case of 2 million tons per year.

Plant size thousands of tons)	Index of capital cost	
	Integrated steelworks (BF-BOF)	Integrated mini-mill (DRI - EAF)
1000	129	109
2000	115	108
3000	100	107

Source: Commodities Research Unit Survey

Table 2 b:

Process sequence	Capacity in raw steel (tons/year)	Total cost of raw steel (millions of dollars)
Integrated steelworks: Ore 6000 tpd BF, sinter plant, coke plant, two 150-ton BOF, continuous caster, hot mill, merchant mill	2 000 000	955*)
Integrated mini-mill: Direct reduction, six 200-ton EF, continuous caster, hot mill, cold mill, galvanizing	2 000 000	965*)

Source· UNIDO/ICIS. 25

*) based on prices of the year 1975

Production scale of the mini-mills varies widely because its main production facility, EAF (electric arc furnace) using scrap, ranges from the small 1 to to more then 200-ton capacity.
However, the adequate scale of a mini-mill is this one that keeps the balance with the capacity of the rolling mill it possesses and that makes the best of the big advantage of low investmwent.

By 1980 there were about 50 mini-mills in Europe, North America, and Japan, all broadly similar, with EAF-scrap melting, dontinuous casting and long product mills. Their capacities ranged between 50 000 and 800 000 tpy, most being around 250 000 tpy (see Table 2c).

Table 2c: Scrap-based mini-plants in industrial countries

Countries	Number of plants	Capacity range 1 000 s tpy	Capacity mean 1 000 s tpy
Europe	23	89 - 600	200
North America	12	200 - 500	300
Japan	11	150 - 800	360
All	46	80 - 800	265

(Source: Steel Times International 1985)

Table 3a

DIRECT REDUCTION - PRODUCTION AND PRODUCTION CAPACITIES

(in thousands tonnes)

Country	Capacity	Production
Argentina	930	949
Brazil	315	255
Burma	20	10
Canada	1625	538
India	180	42
Indonesia	2300	500
Iran	330	-
Iraq	485	-
Mexico	2025	1498
New Zealand	150	155
Nigeria	1020	162
Peru	100	26
Qatar	400	383
Saudi Arabia	800	351
South Africa	225	76
Sweden	70	20
Trinidad	840	283
USSR	417	15
United States	1090	-
Venezuela	4452	2468
Fed. Rep. of Germany	1280	70

(Source: Steel Times International)

Table 3b

The following table lists direct reduction plant installed worldwide. It includes both gas-based and coal-based direct reduction installations, covering the various DR processes that have been developed. In addition to plants that are now comparatively well established, the table shows the major installations and DR plant recently started up. Plants that are currently shut down are indicated by an asterisk.

Country, company and location	Process	Start-up	Capacity (Mt/year)
Algeria			
SNS, El Milia	—	1990s	2.3
Argentina			
Acindar, Villa Constitución	Midrex	1978	0.42
Dalmine Siderca, Campana	Midrex	1976	0.33
Brazil			
Aços Finos Piratini, Charqueadas	SL/RN	1972	0.065
Cosigua*, Santa Cruz	Purofer	1976	0.33
Usiba, Bahia	HYL I	1974	0.25
Burma			
Government, Maymvo	Kinglor Metor	1981	0.02
Government, Maymvo	Kinglor Metor	1984	0.02
Canada			
Niagara Metals, Niagara	Accar	1973	0.035
Sidbec-Dosco*, Contrecoeur	Midrex	1973	0.40
Sidbec-Dosco, Contrecoeur	Midrex	1977	0.625
Stelco*, Bruce Lake	SL/RN	1975	0.35
Sudbury Metals,* Sudbury	Accar	1976	0.24
Egypt			
Alexandria National Iron & Steel Co, El Dikheila	Midrex	1987	0.716
Germany FR			
Hamburger Stahlwerke, Hamburg	Midrex	1971	0.40
Nordferro*, Emden	Midrex	1981	0.88
Thyssen Niederrhein*, Oberhausen	Purofer	1981	0.15
India			
Tata Iron & Steel, Jamshedpur	Tata	1979	0.005
Ipitata, Joda	Tata	1985	0.09
Sponge Iron India, Paloncha	SL/RN	1980	0.03
Sponge Iron India, Paloncha	SL/RN	1984	0.031
Orissa Sponge Iron, Orissa	Accar	1982	0.15
Sail, Ranchi	SL/RN	1982	0.003
Indonesia			
PT Krakatau Steel, Kota Baja	HYL I	1978	2.3
Iran			
Nisco*, Ahwaz	Purofer	1977	0.33
Nisco, Ahwaz	HYL I	—	1.0
Nisco, Ahwaz	Midrex	1985	1.0
Nisco, Isfahan	Midrex	—	3.2
Iraq			
Soidac, Khor Al Zobair	HYL I	1980	0.543
Soidac, Khor Al Zobair	HYL I	—	0.925
Italy			
Danieli, Buttrio	Kinglor Metor	1973	0.01
Arvedi*, Cremona	Kinglor Metor	1976	0.04
Japan			
Nippon Steel*, Hirohata	NSC	1977	0.15
NKK, Fukuyama	SL/RN	1974	0.24
Sumitomo Metal, Wakayama	Sumitomo	1975	0.168
Sumitomo Metal, Kashima	Kubota	1975	0.15
Sumitomo Metal Ind	LS-RIOR	1979	0.003
South Korea			
Inchon Iron & Steel*, Inchon	SL/RN	1970	0.15
Libya			
Government, Misurata	Midrex	1985	1.1
Malaysia			
Government + partners, Labuan	Midrex	1984	0.65
Hicom + partners, Trengganu	Nippon Steel	1985	0.60
Mexico			
Hylsa, Monterrey	HYL I	1957	0.105
Hylsa, Monterrey	HYL III	1980	0.25
Hylsa, Monterrey	HYL III	1983	0.50
Hylsa, Puebla	HYL I	1969	0.25
Hylsa, Puebla	HYL I	1977	0.63
Sicartsa, Lazaro Cardenas	HYL III	1985	2.0
Tamsa, Veracruz	HYL I	1967	0.28
New Zealand			
NZ Steel, Glenbrook	SL/RN	1970	0.15
NZ Steel, Glenbrook	SL/RN	1987	0.80
Nigeria			
Delta Steel, Warri	Midrex	1982	1.1
Peru			
Siderperú, Chimbote	SL/RN	1980	0.12
Qatar			
Qatar Steel Co, Umm Said	Midrex	1978	0.40
Saudi Arabia			
Hadeed, Al Jubail	Midrex	1983	0.80
South Africa			
Dunswart Iron & Steel, Benoni	Codir	1973	0.15
Scaw Metals, Germiston	DRC	1983	0.075
Iscor, Vanderbijlpark	SL/RN	1984	0.60
Sweden			
Höganäs, Oxelösund	Höganäs	1954	0.035
Sandvik, Sandviken	Wiberg	1952	0.024
SKF Stål, Hofors	Plasmared	1981	0.070
Trinidad			
Iscott*, Point Lisas	Midrex	1980	0.40
Iscott, Point Lisas	Midrex	1982	0.40
UK			
British Steel Corp*, Hunterston	Midrex	1979	0.80
USA			
Armco*, Houston, Texas	Armco	1972	0.33
Direct Reduction Corp, Rockwood, Tenn	DRC	1978	0.06
Georgetown Ferreduction, Georgetown, SC	Midrex	1971	0.40
Gilmore Steel Corp*, Portland, Ore	Midrex	1969	0.30
Titan Engineering*, Casa Grande	SL/RN	1975	0.06
Midrex, Charlotte, NC	Midrex EDR	1977	0.002
Inmetco, Ellwood City, Pa	Inmetco	1982	0.25
USSR			
OEMK, Kursk	Midrex	1985	1.6
OEMK, Kursk	Midrex	1990	3.2
Venezuela			
Fior de Venezuela, Puerto Ordaz	Fior	1976	0.35
Minorca, Puerto Ordaz	Midrex	—	0.75
Sidor, Matanzas	Midrex	1977	0.355
Sidor, Matanzas	HYL	1977	0.36
Sidor, Matanzas	Midrex	1979	1.0
Sidor, Matanzas	HYL	1980	2.0

(Source: Steel Times International)

2. Characteristics of the production methods

Each production method has its own advantages in each facilities, raw materials and energy it uses. Selection of a method should be based on the geographical, economic and cultural condition of the site. The characteristics as raw materials, energy, production facilities and cost and type of products of each method are discussed in the following paragraph.

2.1 Raw materials

Iron ore is the basic material to make iron which is refined to make steel. BF - BOF is the most common, proven, economical and large scale production system. The system, with BOF using molten pig iron from BF, is free from facilities to melt cold materials. In the DRI-EAF route iron ore is reduced directly to iron the so called DRI (directly reduced iron). This type of feed stock cannot be understood to be scrap (see definition in the next process route) in the conventional sense but it must be considered to be the equivalent of scrap as regards its function. Production and production capacities in 1983 were divided up as shown in Table 3a, Table 3b lists direct reduction plants installed worldwide.

The production of DRI ore rose to 7 800 000 tonnes in 1983 from 7 500 000 tonnes in 1982 (+ 3.8 %).

To secure stable supply of iron ore to mass-produce steel, an organized arrangement is required for operations starting from mining to shipping, unloading,storing and to charging into the furnace.

Formerly, steel industry grew in the area near the iron and coal deposits. Recently, with the advance of commodity distribution system the steel industry is being developed on the coast having part facilities to secure stable supply of iron ore through a regular route.

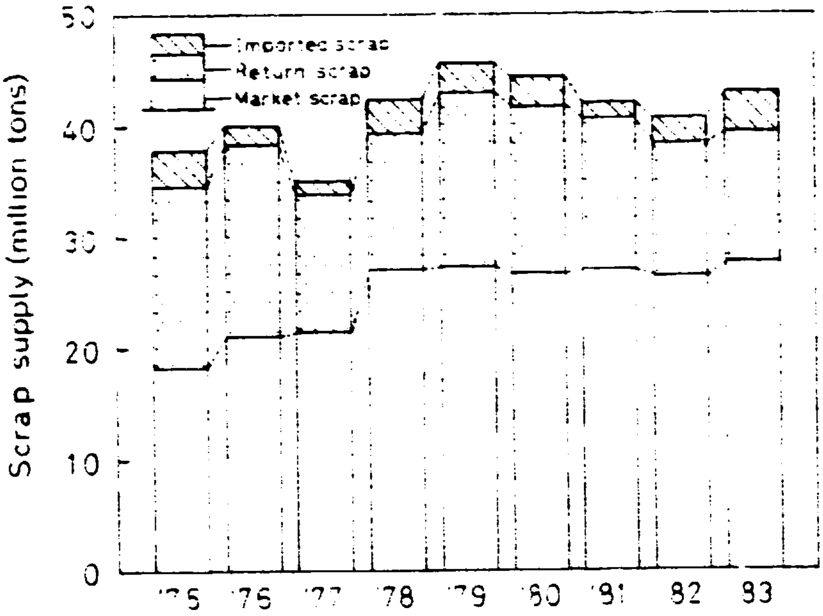
Scrap is the main raw material for mini-mill operation. Domestic scrap in large part recovered in the steel consuming regions may be classified into three categories according to the mode of generation, namely:

- Internal scrap
- Producer scrap
- Capital scrap

Scrap lacks elasticity in supply and the price fluctuates, see Fig. 3 a, b.

International sources of scrap are limited to few industrialized countries. Improvement in fabrication practice and increasing application of the continuous casting process have significantly reduced the available recycled scrap (see Fig. 3 c).

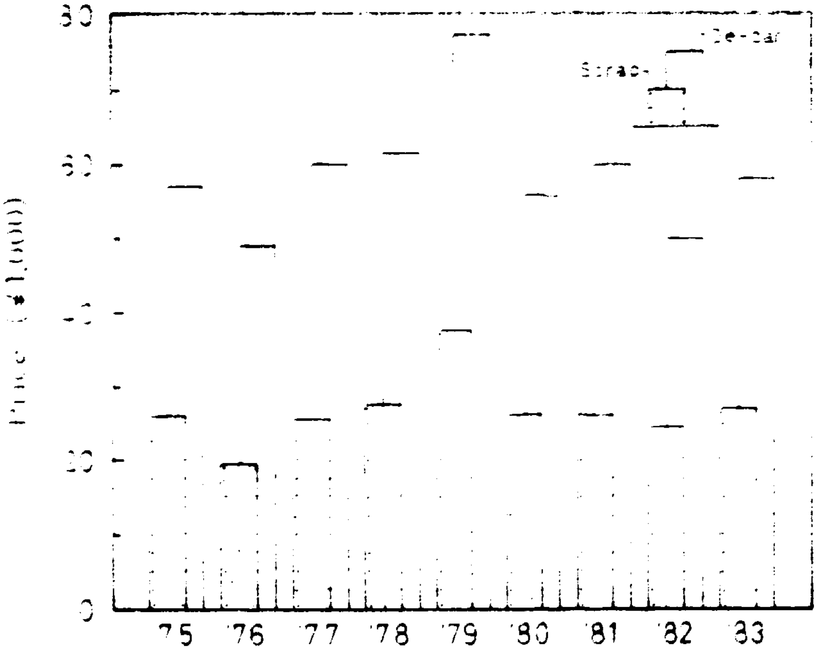
But on the other hand scrap collected in the market is increasing with the economic development and the continuous reduction in the life span of consumer goods. Availability of scrap is one of the important conditions to determine the location of a mini-mill. Prices of the products made by the mini-mill are greatly influenced by the prices of scrap.



Movement of scrap supply in Japan

Fig. 3a

(Source: Reference Nr.34)



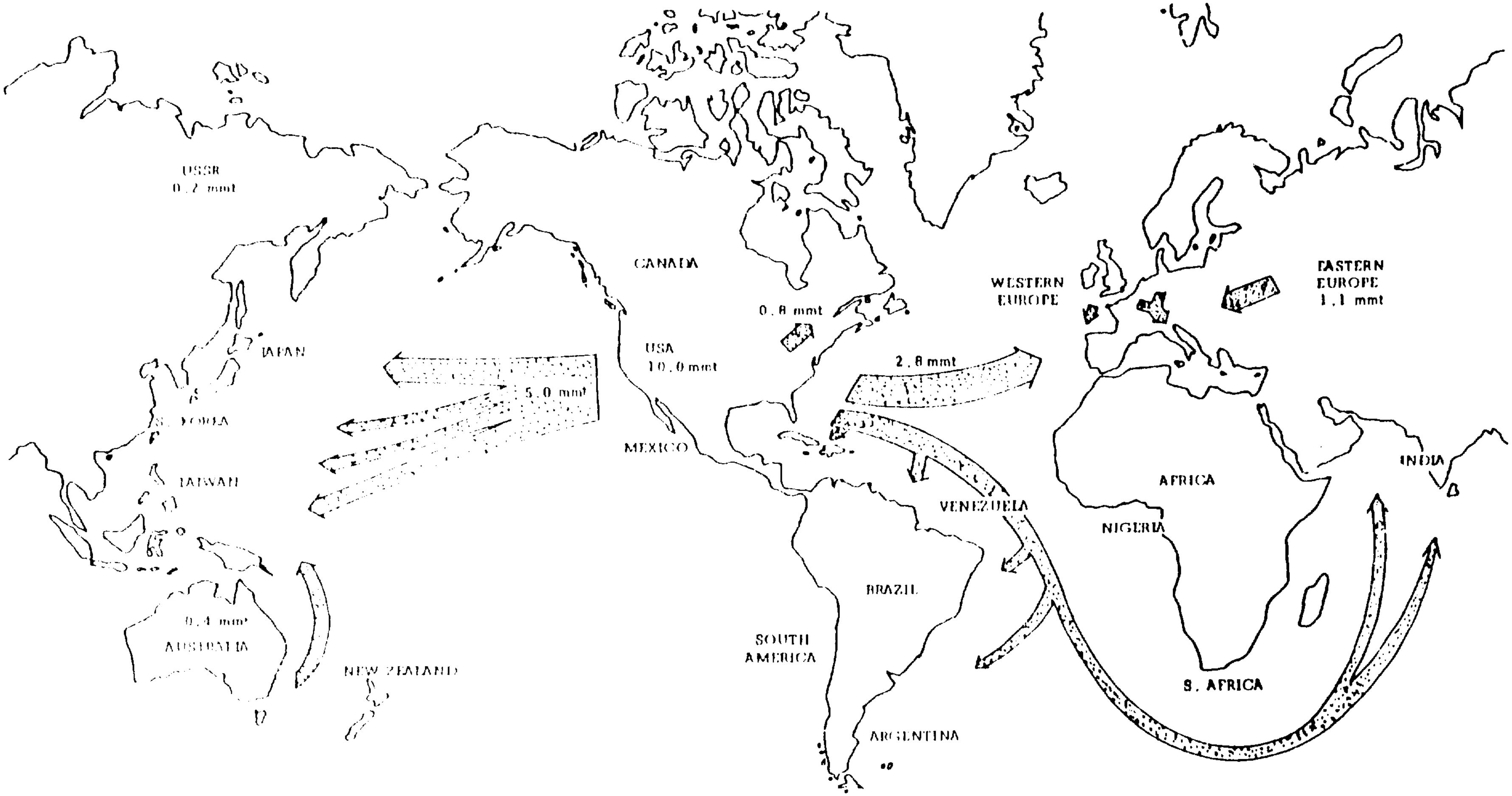
Movement of scrap^{x} and De-bar^{x} price per ton in Tokyo

X Scrap Special class heavy, De-bar 19mm dia SD30

Fig. 3b

(Source: Reference Nr. 34)

Major world ferrous scrap flow: 1979



Source: Union Carbide.

Figure 3c

2.2 Energy

The steel industry is a major chonsumer of energy. OECD figures show that it typically accounts for around 7.5 % of the total energy used in an industrialized country, and for 18 to 20 % of the total energy used by industry.

In Japan the steel industry's share is even greater, with 15 % of total energy and 35 % of total industrial energy consumption. Efforts to save energy consumption have resulted in the saving of 20 % in 10 years as shown in Fig. 4.

Energy consumption by different iron and steelmaking processes is shown in Fig. 5. DRI (integrated mini mills) generally uses natural gas, though it can also use coal. Easy availability of natural gas at low cost is one of the conditions to determine the location of DRI.

By 1984, there were around 30 gas (or oil) based integrated mini mlls around the world. (See Table 4).

TABLE 4 NATURAL GAS INTEGRATED MINI-MILLS (1984)

Country	Number of plants	Capacity range 1,000 s tpy	Capacity mean 1,000 s tpy
Iran	4	150 - 2,200	1,250
Iraq	2	1,000 - 1,500	
Qatar	1	400	400
Indonesia	3	450 - 1.750	900
Venezuela	1	3,000	3,000
USA	1	2.500	2.500
MEXICO	6	90 - 1,000	450
ALL	18	90 - 3,000	1,050

(Source: Steel Times International)

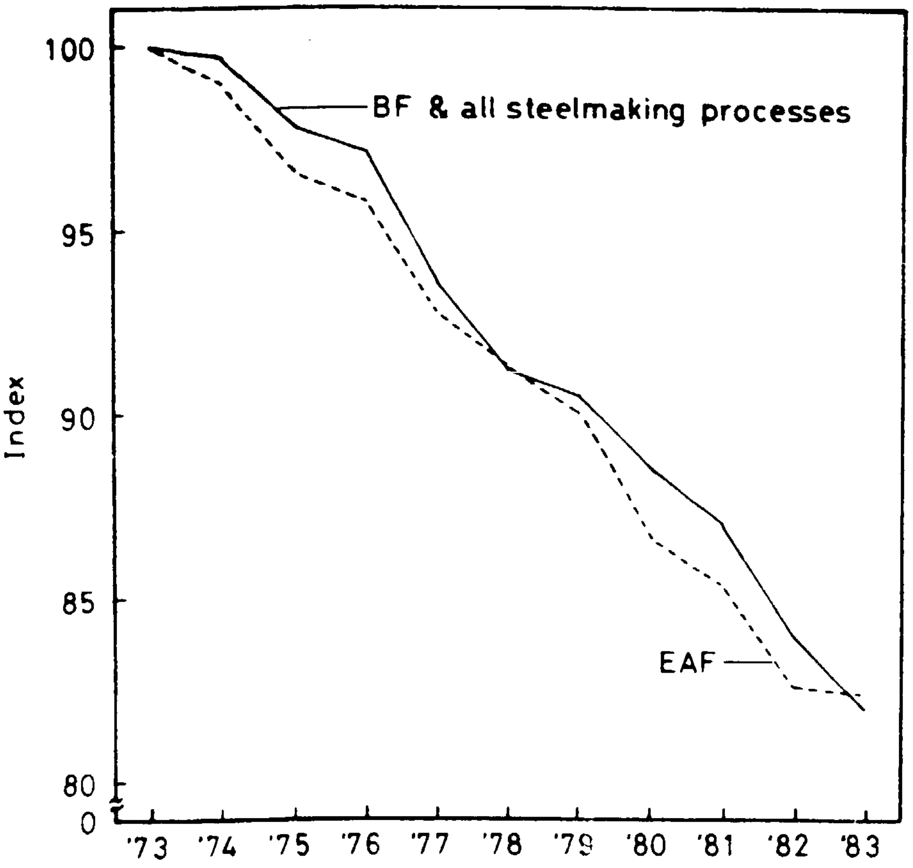


Fig 4 Indices of energy consumption per ton of crude steel production in Japan

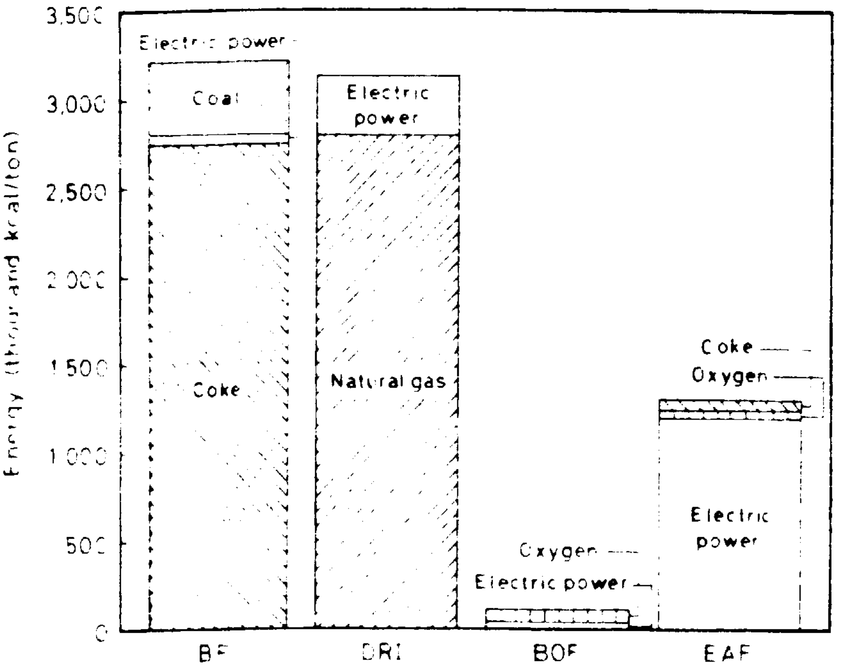


Fig 5 Energy consumption per ton of pig iron, reduced iron and crude steel production by process

Note: Energy conversion : coke 7,000 kcal/kg, coal 6,500 kcal/kg, oil 9,500 kcal/[illegible] oxygen [illegible] kcal/Nm³ and electric power* 2,4[illegible] kcal/kWh

* Based on the power generated by fuel [illegible]

(Source: Reference Nr. 34)

As shown in Fig. 5 and with regard to the absolute energy comsumption the integrated steelworks (BF - BOF) route is more favorable than the integrated mini-mill (DRI-EAF) route.

The second essential input for the mini-mill type (next to adequate and cheap scrap) is cheap electric power availability. When oil or coal is converted to electric power, the energy loss including the loss from power transmission amounts to more tahn 60%. Technical studies to make use of fuels substituting power are an important task to EAF steel makers at the location where hydro-power is not available.

Table 5 shows raw materials and energy required for each type of plant.

Table 5 Material and energy for steel production by type of plant

Material R Energy	Integrated Steelworks (BF - BOF)		Integrated mini-mills (DRI - EAF)		Mini-mill
Iron ore	o		o		
Scrap		X		X	o
Coal (Coke)	(o)		X*)		
Oil	X				X
Natural Gas			o		
Electric power	X	X	X	o	o
Oxygen	X	o		X	X

Notice:

o means primary material or energy
X means secondary material or energy
*) Some of DRI processes use coal instead of natural gas.

(Source: References 17,24,25,34 and 45)

3. Economics of steel plants

3.1 Capital cost

The "plant cost" covers all costs associated with the actual construction of the steel plant and includes the costs of site preparation, production and auxiliaty department, utilities, auxiliary buildings, engineering and administration charges during construction, as well as contigencies. The costs to be incurred on capital spares, preliminiary and promotional expenses, start-up expenses, construction fuacilities and interest during implementation are added to the plant cost to arrive at the "fixed investment".

The wide range of possible capital cost variations can be seen in Tables 6a,b.

Figure 6 illustrates the decrease of cost index with increasing plant capacity for the three types of steel plants. The capacity ranges for the economical operation of the respective types of plants are indicated.

The capital cost of BF-BOF perton of steel is compared with that of DRI-EAF in Fig. 7a,b. The difference reflects the cost of the coke oven and the fact that an integrated mini mill costs about 80 % of that of a integrated steelworks.

As a further general observation one could perhaps say that the investment cost per ton of installed capacity of a mini-mill is about 4o % of an integrated steelwork cost when only scrap is charged (see Fig. 7 b and 6).

The investment cost will, of course, vary from project to project and it would not, threfore, be easy to indicate any specific figures for it.

Table 6 a: Estimated capital costs of steel producing routes

Process facility \ capacity tpy	Integrated ateel works (BF - BOF)			Integrated mini-mills (DRI - EAF)			Mini-mills (EAF)		
	500 000	2 000 000	8 000 000	50 000	500 000	1 000 000	50 000	500 000	1 000 000
Coke plant	X	X	X						
sinter plant		X							
blast furnace	X	X	X						
basic oxygen furnace	X	X	X						
direct reduction plant				X	X	X			
electric arc furnace				X	X	X	X	X	X
continuous casting machine	X	X	X	X	X	X	X	X	X
rolling mill	X	X	X	X	X	X	X	X	X
Galvanizing unit			X						
Total costs (million dollars)	305	955	6 000	17	213	606	12	160	346

Source: UNIDO/ICIS. 25.

Table 6b

Estimates of the Cost of Building New Integrated Steel Plants in Various Countries

Costs in dollars per net raw ton

Estimate source and region	*1976*			*1978*[a]		
	Slabs	*Finished steel*	*Index (U.S. = 100)*	*Slabs*	*Finished steel*	*Index (U.S. = 100)*
Barnett[b]						
United States	399	726	100	468	853	100
Canada	400	756	104	403	762	89
Japan	332	525	72	482	764	90
European Coal and Steel Community[c]	368	649	89	488	860	101
Aylen[d]						
United States	...	...	100	...	...	100
Japan	...	...	78	...	...	88
Europe	...	...	59	...	...	73
Industry estimates[e]						
United States	...	...	...	...	900	100
United Kingdom	...	...	...	382	886	98
Canada	...	...	...	438	...	...
Australia	...	...	...	503	...	...
Indonesia (direct reduction)	...	...	...	...	900	100
Turkey (direct reduction)	...	...	...	...	862	96
Taiwan	...	...	...	...	651	72
Japan	...	...	...	...	721	80

a. Author's estimate, using domestic gross-capital formation deflators and changes in average exchange rates, 1976–78.

b. D. F. Barnett, "Comparative Capital Costs in World Steel Industries," in D. F. Barnett, *The Canadian Steel Industry in a Competitive World Environment*, vol. 2: *Costs and Performance* (Ottawa: Resource Industries and Construction Branch, Industry, Trade and Commerce, 1977).

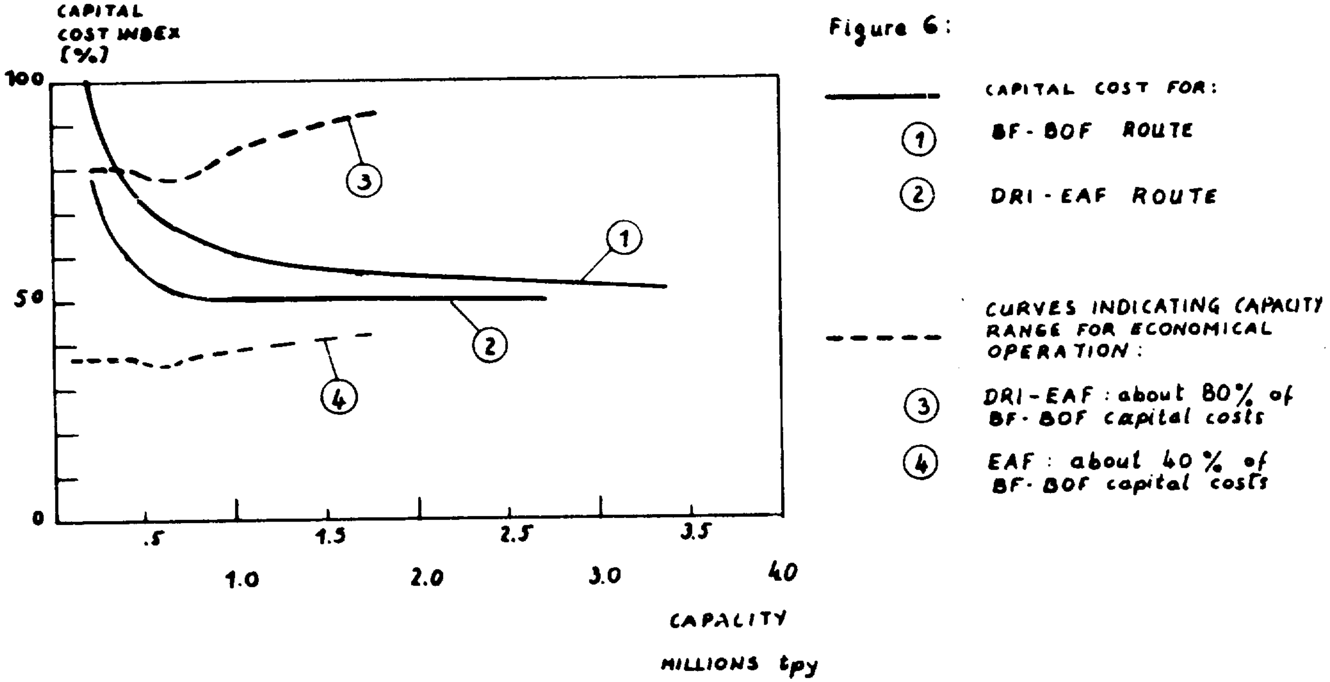
c. Includes Belgium, France, Italy, Luxembourg, Netherlands, and West Germany.

d. Jonathan Aylen, "Innovation, Plant Size, and Performance: A Comparison of the American, British, and German Steel Industries," paper presented at the Atlantic Economic Association Conference, Washington, D.C., October 12, 1979.

e. From confidential industry sources.

(Source: Reference Nr. 50)

Figure 6:



(Source: Based on references 4,5,17,18,29,32,33,34,35,36.37,38,39 and 45)

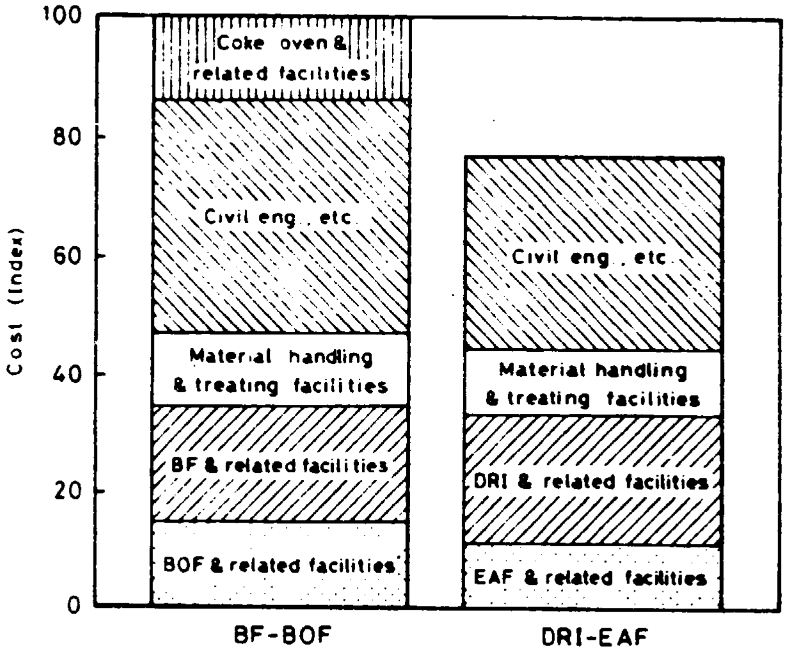


Fig. 7a Comparison of capital cost of steel production facilities by process

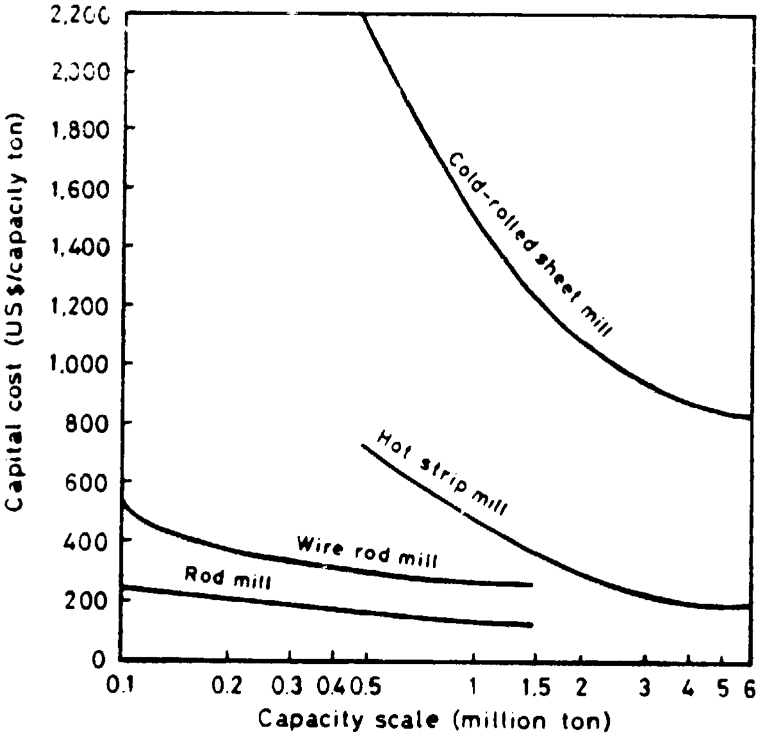
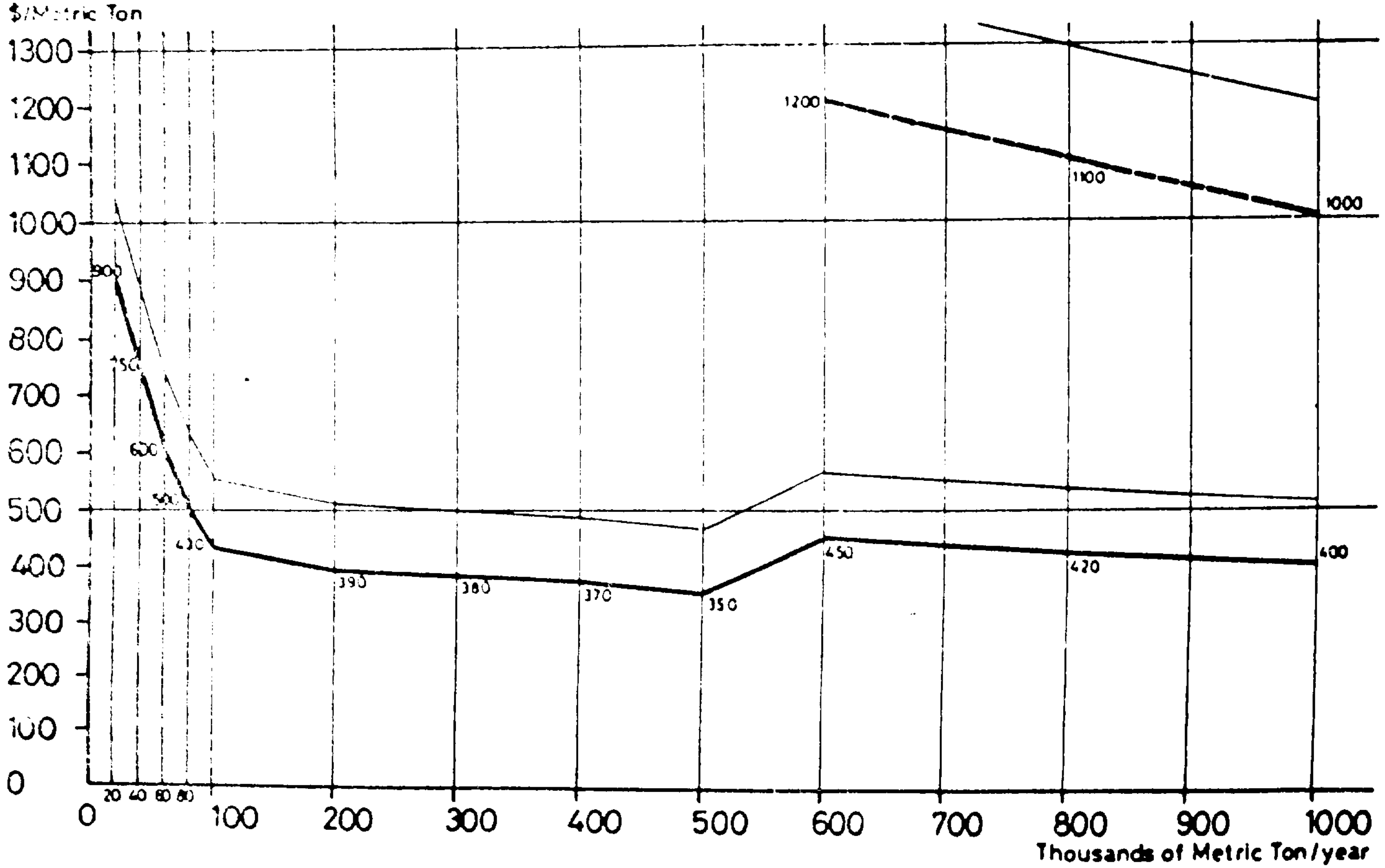


Fig. 8 Capacity scale and capital cost by rolling mill

(Source: Reference Nr. 34)

INVESTMENT COSTS PER METRIC TON - MINIMILLS VS. STANDARD INTEGRATED MILLS



NOTE :

a) plants constructed on a turnkey basis
b) the costs for extra civil work due to unsuitable ground are not included
c) we have assumed a minimill complete with electric arc furnace, conticaster and rolling mill vs an integrated steel mill with coke ovens, blast furnace, converter, casting, services, plus blooming and rolling mill
d) should a minimill have to make use of spong iron instead of scrap, an additional cost of $ 220/250 per metric ton for the installation of Direct Reduction must be considered

Figure 7b

(Source: Reference Nr. 39)

3.2 Production cost

Production cost of steelmaking varies depending on the conditions under which the steel works is run. The operation cost of an integrated mini-mill is affected by natural gas prices and the mini-mill by power cost.

Considering steelmaking costs the BF-BOF route is the most economic. Both gas- and coal-based DRI-EAF routes are more costly due to a number of reasons including the high production costs for DRI and substantial power consumption involved with EAF steelmaking. Tables 7 a,b present to production costs for different iron and steelmaking processes.

Typical iron and steelmaking operating costs are given in Table 7 c and illustrated in Fig. 7 c.

Table 7 a: Production costs of iron and steel in different routes. Ironmaking process

			BF-BOF route		Gas based DR EAF route		Coal based DR-EAF route	
	Unit	Unit price US$	Quantity	Cost US$	Quantity	Cost US$	Quantity	Cost US$
Iron and feedstock								
Fine ore	t	35.0	0.991					
Agglomerated ore	t	48.9	0.498	24.4	1,440	70.4	1.440	70.4
Energy								
Coking coal	t	61.0	0.612	37.3				
Noncoking coal	t	50.0					0.600	30.0
Natural gas		3.5			($300m^3$)	37.8		
Other fuels			(BFG,COG)	+17.3				
Electricity	kWhr	0.045	41	1.9	125	5.6	75	3.4
Auxiliary materials spare				6.3				0.6
Labour amnd maintenance				14.6		10.0		17.0
Depreciation				23.8		9.6		13.7
Miscellaneous				8.3		7.4		13.4
Total manufacturing cost of iron	US$			134.0		140.80		148.6
Energy consumption	Gcal			3.34		2.99		4.19

(Source: Steel Times International)

Table 7 b: Production costs of iron and steel in different routes. Steelmaking processes

	Unit	Unit price US $	BF-BOF route		EAF route		Gas based DR-EAF route		Coal based DR-EAF route	
			Quantity	Cost US $	Quantity	Cost US $	Quantity	Cost US $	Quantity	Cost US $
Ferrous feedstock										
Pig iron	t	133.88	0.823	110.2						
Scrap	t	94	0.267	25.1	1.067	100.0	0.269	25.3	0.269	25.3
DRI	t						0.879	123.8	0.879	130.6
Fuel				2.2		0.5		0.4		0.5
Oxygen	Nm^3		46.o	3.5	25	1.9		1.9		1.9
Electricity	kWhr		26.6	1.2	525	23.6	575	25.0	575	25.9
Auxiliary materials spare				4.6		17.6		16.2		17.8
Labour and maintenance				11.6		15.3		15.3		15.3
Depreciation				7.1		6.8		6.8		6.8
Miscellaneous				9.7		13.5		13.5		13.5
Total manufacturing cost of liquid steel	US$			170.8		179.2		229.1		237.6
Energy consumption	Gcal			3.34		1.27		4.02		5.08

(Source: Steel Times International)

Table 7c

Typical iron and steelmaking operating costs(1): Industrialised country 1982/83

(per metric ton of production)

Production Mode (3)	Estimated operating costs; US$ (2)	
Scrap-based EAF		
Scrap (1.1 mt)		1.1X
Electricity (600 kWh)	25	
Electrodes	10	
Refractories	4	
Fluxes	2	
Miscellaneous (gas, water, etc.)	13	
Labour and maintenance	16	
	70	+ 1.1X
Blast Furnace Hot Metal		
Iron ore and sinter	65	
Coke (less credits for coke breeze and coke oven gas)	55	
Fuel oil (25 kg)	6	
Fluxes	3	
Miscellaneous (gas, water, etc.)	16	
Labour and maintenance	10	
	155	
BOF Steelmaking		
Hot metal (0.8 mt x 155)	124	
Scrap (300 kg)		0.3X
Fluxes	5	
Oxygen	4	
Refractories	2	
Miscellaneous (water, gas, electricity, etc.)	15	
Labour and maintenance	10	
	160	+ 0.3X
Sponge Iron Production		
Iron ore (1.5 mt x $50)	70	
Gas (2.75 GJ)	45	
Electricity	5	
Miscellaneous	10	
Labour and maintenance	10	
	140	
Sponge Iron/Scrap EAF Production		
Sponge Iron (650 kg)	91	
Scrap (450 kg)		0.45X
Electricity	28	
Electrodes	13	
Refractories	5	
Fluxes	3	
Miscellaneous (gas, water, oxygen, etc.)	16	
Labour and maintenance	16	
	172	+ 0.45X

(1) Approximate costs; will vary widely depending upon size and location of works.
(2) Composite scrap price given by US$ X.
(3) The opportunity cost of scrap is used in the analysis, whereas in the real world the oxygen furnace steelmaker could rely entirely on internal arisings and be largely insulated against the vagaries of the scrap price.

(Source: IISI, Brussels 1983)

Comparative steel production costs: Industrialised Country 1982/83

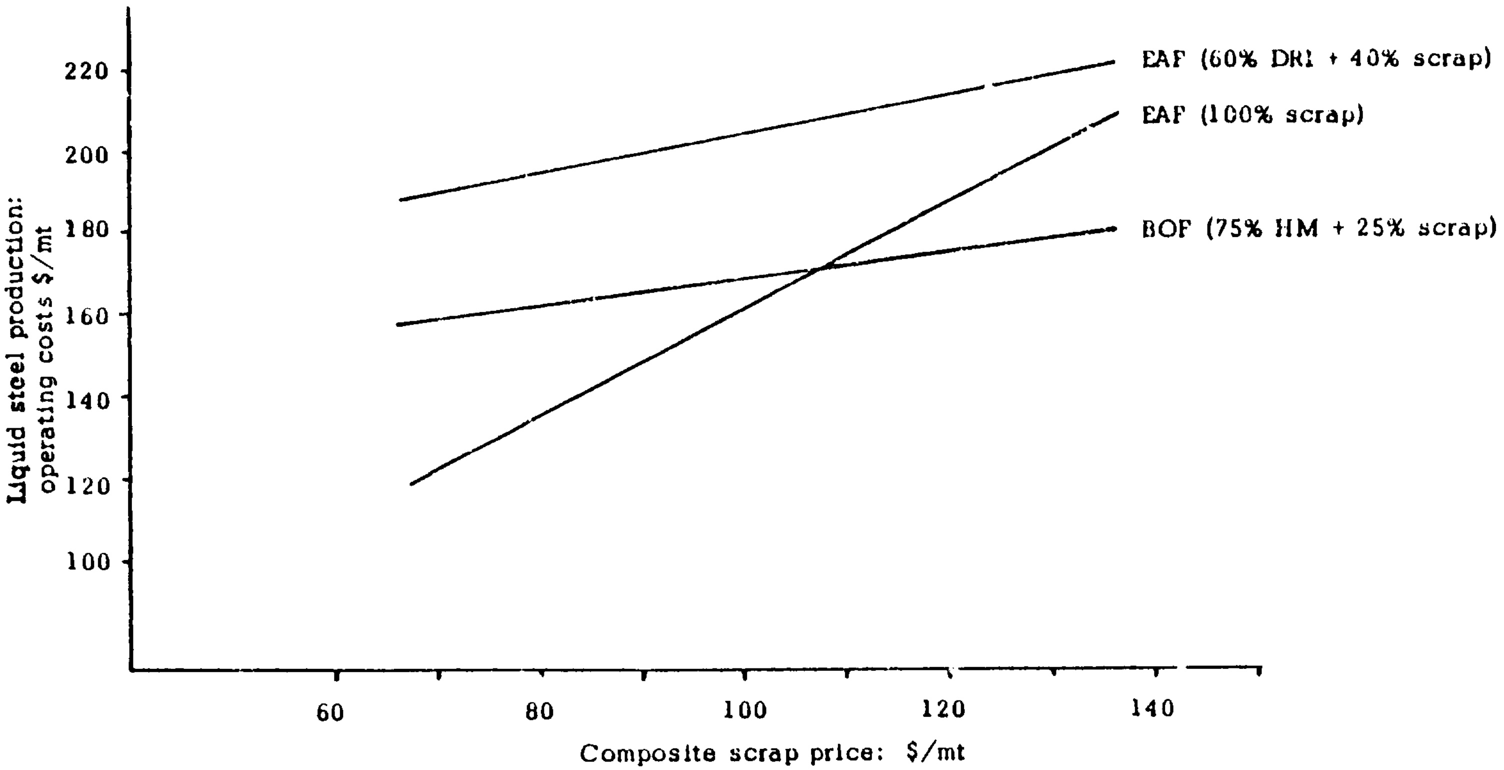


Figure 7c

(Source: IISI, Brussels 1983)

4. Rolled steel products

To select the type and grade of rolled steel products suitable to each iron and steel production process, consideration should be given to the fact that each product has its own scale merit, or the optimum scale of production, as each process has its own. Selection should be made in such way that the scal merit of the product matches that of the process and the quality of the product agrees with the property of raw material used by the process.

The relationship between the production scale of rolling mill and the capital cost per ton of product is shown in Fig. 8. The rolling mills constitute the largest element of capital investment in a mini-mill. Being the key to the profitability of the mill, they have to be tailored to the plant's needs must be flexible and have a high utilization factor.

Together with its electrical and auxiliary equipment, a 150 000 tpy rolling mill could account for over 50 % of the total investment in a mini-mill. A typical breakdown of this cost could be:

Melting	12 %
Casting	14 %
Rolling	52 %
Building	12 %
Services	10 %

In the case of expensive rolling mills such as hot strip and cold strip mills, the smaller the production scale is the higher (Fig.8) the capital cost per ton becomes. The unit capital cost of these mills begins to level off when the production exceeds 2 million tons a year. In the case of less expensive rod and wire and mills, the unit capital cost levels off when the production is over 500,000 tons a year.

Large scale BF-BoF is desired to be combined with such rolling mills as hot strip, cold strip and plate mills, and the mini mill rod and wire rod mills.

Molten pig iron from BF and reduced iron from DRI, both the steelmaking materials made from iron ore, contain less impurities. The recent technological advance to desulfurize and dephosphorate molten pig iron has made it possible to make steel of high purity in BOF. Chemical contents of the steel from BF-BOF and DRI-EAF pose no restriction on the type and grade of rolled steel to be produced. In the case of mini mill steelmaking, impurities such as Cu and Cr contained in scrap mix into the steel produced. Since it is hard to remove them economically, the mini mill is less suitable to the production of high quality rolled steel such as plate for high grade electric welded line pipe and other steel products to which the trump elements contained may present a problem.

The existing products mix still limits mini-mills to a share of around a quarter of the total steelmarket by adding sheet to their product range, mini-mills could add another 45% slice to their market potential. Several attempts have been made to design a mini-strip mill such as sendzimir planetary mill, steckel and reversing compact (HSRC) mill, all present(small)flat product plants which could be economically desirable for developing countries. But most mini steel operators feel that sheet will be completely included in their production capability when continuous casting technology is able to cast slabs 1 ½ - 3 in thick. Plantmakers in developed countries believe that this technology is only three to five years away

Analysis of other financial and econmic factors like capital output ratio, distribution costs inventory costs, enterpreneur cost construction time and costs etc. suggest that the overall advantage lies with the mini-mill.

5. Infrastructure

Infrastructure in connection with developing countries can often include difficulties. Especially for large integrated steelworks, large infrastructures are needed. But even for mini-mills the weight of this factor should not be underestimated.

Some ideas about the importance of the infrastructure can be obtained from Table 8a which illustrates typical quantities for a 1 Mtpy integrated steelworks.

6. Manpower requirement

The efficient operation of a steel plant is determined to a large extent by the skills possessed by the work force. A wide range of skills and capabilities is involved, as the operations carried out in a steel plant are many and complex.

The work force in a steel plant can be broadly grouped into the following categories of personnel according to the characteristic skill for carrying out their respective tasks:

i) Managerial

ii) Supervisory

iii) Highly skilled such as steel making, continuous casting, rolling, maintenance of electrical and mechanical equipment.

iv) Skilled like masons, welders, crane operators, control panel operators etc.

v) Semi-skilled as typefied by the work of conveyor attendants, oilers, packers, loaders etc.

vi) Unskilled such as those reuqired for cleaning handling materials, messengers, janitors etc.

vii) Office staff carrying out works such as secretarial, typing, filing etc.

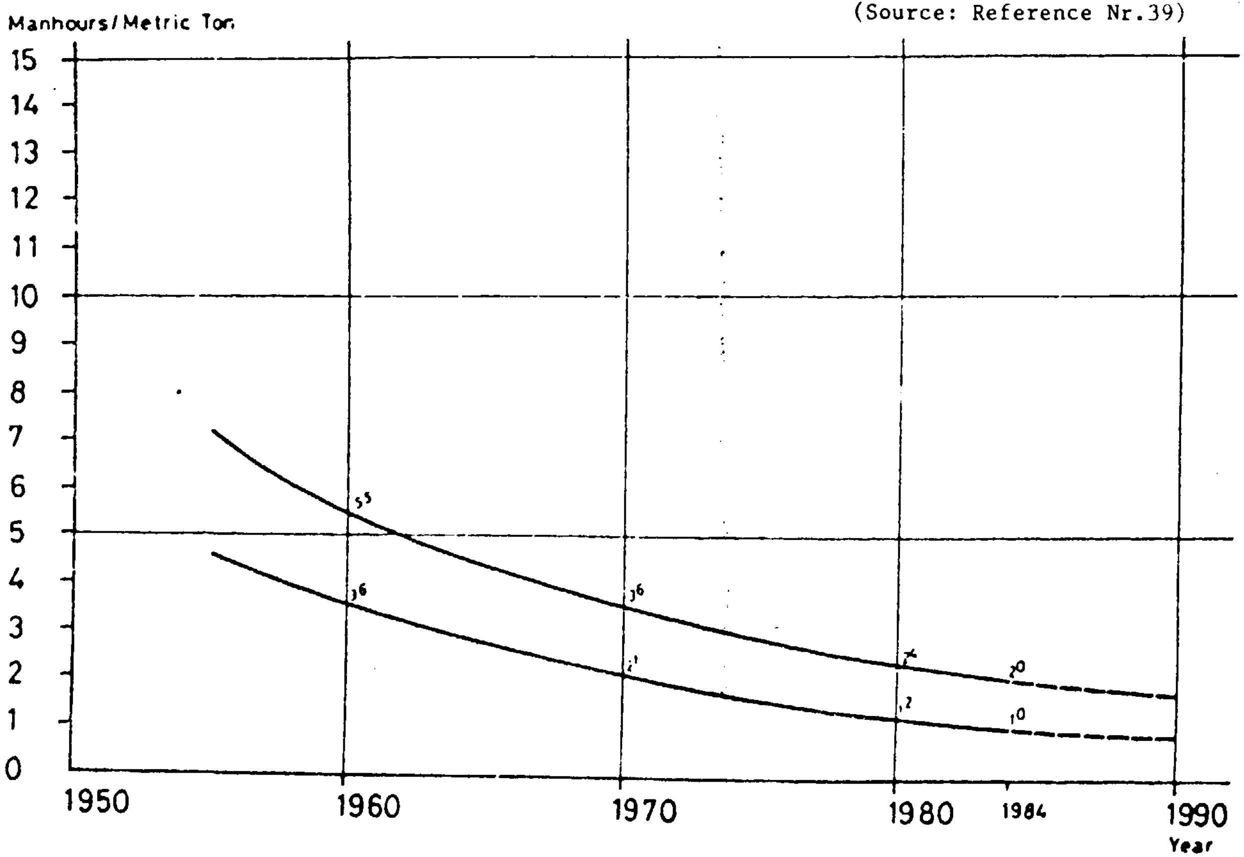
Table 3a
(Source: Steel Times International)

Typical quantities for a 1Mt/year integrated steelplant

Plant area		Civil and structural					Process and plant							
		Concrete (m³)	Reinforcing bar (t)	Foundation bolts (t)	Structural steel (t)	Sheeting (m²)	Process equipment (t)	Refractories (t)	Tubes (t)	Cables (m)	Motors	Pumps	Cranes	Conveyors (m)
Raw material handling, storage and reclamation		14,000	2500	100	4500	48,000	2700	—	—	127,600	218	5	—	23,700
Coke ovens		30,000	3500	100	6500	38,000	6500	21,600	1500	405.000	377	107	3	2200
Pellet plant		26.000	3000	110	3000	21,700	5700	1900	100	225.000	220	51	3	2100
Lime plant		4000	500	20	1200	6500	1200	1050	50	101.000	116	2	—	600
Blast furnace and gasholders		37.000	6000	449	6700	16.000	10,500	15.700	1200	500.000	254	35	4	1500
Steel plant		25.000	6400	420	13.500	33,000	5500	2900	600	170.000	250	50	10	600
Continuous casting		30,000	5000	180	5000	30.000	4500	350	950	130.000	650	62	6	—
Rod mill and light section mill		102,000	10,000	550	11.500	130,000	17,500	2200	1000	990,000	1400	145	21	—
Power plant		3600	350	40	900	1900	2500	300	230	100,000	109	70	1	-
Oxygen plant		5500	500	25	300	4000	2200	—	230	50.000	52	27	1	
Mechanical inter-plant services		35,000	7000	150	7000	2400	2200	—	7000	100.000	438	48	3	—
Electrical distribution		2200	72	—	70	8500	1250	—	—	406.000	8	4	—	—
Coal unloader and container cranes		—	4	104	—	—	1550	—	30	10.800	64	4	2	—
Auxiliary buildings		34.000	3000	40	1500	72.000	500	—	100	—	86	—	27	—
	Total	348.300	47.826	2288	61.670	412.000	62,100	46.000	12.990	3.187.800	4142	610	81	30,700

"MINIMILL" HOURLY PRODUCTIVITY

Table 3b
(Source: Reference Nr.39)



NOTE : The actual position within the productivity span depends on the type of product and quality of steel

The manpower estimates have to be based on the production processes, equipment and facilities envisaged in different departments (see Table 8 b). The estimates have also to take into account, as far as possible, the prevailing practices of manning in the steel plants. Whenever direct manning is involved, the positions have to be as far as possible identified on the basis of the layout, technology, equipment, location, job affinity etc.

A centralized maintenance system can be considered. The merits of the centralized system are:

- efficient co-ordination and monitoring of the maintenance activities.
- better utilization of maintenance power,
- standardization of spares and maintenance procedures.

The incorporation of a working concept with multi-skill worker can reduce the work force. The multi-skill concept will assist in developing the skill of operational personnel for carrying out minor repairs and inspection of the equipment, and assisting the maintenance crew in carrying out capital repairs and break-downs.

7, Training

Trained manpower is one of the essential pre-requisites for the successful maintenance and operation of the steel plant in question. The education and training of industrial manpower takes considerable time. As recruitment and training of work force is time consuming, it is imperative to initiate comprehensive manpower planning well in advance so that the required number of qualified and trained personnel are available during commissioning and operation of the steel plant. The objective of such a plan should not be limited to merely listing out the requisite number of men and their qualifications and training needs, but should also provide for adequate opportunities to the workmen for development of additional skills and for advancement. Manpower planning should therefore, embody the following aspects:

i) Manning schedule

ii) Job specification and qualification for recruitment

iii) Organization planning, span of control, functional responsibilities, reporting relationship and delegation of power

iv) Wage and salary scales

v) Lines of promotion and age matrix

vi) Job description and

vii) Recruitment, training and placement programme.

The training policies and programmes will have to be necessarily oriented towards ensuring maximum participation by the domstic personnel. The training schedule will include among others:
training in skills and jobs outside the country in question (if necssary) in plants with facilities similar to those being proposed for installation;
training at the equipment suppliers' works in order to familiarize the personnel with the design, operation and maintenance requirements of the equipment being supplied.

Besides the above, it will be necessary to provide on-the-spot training at the plant site itself during the erection,commissioning and operation of the plant.

The total cost of training will depend on the training changes per man-month, the living and out-of-pocket expenses of the trainees and their travelling expenses.

8. Comprehensive review about the three iron and steel production plants

The concept of a BOF plant (integrated steelworks) for the realization of a wide product range requires the presence of a certain degree of industrial infrastructure and an exisiting massive demand for steels. It also needs an arrangement to secure stable supply of iron ore and coal of high coking property. The scale of 1 million tpy is considered minimum for an economic operation. As a matter of fact, the growth of demand on the steel plant is dependent on the growth of demand on the downstream engineering plant and its performance in building-up is production.

In the early phases of the steel industry in many developing countries, the size of the market has not justified large integrated steelworks or the commissioning of steel plants has taken much longer than planned. Thus, development of direct reduction processes with low technical risk, reliability and simplicity in operation and downstream facilities (e.g. refractories, gas treatment, heat recovery etc.) could give the best economic benefits for these countries.

The integrated mini-mill composed of the stages direct reduction, electric arc furnace, continuous casting and rolling mills suit to medium scale production and is useful in the region where natural gas is easily available.

Concerning the reduced iron precaution should be taken against natural oxidation while it is shipped and stored. Capacity of an integrated mini-mill can be easily increased by adding modules. The modular design supports also the technological growth. For developing countries where steel requirements are primarily for non-flat products and when gradual expansion is planned with relatively small investment, these EAF steel plants are attractive and could fundamentaly offer a good alternative to large-scale BOF-plants.

The ability of the arc furnace process to operate on a relatively small scale makes this process attrative to developing countries seeking to establish an iron and steel industry to satisfy local demand for reinforcing bar, structural steel sections and similar products essential for a developing industrial sector.

The variable cost per ton of DRI-EAF steel is higher than that of BF-BOF but it can vary depending on the cost of natural gas. DRI-EAF can be competitive against BF-BOF after the capital investment on mini-steel plant is much lower. The plant starts yielding returns on investment from a very early stage, because of a shorter construction period in addition to low requirements trained manpower and high managerial experience.

The mini-mill with simple production facilities and small investment has a value in a district where steel production is needed even on a small scale. Further, mini-mill is an important tool of steel production in a place where low cost power for the EAF operation is available. The mini-mill has a significance in assuring the role of recycling scrap. The availability of scrap can basicaly contribute to a stepwise establishment of a steel plant according to the following time sequence:

<u>1. period</u>: Scrap availability results in a <u>downstream</u> route: electric arc furnace --> continuous casting --> rolling mills (in respect of the facilities a plant build-up starts with the rolling mill <u>upstream</u>).

Due to the ability of the arc furnace to melt sponge iron (DRI) an <u>upstream</u> extension of the above process and a conversion of the mini-mill to an integrated mini-mill can take place.

<u>2. period</u>: Unit for DRI --> EAF --> CC --> RM

The mini plant concept (integrated mini-mill and mini-mill) owes its very existence to the advent of new processes in the steel industry; these included the development of continuous billet casting (incl. computer control), which shortened the processing route and gave a 10-12 % improvement in yield, and of UHP (Ultra High Power) arc furances. Innovations have included the use of water-cooled panels instead of refractories and the introduction of oxy fuel burners; foamy slag techniques were developed to reduce electrode consumption, and increased use was made of oxygen and coal to cut electric power requirements. The ladle refining contributed to the quality revolution achieved and new continuous casting practices opened new markets for special quality tube and wire. Flat products could become mini-plant type product either through rolling techniques or through thin-slab (or even strip) casting.

If a mini mill produces products made with relatively small scale production facilities, such as reinforcing steel bars, medium and small sections the mini-mill is feasible due to the depreciation, administration and fixed costs, all ofwhich are lower than those of BF-BOF. Production facilities of the mini-mill should be on such scale that the production cost is lower than that of BF-BOF and the scrap consumption keeps balance with the supply. Too many mini-mills will result in keen competition not only with BF-BOF but among the mini-mills. Figure 9 a shows the cost of rolled steel in the mills of Japan, USA and West Germany.

Tables 9a and 10a show capital costs for a 3-million - BF-BOF plant and for a 500 000-ton DR-EAF plant, respectively.

The estimates given in these Tables do not take into account costs for mining, power, housing, contingencies and interest paid during the construction period.

The capital investment and operating cost for an electric furnace with a capacity of 1.71 million tpy are given in Table 10 b. Cost figures for an oxygen furnace of similar capacity are given in Table 9b. The percentage distribution of inputs in a BF-BOF plant in relation to total operating costs is shown in Table 9c.

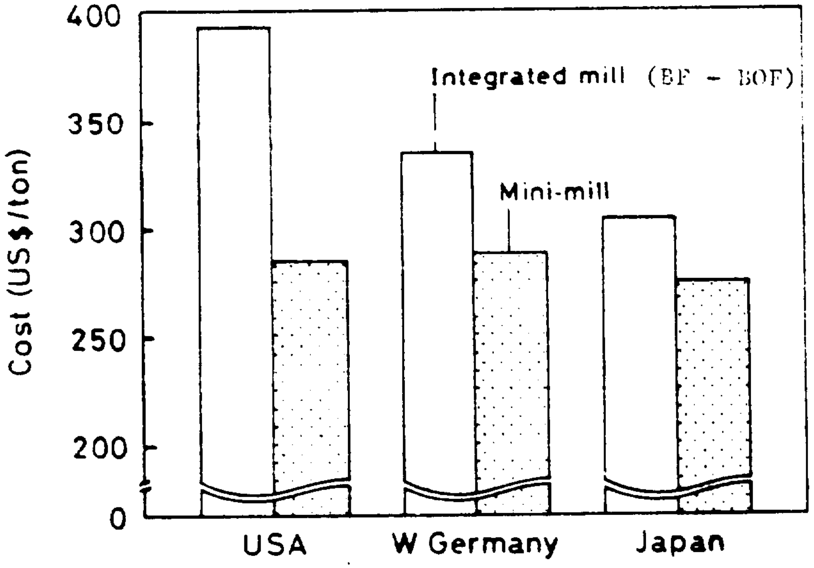
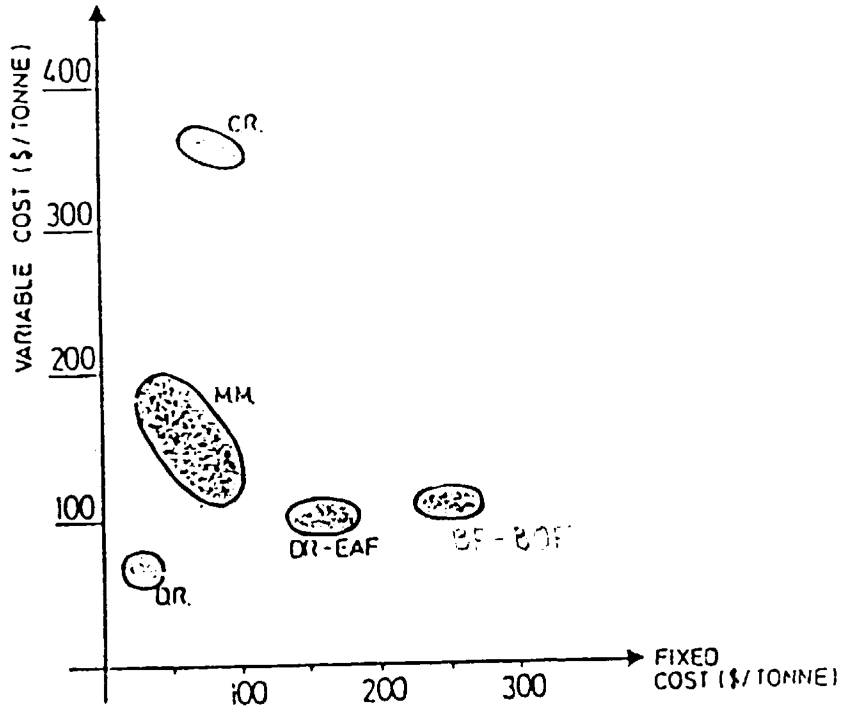


Fig. 9a Wire rod production cost at integrated mill and mini-mill in 3 countries in 1981 (Source: Ref. Nr.34)



CR	Merchant Cold Rolling Mill
DR	Direct Reduction Plants
DR - EAF	Fully Integrated Plants with DR-EAF-Route (1.35 million tpy)
BF - BOF	Fully Integrated Plants with BF-LD-Route (1.35 million tpy)
M.M	Mini Mills (0.5 million tpy, different grades of integration)

(Source: Reference Nr.18)

Fig 9b VIABILITY-NOMOGRAM:
Position of metallurgical plants

TABLE 9a CAPITAL COSTS OF A 3-MILLION-TON BF-BOF PLANT

Item	*Installed steel-making capacity ($/ton)*	*Capital cost structure (%)*	*Capital costs (millions of dollars)*
Coke plant	56.0	8.6	168.0
Blast furnace	75.0	11.6	225.0
Basic oxygen furnace	43.0	6.6	130.0
Continuous casters	43.0	6.6	131.0
Mixed rolling facilities	188.0	29.0	563.0
General facilities	42.0	6.5	125.0
Subtotal (fixed assets)	447.0	68.9	1 342.0
Engineering, procurement and inspection (5% of fixed assets)	22.0	3.4	
Administration, advisory and expediting costs (6% of fixed assets)	27.0	4.2	
Pre-operating expenses (3% of fixed assets)	13.0	2.0	
Subtotal (project implementation and pre-operating expenses)	62.0	9.6	
Fixed capital costs	509.0	78.6	
Infrastructural investment	72.0	11.1	
Subtotal (fixed capital costs plus infrastructure	581.0	89.7	
Working capital (15% of fixed assets)	67.0	10.3	
Subtotal	648.0	100.0	
Interest paid during implementation	42.0		
Total	690.0		

Source UNIDO/ICIS.25.

Note BF-BOF blast-furnace/basic oxygen furnace

TABLE 9b COST STRUCTURE OF A NEW BASIC OXYGEN FURNACE

(Annual design capacity, 1.71 million tons of steel, capital investment (CI), $45 million, location, Great Lakes)

Cost components	*Costing units or annual cost basis*	*Dollars per unit*	*Units consumed per ton of steel*	*Dollars per ton of steel*
Variable costs				
Raw materials				
Hot metal (93% Fe)	Ton	106.42	0.83	88.33
Scrap	Ton	80.00	0.35	28
Energy				
Electric power purchased	kWh	0.016	30	0.48
Energy credits (term to be specified)				
Carbon monoxide	10^6 B t u	2.00	0.44	(0.88
Water				
Cooling (circulating rate)	1 000	0.05	2	0.10
Direct operating labour (wages)	Man-hours	7	0.25	1.75
Direct supervisory wages	15% labour			0.26
Maintenance labour and materials	8% CI			2.11
Labour overhead	35% (L+S)			0.70
Miscellaneous variable costs credits				
Oxygen	Ton	10	0.08	0.80
FeMn, lime, spar				3.00
Slag disposal, hot metal scrap treatment				1.00
Total variable costs				125.61
Fixed costs				
Plant overheads	65% (L+S)			1.31
Local taxes and insurance	2% CI			0.53
Depreciation (18 years)	5.55%			1.45
Total production costs				128.90
Return on investment (pretax)	20% CI			5.26
Total				134.16

Source United States Industrial Environmental Research Laboratory, EPA-600/2-76-034c

Note B t u British thermal units L direct operating labour, S direct supervisory wages

TABLE 9c COST STRUCTURE OF A BF-BOF PLANT

(Percentage)

	Blast-furnace shop	*Basic oxygen steelmaking*
Raw materials and primary energy	84.7	93.0[a]
Utilities	1.9	1.0
Labour	5.2	0.8
Overheads	3.3	0.5
Maintenance (4% of investment)	2.0	2.9
Local taxes and insurance	0.1	0.4
Depreciation (5.5% of investment)	2.8	1.4
Total	100.0	100.0

Source UNIDO/ICIS.25

[a] Liquid metal resulting from the previous process and transfer costs

TABLE 10a CAPITAL COSTS OF A 500 000-TON DR-EF PLANT

Item	*Installed steel-making capacity ($/ton)*	*Capital cost structure (%)*	*Capital costs (millions of dollars)*
Direct reduction (350 000 tons)	77.0	25.5	38.4
Electric furnace (500 000 tons)	40.0	13.2	20.0
Six-strand caster (500 000 tons)	45.0	14.9	22.5
Merchant bar mill (450 000 tons)	63.0	20.9	31.5
Subtotal (fixed assets)	225.0	74.5	112.4
Engineering, procurement and inspection (5% of fixed assets)	11.0	3.6	
Administrative, advisory and expediting costs (3% of fixed assets)	7.0	2.3	
Pre-operating expenses (3% of fixed assets)	7.0	2.3	
Subtotal (project implementation)	25.0	8.2	
Fixed capital costs	250.0	82.7	
Infrastructural investment (15% of fixed assets)	34.0	11.3	
Subtotal (fixed capital costs plus infrastructure)	284.0	94.0	
Working capital (8% of fixed assets)	18.0	6.0	
Subtotal	302.0	100.0	
Interest paid during implementation	10.0		
Total	312.0		

Source UNIDO/ICIS.25.

Note DR-EF direct reduction/electric furnace

TABLE 10b COST STRUCTURE OF A NEW ELECTRIC FURNACE SHOP

(Annual design capacity, 1.71 x 10^6 tons of steel capital investment (CI), $65 million, location, Great Lakes)

Cost components	*Costing units or annual cost basis*	*Dollars per unit*	*Units consumed per ton of steel*	*Dollars per ton of steel*
Variable costs				
Raw materials				
Reduced pellets	Tons of iron	102.88	0.75	77.16
Scrap	Tons	80	0.32	25.60
Energy				
Electric power purchased	kWh	0.016	600	9.60
Electrodes	lb	0.55	10	5.50
Direct operating labour (wages)	Man-hours	7.00	0.3	2.10
Direct supervisory wages	15% labour			0.32
Maintenance labour and materials	6% CI			2.27
Labour overhead	35% (L+S)			0.85
Miscellaneous variable costs/credits				
Refractories				2.00
Fluxes, oxygen, miscellaneous nonmetallics				1.00
Metallic additions				1.50
Total variable costs				127.90
Fixed costs				
Plant overheads	65% (L+S)			1.57
Local taxes and insurance	2% CI			0.76
Depreciation (18 years)	5.55%			2.10
Total production costs				132.33
Return on investment (pretax)	20% CI			7.60
Total				139.93

Source United States Industrial Environmental Research Laboratory, EPA-600/2-76-034c

Note L direct operating labour, S direct supervisory wages

An interesting example is that of the steel plant set up at Matanzas in Venezuela. Extensive analysis carried out before investment decision had shown that given the available conditions a DR/EAF combination was more advantageous in comparison to a conventional BF/BOF plant. This was also supported by the study carried out in 1975 by a World Bank group of experts which had shown that the

- quality of steel produced by two routes would be about the same;
- estimated capital costs of facilities for pelletizing, ironmaking, steelmaking and continuous slab casting of 3-4 million tons per year favoured a DR/EAF plant by nearly 40 % over a comparable BF/BOF installation;
- production costs, excluding fixed charges and taxes, for a tonne of carbon steel slabs are approximately 20% lower when produced by a DR/EAF operation than when made by BF/BOF route:
- average return on investment was from 2.5 to 3 times as great for the DR/EAF facility as for the BF/BOF plant.

Another intersting example is the comparative study of the absolute and the specific direct consturction costs for the following steel plants:

Localisation	Route	Capacity	Construction Cost	Specific const.cost
ALOMINAS (Brazil)	BF-BOF	$2x10^6$ tpy	4.5×10^9 US$	2250 US $/t
SIDOR (Venezuela)	DR-EAF	$3.6x10^6$ tpy	5.3×10^9 US $	1470 US $/t
DELTA STAL Co. (Nigeria)	DR-EAF + 3 rerolling mills	$1.0x10^6$ tpy	1.5×10^9 US $	1500 US $/t

Figure 9 b illustrates the cost point areas for various processes. It shows that the integrated steelworks (BF-BOF) are situated in a range involving a higher degree of risk (referred to utilization and availability) than the mini mills. This is mainly due to the inherently higher capital charges for the traditionals.

9. Integration of mini-steel plants with other industrial sectors

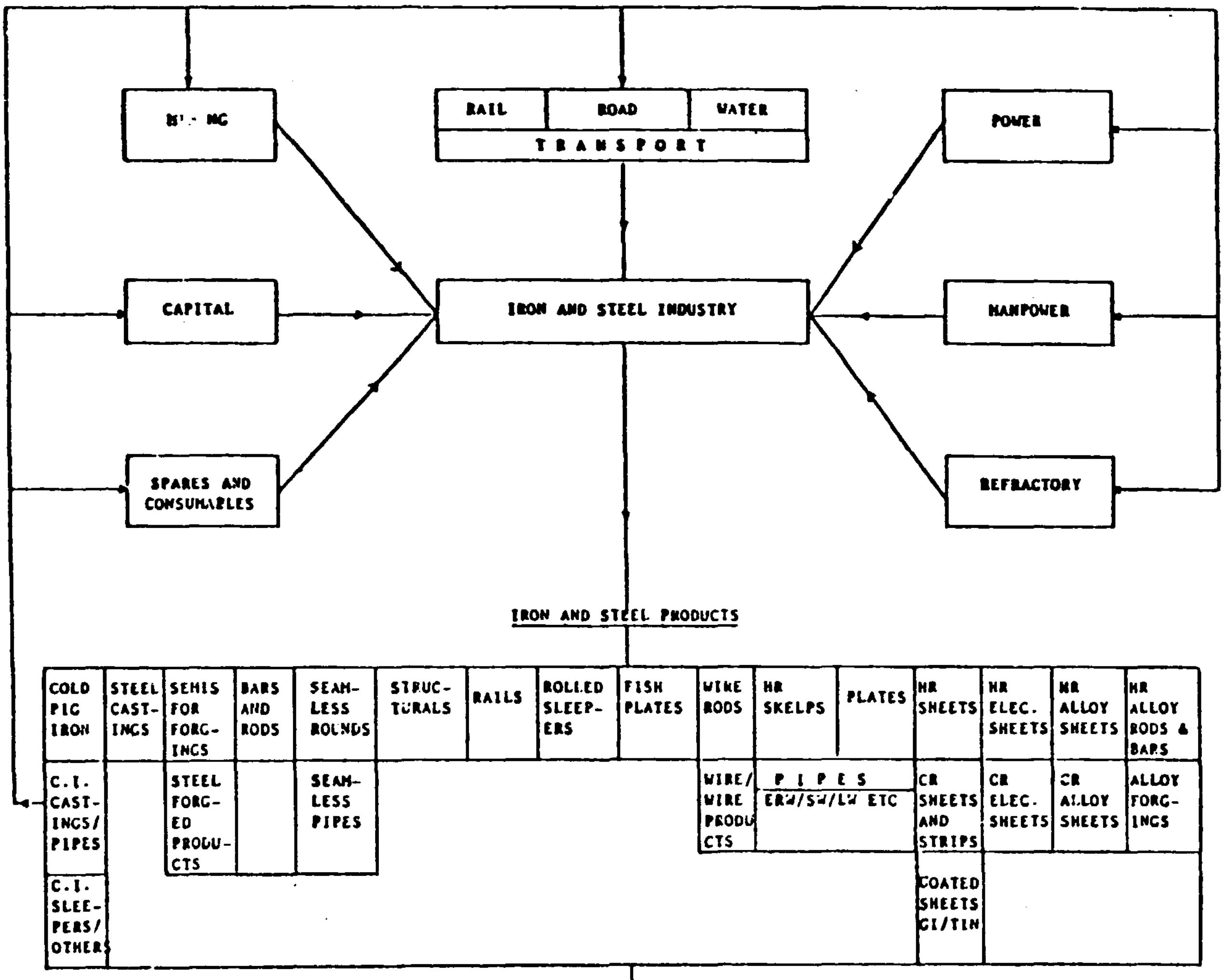
An integrated approach to the development of the iron and steel industry with other economic sectors, especially the Capital Goods and Agricultural Machinery, in developing countries is important in order to ensure an integrated and interlinked industrial sector, to promote further processing of semi-processed and processed raw materials.

An illustrtive model of the inter-relationship between the various iron and steel products and the various sectors of agriculture and capital goods industry, relevant to developing countries, is given schematically in Figure 10. But these existing links among the various sectors of the economy do not constitute an automatic process. Hence they must be the subject of long-term planning.

Table 11 gives an overview of the types and the proportions of products produces by mini-steel plants. Various integrated steelworks, integrated mini-mills and mini-mills operating in Latin America are illustrated in the Tables 12 a, b, c.

A large proportion of the output of mini-steel plants in developing countries (also in developed countries) comprises rod and bar products and wire rod and wire products.

PROCESS OF INTEGRATED ECONOMIC DEVELOPMENT WITH IRON AND STEEL INDUSTRY



AGRICULTURE

AGRICULTURAL IMPLEMENTS - (FORGINGS & PLATES)

AGRICULTURAL MACHINERY - (FORGINGS, ALLOY RODS, PLATES)

AGRICULTURAL SHEDS/SILOS - (BARS & RODS, HR SHEETS, GALVANIZED SHEETS)

CONTAINERS AND PACKAGING - (HR/CR SHEETS, GALVANIZED SHEETS, TINPLATES),

IRRIGATION - (BARS AND RODS, STRUCTURES, PLATES, PIPES)

CAPITAL GOODS

INDUSTRIAL BUILDING AND SHEDS - (BARS & RODS; STRUCTURALS; PLATES; HR SHEETS; PIPES; GALVANIZED SHEETS)

HOUSING - (BARS & RODS, STRUCTURALS; GI SHEETS; CASTINGS; PIPES)

RAILWAYS - (RAILS; SLEEPERS; FISHPLATES; PLATES; ENG. CASTINGS AND MOST OTHER STEEL ITEMS)

DEFENCE - (PLATES; CASTINGS AND MOST OF OTHER STEEL ITEMS)

POWER - (STRUCTURALS; PLATES; GALVANIZED SHEETS; BARS AND RODS, ETC)

MACHINE TOOLS - (CI CASTINGS; STEEL FORGING ALLOY RODS, FORGINGS ETC.)

PETROLEUM - (PIPES; STRUCTURALS)

AUTOMOTIVE - (HR AND CR SHEETS; ALLOY FORGINGS)

CYCLE/MOTOR CYCLE - (CR STRIPS; PIPES)

FASTNER - (WIRE RODS; RODS)

ELECTRICAL MACHINE - (ELECTRIC SHEETS)

Figure 10 Source: UNIDO/ID/WG. 438

TABLE 11 PRODUCTION STRUCTURE BY TYPE OF PRODUCT: DEVELOPING COUNTRIES

(Percentage) (Source: UNIDO/ID/WG. 458)

Type and Size of Plant	No. of Plants in Sample	Output 1983 (000 tons)	TYPE OF PRODUCT							
			Ingots and Semis	Wire Rod and Wire Products	Rod and Bar Products	Sections, Flats, Angles, etc.	Steel Castings	Pipes and Tubes	Spec. Steel Products	Total
Semi-integrated Plants										
1-40,000 t/a	10	208	21	-	54	23	2	-	-	100
41-100,000 t/a	4	202	12	39	39	-	10	-	-	100
101-200,000 t/a	9	807	3	13	51	5	3	-	25	100
> 200,000 t/a	2	448	18	26	56	-	-	-	-	100
Total semi-integrated plants	25	1,585	10	18	52	5	3	-	12	100
Integrated Plants	4	752	-	11	42	10	-	37	-	100
Crude Steel Producers	6	138	100	-	-	-	-	-	-	100
Processors of semi-finished products										
1-40,000 t/a	9	87	-	-	46	4	-	50	-	100
41-100,000 t/a	3	91	-	-	5	-	-	95	-	100
101-200,000 t/a	2	247	-	11	10	10	-	69	-	100
> 200,000 t/a	1	87	-	31	69	-	-	-	-	100
Total Processors	15	512	-	11	25	6	-	58	-	100
Total Developing Countries in Sample	50	3,066	10	14	43	6	2	19	6	100
Total of sample, developed and developing countries	74	6,073	10	22	41	10	3	11	3	100

Integrated steelworks

These works are involved in ironmaking, steelmaking and rolling to a finished or semi-finished product.

Integrated steelworks	Raw material		Reduction				Steelmaking							Mills															Other operations		
														Non-flats					Flats								Tubes				
	Sinter plants	Cokemaking	BF (coke)	BF (charcoal)	Electric furnace	Direct reduction	Annual steelmaking capacity (1000t)	Thomas	Bessemer	Siemens Martin	Electric furnace	Oxygen converter	Continuous casting	Bar	Reinforcing bar	Light sections	Heavy sections	Wire	Slabbing mill	Hot mill	Cold mill	Temper mill	Strip	Tinplate	Galvanising	Other coating	Seamless	Welded	Foundry	Forge	Drawing*
Argentina																															
Acindar - Industria Argentina de Aceros						1	1400				12		3 × 4 ☐	X	X	X		X					X					X		X	w b
Dálmine Siderca						1	415				4		2 × 4 ○														X				t
D.G.F.M. - Altos Hornos Zapla	1	2		5			310	3			2			X		X	X	X											x	x	
Sociedad Mixta Siderurgia Argentina - SOMISA	1	4	2				2700			6		3	2 × 6 ■				X		X	X	X			X							
Brazil																															
Aço Minas Gerais, AÇOMINAS (under construction)	1	2	1				2000					2		X		X	X														
Aços Finos Piratini						1	179				2			X				X												X	
Cimetal Siderurgia	1			13			192			1		1	2 × 2 ☐	X	X	X													X		
Companhia Aços Especiais Itabira - ACESITA	1			2	2		680				3	2	2 × 1 ☐☐	X						X	X	X	X						X	X	b
Companhia Siderúrgica Belgo-Mineira	1			7			902			6		2		X		X		X											X		w
Companhia Siderúrgica de Mogi das Cruzes - COSIM				1			171			6				X	X												X		X		t
Companhia Siderúrgica de Turabão - CST	1	3	1				3371					2							▬												
Companhia Siderúrgica Nacional - CSN	4	3	3				2970			6		3	3 × 2 ☐☐	X			X		X	X	X			X	X	X			X		
Companhia Siderúrgica Pains - PAINS				4			209			3			1 × 2 ☐	X	X			X											X		w
Companhia Siderúrgica Paulista - COSIPA	3	4	2				2448					4							X	X	X										
Lafersa Laminação de Ferro				1			40			1		1	1 × 2 ☐	X	X			X											X		
Mannesmann				1	2		741				3	1		X													X	X		X	t
Siderurgica Barra Mansa	1			3			210			4		2	1 × 2 ☐	X	X	X		X													w b
Siderúrgica J. L. Aliperti				2			320			5	1			X	X	X															
Usina Siderúrgica da Bahia - USIBA						1	264				1		1 × 6 ☐			X		X													
Usinas Siderúrgicas de Minas Gerais - USIMINAS	2	4	3				2763					5	3 × 2 ☐						X	X	X										
Colombia																															
Acerias Paz del Rio	1	1	1				400	1			1	2		X	X	X		X	X	X	X										w
Chile																															
Compania Siderurgica Huachipato		1	2				925					2		X	X	X		X	X	X	X	X		X	X			X			
Mexico																															
Altos Hornos de México - AHMSA	2	6	6				4330			11		4	1 × 2 ☐☐	X	X	X	X	X	X	X	X			X				X			w
Fundidora Monterrey			2				2000			4		2		X	X	X	X	X	X	X	X							X	X	X	
Hylsa						5	1960				10		2 × 4 ☐		X			X	X	X	X			X				X			
Siderurgica Lázaro Cardenas Las Truchas - SICARTSA		2	1				1170					2	3 × 6 ☐	X	X	X		X													
Tubos de Acero de México - TAMSA						1	425				4			X													X			X	t
Paraguay																															
Acero del Paraguay - ACEPAR (under construction)				2			500					2	2 × 2 ☐	X	X	X		X													
Peru																															
Empresa Siderurgica del Peru - SIDERPERU			1			1	490				4	2	1 × 4 ☐ 1 × 3 ■	X	X	X		X	X	X	X	X		X	X				X		
Trinidad & Tobago																															
Iron and Steel Company of Trinidad & Tobago - ISCOTT						2	700				2		2 × 4 ☐					X													
Venezuela																															
C.V.G. Siderurgica del Orinoco - SIDOR	1				9	4	4800			4	10		3 × 6 ☐	X	X	X	X	X	X	X	X			X		X	X		X		x

w - wire, t = tube, b - bar, = no data, ▬ = Only produces slab, ☐ - Billet, ■ = Bloom, ☐☐ - Slab, ○ - Rounds

(Source: Steel Times International)

Table 12a

This table is intended to give readers an insight into the plant and equipment which is installed throughout the member companies of the Instituto Latinoamericano del Fierro y el Acero (ILAFA). It was compiled by the magazine *Siderurgia Latinoamericana* with the cooperation of ILAFA, and was first published in the December 1983 issue of that journal. *Steel Times International* is grateful for permission to reproduce the information.

It does not claim to be comprehensive, but is based on information which has been supplied by the companies involved.

(Semi-integrated plants) Mini-mills	Steelmaking					Mills								Other operations		
						Non-flats					Flats		Tubes			
	Annual steel-making capacity (1000t)	Siemens Martin	Electric furnace	Oxygen converter	Continuous casting	Bar	Reinforcing bar	Light sections	Heavy sections	Wire	Galvanising	Other coatings	Welded	Foundry	Forge	Drawing
Argentina																
Aceros Bragado	130		6		1 × 3 ☐	X	X			X				X		X
La Cantábrica	150	4				X	X	X	X	X				X	X	X
Brazil																
Aços Anhanguera	340		3			X										
Aços Villares	110		5			X								X	X	X
Companhia Brasileira do Aço - CBA	50	2					X									
Companhia Ferro Aço de Vitória - COFAVI	162		3		2 × 2 ☐	X	X	X		X						
Companhia Industrial Itaunense - ITAUNENSE	101		2		1 × 2 ☐	X	X									
Companhia Siderúrgica da Guanabara - COSIGUA	786		2		1 × 5 ☐ 1 × 6 ☐	X	X			X						X
Companhia Siderúrgica de Alagoas - COMESA	44		1			X	X									
Companhia Siderúrgica do Nordeste - COSINOR	67		3		1 × 2 ☐	X	X	X						X		
Copala Industrias Reunidas	14	1				X	X									
Dedini S A Siderúrgica	290		6		2 × 3 ☐	X	X							X		
Eletrometal - Aços Finos	37		2			X				X					X	
Siderúrgica Açonorte	243		2		2 × 2 ☐		X			X						X
Siderúrgica FiEl	112		2		1 × 2 ☐	X				X						X
Siderúrgica Guaira	76		1				X									
Siderúrgica Hime	56		1		1 × 4 ☐	X		X		X				X	X	X
Siderurgica Lençois Paulista - SIDELPA	40		1			X		X								
Siderurgica Mendes Júnior (projected)	...		1		1 × 4 ☐	X	X			X						X
Siderurgica Nossa Senhora Aparecida	110		4			X		X		X						X
Siderúrgica Riograndense	338		4		3 × 2 ☐	X	X	X		X						X
Siderúrgica Santo Amaro	7		1					X								
Siderurgica Santo Stefano	21		1			X	X	X								
Usina Santo Olimpia	96		3			X				X				X	X	
Villares Industrias de Base - VIBASA	270		3					X								
Colombia																
Fundiciones Técnicas - FUTEC	...		2				X							X		
Metalurgica Bocayá - METALBOCAYA	40		1		1 × 2 ☐			X								
Siderúrgica del Muña - SIDEMUÑA	30		3		1 × 3 ☐	X										
Siderurgica del Pacifico - SIDELPA	70		2		1 × 3 ■	X	X	X	X						X	X
Siderurgica de Medellin - SIMESA	80		2		1 × 3 ☐	X	X	X		X			X	X	X	
Costa Rica																
Laminadora Costarricense	...		1		1 × 1 ☐	X	X	X		X						
Chile																
Compañía de Acero Rengo	...		1			X	X			X						
Fábricas y Maestranza del Ejército - FAMAE	10		2			X	X			X				X	X	
Industrias Metalurgicas Ara	10		1		1 × 1 ☐	X	X	X								
Industrias del Acero Limitada - INDAC	20		1			X	X	X								
Ecuador																
[illegible] (projected)	370		1		1 × 1 ☐	X	X			X						

(Source: Steel Times International)

Table 12b

(Semi-integrated plants) Mini-mill	Steelmaking					Mills								Other operations		
						Non-flatr					Flats		Tubes			
	Annual steel-making capacity ('000t)	Siemens Martin	Electric furnace	Oxygen converter	Continuous casting	Bar	Reinforcing bar	Light sections	Heavy sections	Wire	Galvanising	Other coatings	Welded	Foundry	Forge	Drawing
El Salvador																
Acero S A	...		1			X	X	X								
Corporacion Industrial Centroamericana - CORINCA	10		1			X	X			X						x
Siderurgica Centroamericana del Pacifico - SICEPASA	10		1		1 × 4 □	X	X			X						
Siderugica Salvadorena Tinetti	...		1			X	X	X								
Guatemala																
Aceros de Guatemala	...		3		1 × 2 □	X	X			X	X					x
Aceros Suarez	...		1		1 × 1 □	X	X			X						x
Honduras																
Aceros de Honduras - ACEROHSA	24		1		1 × 1 □	X	X									
Mexico																
Acero Solar	15		2			X				X				x	x	x
Aceros de Chihuahua	110		2		1 × 3 1 × 1	X	X			X					x	x
Aceros Ecatepec	110		3		2 × 2 □	X	X	X		X						
Aceros Industriales	36		1		1 × 2 □	X	X			X						
Aceros Nacionales	320		3		1 × 4 □					X						x
Aceros San Luis	130		2		2 × 2 □	X	X			X						
Compania Siderurgica de Guadalajara	250		3		1 × 2 □ 1 × 3 □	X	X	X								
Fundiciones de Hierro y Acero - FHASA	20		4			X								x		
Industrias C H	210		2			X										
Laminadora Atzcapotzalco	88		1		1 × 2 □		X	X		X						
Metalurgica Veracruzana	80		3		1 × 2 □		X									
Omega Manufacturera	36		2		1 × 1 □		X									
Placas de Metal y Laminación	10		1				X									
Siderurgica de Yucatan	120		2		1 × 1 □		X									
Siderurgica Nacional - SICENA	21		4			X									x	x
Panama																
Acero Panamá	10		1			X	X	X		X						
Peru																
Aceros Arequipa - ACERSA	160		2		1 × 3 □		X	X	X							
Dominican Republic																
Metaldom - Compañia Metalurgica Dominicana	60		3		1 × 2 □		X					X	X			
Uruguay																
Industria Nacional Laminadora - INLASA	60		1		1 × 2 □	X	X	X		X						
Siderurgica Laisa	...		1			X	X	X								
Rattar	...		1		1 × 1 □			X								
Venezuela																
Siderurgica del Turbio - SIDETUR	160		2		1 × 4 □			X								
Siderurgica Venezolana - SIVENSA	400		2			X	X	X								
Siderurgica Zuliana - SIZUCA	...		2		1 × 4 □	X	X									

(Source: Steel Times International)

Table 12c

10. Programme for the establishment of a mini-steel plant

The procedure for the establishment of a mini-mill would roughly involve the following stages:

1. Principal objectives of the mini-mill establishment (even as a part of a development programme)
1.1 Links with other industrial sectors
1.2 To satisfy basic needs of the population
1.3 To strengthen the various infrastructure sectors
1.4 To strengthen the employment rate
1.5 To raise education standards
1.5 To increase the trade intensity

2. Steel demands and product-mix selected
2.1 Actual economic profile of the country
(raw materials, energy sources, industry, agriculture, transport, social service etc.)
2.2 Steel demand: regional, interregional
actual, forecasting
2.3 Product-mix (e.g. bars, rods, structurals, others):
selection, possibilities of category-wise consumption
2.4 Plant capacity - Production capacity

3. Scrap availability
- domestic: actual, possible future generation
- possibility of scrap imports, price

4. Availability of process related raw materials such as: limestone, iron ore, ferroalloys, aluminium, etc.

5. Production process selection and plant size based on production demands, raw materials and power availability and/or eventually related limitations.
5. 1 mini-mill route (scrap or DRI if available)
5. 2 integrated mini-mill route (DRI, scrap as recycled)
5. 3 raw materials preparation, preheating etc.

5.4 Steelmelt shop: Design
5.5 Modular extension possiblities of the process selected:
  - feed related (scrap, sponge iron)
  - productivity related (DRI-units, EAF-units, cc-strands, rolling facilities)

5.6 Casting process/machine selection
5.7 Rolling facilities
5.8 Facilities for treatment of effluents

6. Plant location
Factors of influence as: availability of adequate area, tranaport possibilities, sources of power and water, access to domestic market centers, availability of construction materials, provision for future expansion

7. Masnpower and training requirements
7.1 Organization structure
7.2 Manpower requirement
7.3 Manpower availability
7.4 Training

8. Capital cost
8.1 Civil and structural
8.2 Mechanical and electrical equipment (incl. transport, erection, installation)
8.3 Engineering and Administration

9. Operating cost
9.1 Manufacturing expenses such raw materials, labour, supervision, electric power, repair, maintenance, refractories, electrodes, additives etc.
9.2 Administration and sales expenses, intersts ect., depreciation, amortization

10. Financial analysis including mode of financing the project, sales realization, break-even analysis, internal rate of return, net present value etc.

11. Drawings including amoung others: topographic plans, scrap locations, locations of other raw materials (if existent), plant general layout, flow of material and balance, distribution routing of major utilities, steel melt shop layout, rolling mill layout, plant power distribution system, plant water system, plant flow sheet, construction schedule including initial testing, all possible detail-drawings for mechanical and electrical equipment, auxiliary equipment, pipe-lines, energy distribution system etc.

12. Suggestions for project implementing with minimum delay (with priority in advance):

12.1 Establishing of a project authority as a separate organization with the task of taking all necessary steps towards implementing the set up of the steel plant in question

12.2 Policy decision will need to be taken for arranging adequate finance for the project.

12.3 Appointment of an independant consulting engineering organization.

12.4 Evaluation and decision on the final site for the steel plant in question.

12.5 Participation of local agencies for providing construction materials and services for the proposed steel plant complex.

PART II: Technological approach of the mini-steel plant alternative routes

1. Alternative routes for iron and steelmaking

As already mentioned in Part I and in accordance with Fig.1a there are three major alternative routes for the production of iron and steel:

i) The conventional blast frunace/basic oxygen steelmaking (BF/BOF-route) as main part of the integrated steelworks
ii) The DR (or/and DRI-scrap combination) - EAF steelmaking route consisting the main part of the integrated mini-mills
iii) The scrap-EAF steelmaking route emboding the main characteristic of the mini-mills.

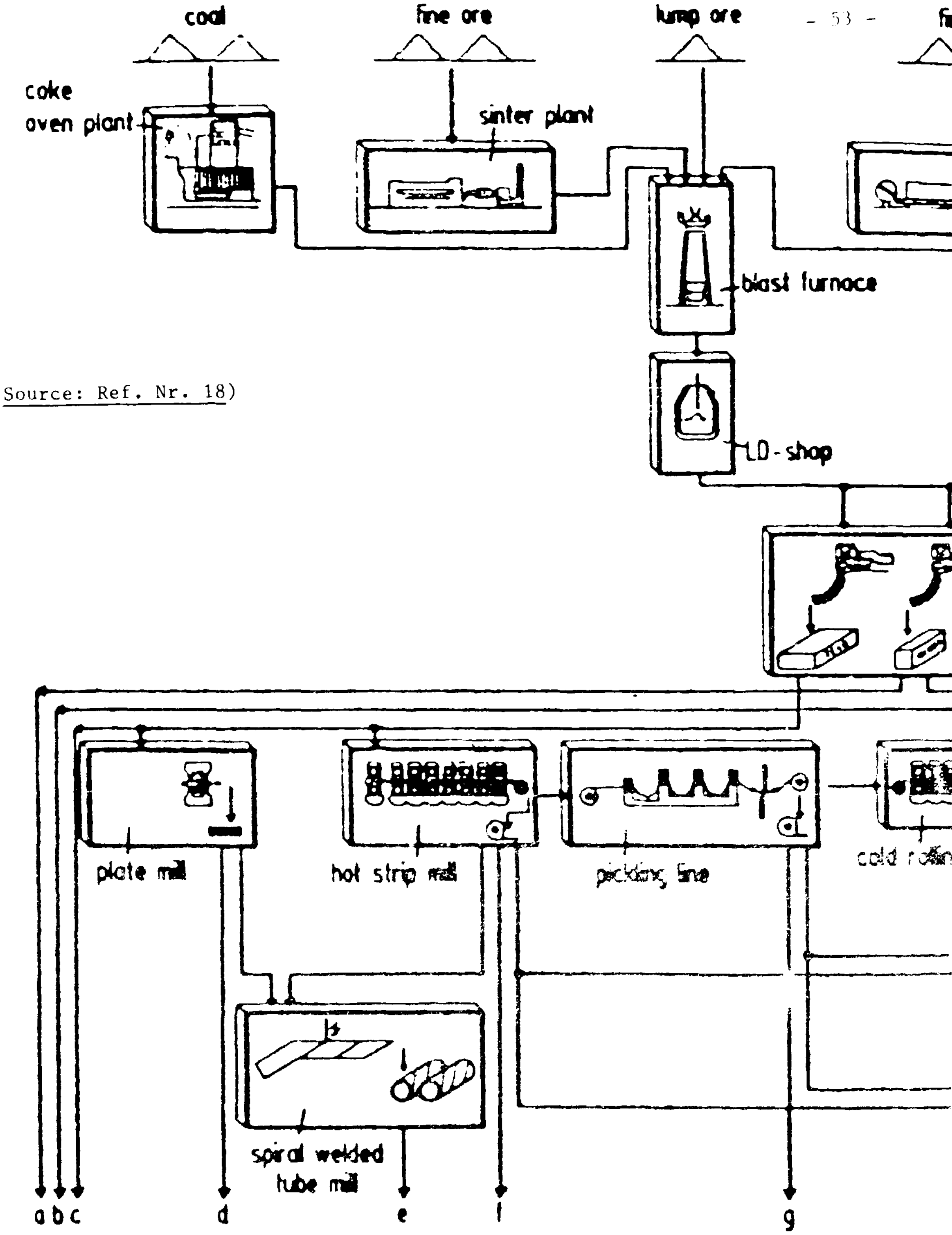
The ability of steelmaking processes to consume scrap varies. For example, the basic oxygen furnace can accommodate a maximum of about 30 % of scrap in its charge. In these circumstances, the growth in popularity of electric arc furnaces melting 100 % scrap or 100 % sponge iron charges (or a combination of both) is not surprising.
Mini-plants concepts are virtually all based on electric-arc melting and the continuous casting of billets or blooms (basically), to produce rod, bars and light sections. But the key element of this concept is the EAF as possessing the additonal possibility of flexible (small or large) scale design.

2. Selection of steelmaking process

The type of raw materials to be used and the gradesof steel to be made constitute the two major considerations that influence the choice of steelmaking process (see also part I and respective Appendix-part).
Since the EAF builds the interface integrated mini-mill/mini-mill the following technical description is devided in three groups of process stages and facilities.

a) Before the EAF
b) The EAF steelmaking
c) After the EAF

See also Fig. 1b. which illustrates the two routes of the mini-plant concept in accordance with the chapters constituting this profile, (Part I, II, and Appendix).

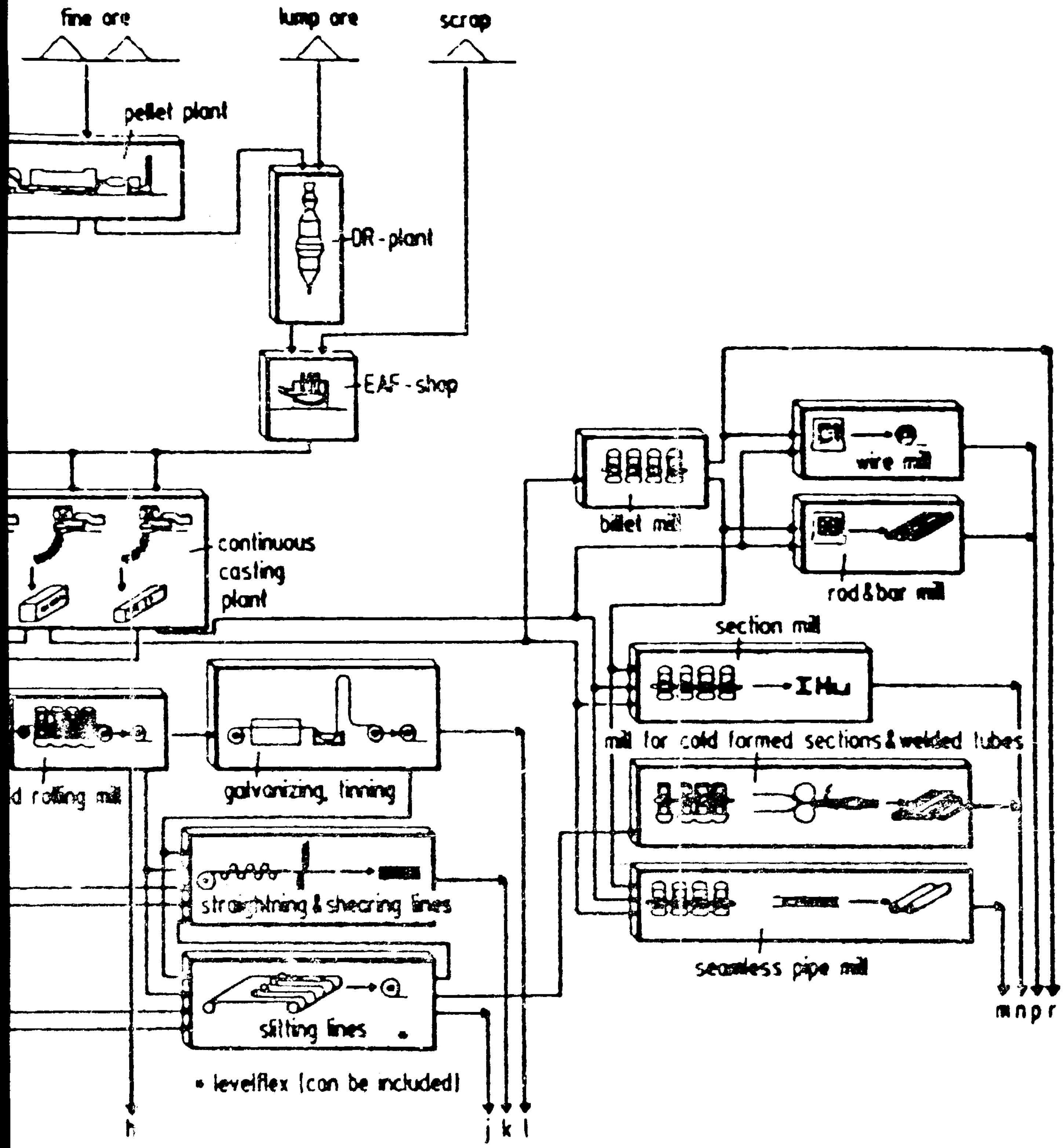


(Source: Ref. Nr. 18)

Figure 1a. Main process steps for the different steel products;

A – Blooms
B – Billets
C – Slabs
D – Heavy plates
E – Spiral welded tubes
F – Hot rolled coils
G – Pickled coils

SECTION 1



;

- H – Cold rolled coils
- J – Strips; pickled, cold rolled, galvanized
- K – Sheets; hot rolled, pickled, cold rolled, galvanized
- L – Galvanized coils, tinned coils
- M – Pipes; seamless, butt-welded
- N – Sections
- P – Wire, rod and bar
- R – Billets

SECTION 2

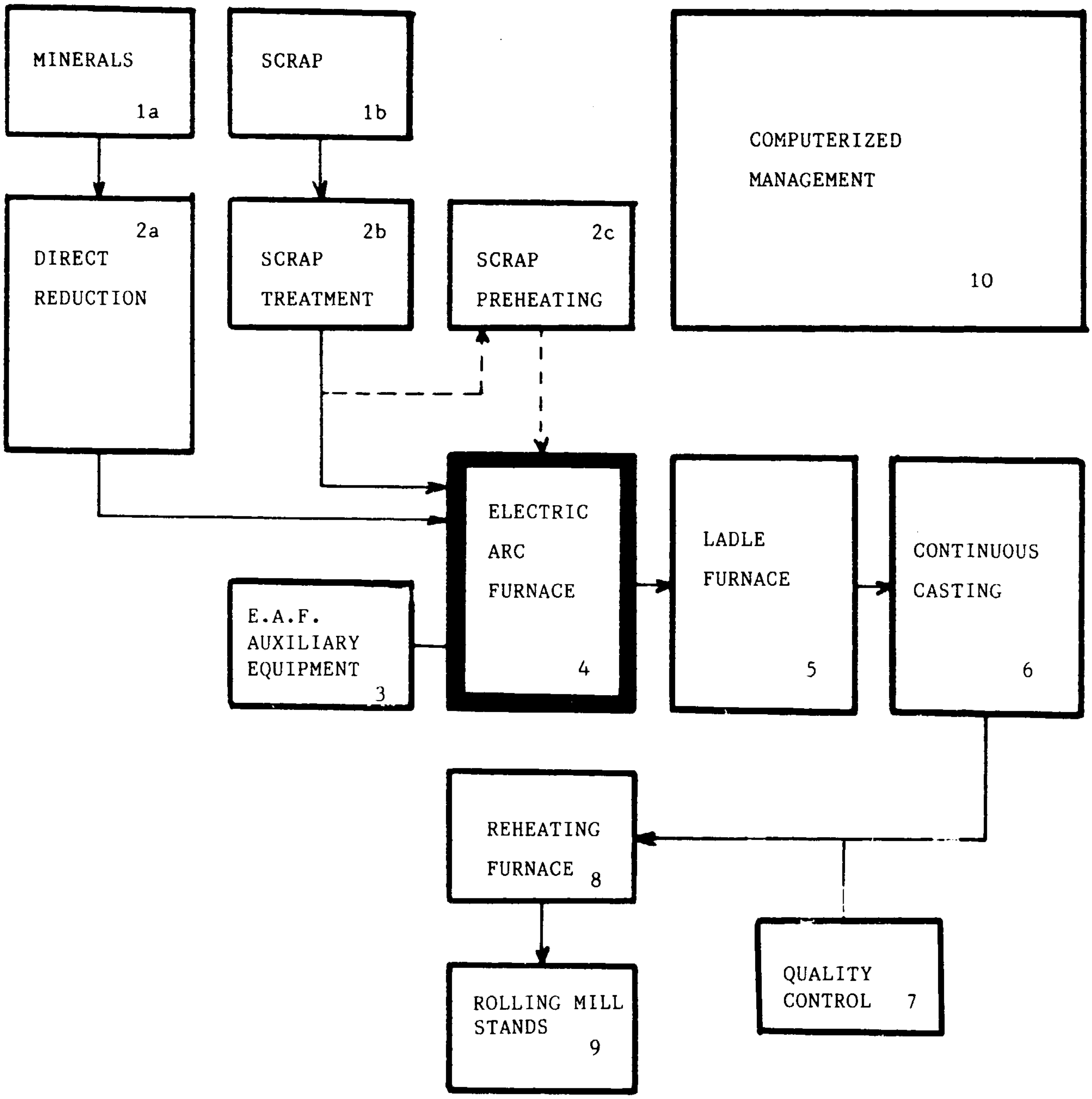


Figure 1b: Integrated Mini Mills (process route)

1a → 2a → 4 (and 3) → 5 → 6 → 7 → 8 → 9

Mini Mills (process route)

1b → 2b → 4 (and 3) → 5 → 6 → 7 → 8 → 9

or 1b → 2b → 2c → 4 (and 3) → 5 → 6 → 7 → 8 → 9

Figure 1b (cont.):

Flowsheet boxes	CHAPTERS		
	PART I	PART II	APPENDIX
1a MINERALS, (ENERGY)	2,2.1,2.2,10	2	1,2,4,6
2a DIRECT REDUCTION	1,2,3,10	1,2,3.1,3.2,3.3, 6.1,9	2,4,5,6
1b SCRAP	1,2,10	1,2,3.1,3.4,5.2, 6.1,9	2,4,5,6
2b SCRAP TREATMENT			
2c SCRAP PREHEATING		3.5,9	2,6
3 E.A.F. AUXILIARY EQUIPMENT	8	4.2,4.6	3,6
4 ELECTRIC ARC FURNACE	1.1,2.2,3,8,10	4,4.1,4.4,4.5,4.6,9	3,4,5,6
5 LADLE FURNACE	8	4.3,4.4,4.5	6
6 CONTINUOUS CASTING	1,2, 8,9,10	5,5.1-5.6,6.4,7,7.2	5,6
7 QUALITY CONTROL	8	5.6, 6.4, 6.6, 7, 7.1, 7.2, 7.3	
8 REHEATING FURNACE		6.5	5,6
9 ROLLING MILL STANDS	1,2,4,8,9,10	6.1-6.6	5,6
10 COMPUTERIZED MANAGEMENT	8	7	7

3. Main process stages and facilities: superposed on the EAF steelmaking

3.1 Direct reduction - Process selection

Todav, processes that produce iron by reduction of iron ore below the melting point of the iron produced are generally classified as direct-reduction processes, and the products referred to as direct-redeuced iron (DRI), (also: sponge iron).

The reduction of iron ore in any direct process is accomplished by the same chemical reactions that occur in the blast furnace. About 1200°C (2190°F) are considered to represent the upper temperature limit for the direct reduction process.

Current DR processes, either in commerical prodcution or in advance pilot plant status differ in approach.
See Table 1
Both the moving bed shaft furnaces and rotary kilns have dominated the field - each with its own set of characteristics, requirements and advantages for a particular situation.

Commercial DR processes can further be identified by the reductant used - either gaseous reductants (e.g. using natural gas, etroleum products, coke oven gas or gasified coals) - or coal reductants, i.e. solid carbonaceous reductants in direct contact with iron ores.

Currently, over 85 % of existing DR production (88.9 % in the year 1984) is shared by two main processes, the HyL (I & III) and Midrex, largely because of their long commercial experience (Hyl since 1957 and Midrex since 1967) and process adaptability.

Static bed, batch-type retort processes ahve been gradually replaced by moving-bed shaft furnaces. This can be attributed to inherent limitations in the retort process which included thermal cycling, non-optimal energy utilisation and intermittent batch discharge peaks requiring an oversized material handling system.

Table 1

Table 1 shows the broad categories of the different processes:

Fuel	Principle	Process
Reducing gas generated externally from reduction furnace (natural gas)	Shaft-Furnace Processes, Moving bed	- Wiberg-Sodefors - Midrex - Hyl III - Armco - NSC - Purofer
	Shaft-Furance Processes, Static-Bed	Hyl I and II
	Fluidized-Bed Processes	- FIOR - HIB
	Plasma Process	Plasmared
Reducing Gas generated from Hydrocarbons in Reduction Furnace (Coal)	Rotary Kiln process	- Krupp-Renn - Krupp-CODIR - SL/RN - ACCAR * - DRC - LS-RIOR
	Rotary-Hearth Processes	- INMETCO - Salem
	Retort Processes	- Hogonas - Kinglor-Metor
	Shaft-Furance Process, Moving Bed	- Midrex EDR - Midrex HBI

* ACCAR: Coal/Gas

cont. Table 1

Direct smelting	- Pig iron Electric Furnace
	- DLM
	- Elred
	- Inred
	- Plasmamelt
	- KR
	- Kawasaki
	- CGS
	- CIG

(Source: US-Steel, 10th edition)

On the other hand, moving-bed shaft furnaces have considerable potential for maximizing energy efficiency because they are truely coutnercurrent and can be designed to recycle unused reductants in the off-gas. The higher energy efficiency for most of the gas-based processes, coupled with availability of cheap natural gas in some countries.contribute further to the preference given to these DR-processes.

In view of relative scarcity and rising costs of natural gas in most countries increased attention has been focussed on the development of DR processes based on direct or indirect use of coal. However, while coal -based rotary-kiln plants have now been in commercial operation for some time, they have not yet attained the versatility and high operating availability of the gas-based processes.

Since early 1980, several new approaches of applying non-coking coals to DR process have received considerable attention, and a few have been operated commercially.

Capital Costs: Capital investment costs for coal-based processes are higher than the similar capacity natural-gas DR plants (Table 2) owing to extra costs of coal handling and pollution control facilities. But rotary kilns are best suited to small scale operation, ranging between 50 000 to 250 000 tpy, where costs of fuel and simplicity in operation tend to be overriding considerations.

Energy requirements: The most efficient gas-based direct reduction processes require about 10 GJ/t (2.4Gcal/t) of primary energy (see Table 3).

Table 2

(Source: References 12, 15 and 23)

Capital costs of DR processes classified by reductant type (1979 US dollars).

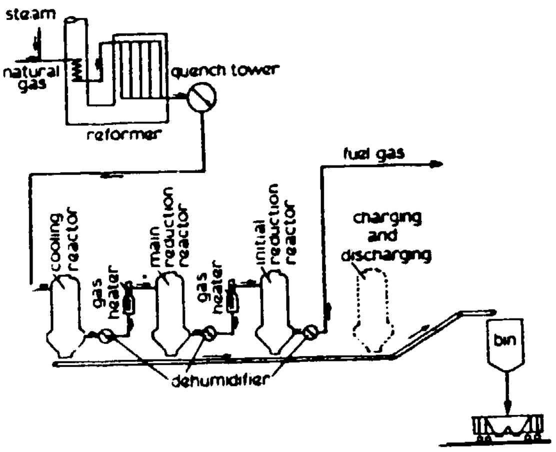
	Cost, $/tonne
Natural gas	
Typical process in the US	100 to 120
HYL	100
Midrex, Venezuela	110
Coke oven gas (existing coke plant)	190
Coal gas	
Midrex with either Lurgi or Texaco gasifiers	300
Coal	
SL/RN	180 to 220
Midrex EDR	200
Accar, India	167
Plasmared	210
Azcon DRC, South africa	200
CS Rio	150

Table 3

(Source:Ref. 12,15,23)

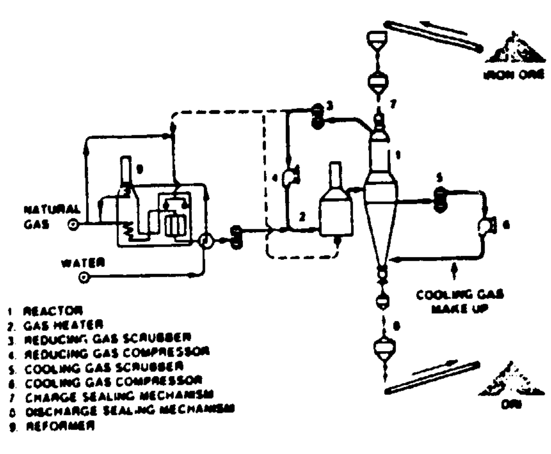
Energy comparison of some DR processes
(courtesy Ironmaking and Steelmaking ref. 6)

Process	Source of reductant	Fuel required GJ/t	Electricity GJ/t	Total energy GJ/t
Midrex	Natural gas	10-11.7	1.10-1.15	11-12.8
HyL III	Natural gas	10-12.2	0-0.90	10-12.2
Krupp Codir	Coal	13.8-19.3	0.50	14.3-19.6
SL/RN	Coal	12.0-23	0.75	12.8-23.8
DRC	Coal	19.4-19.9	1.10	20.5-21.0
Accar	Coal/oil/natural gas	11.6-15.8	0.35	12-16.4
Midrex EDR	Coal/electricity		-	8.4-10.2
Inmetco	Coal		-	10.9



HYL DR process flowsheet.

Fig. 2a (Source:US-Steel,10th edit.)



HYL III DR process diagram.

Fig. 2b

3.2 Short description and characteristics of major DR-processes

HYL: The Hyl process was the first to produce sponge iron on an industrial scale. HylSA of Mexico has developed this process and plants in Mexico, Brazil, Iraq, Venezuela and Indonesia, have produced a combined total of more than 31 Mt of sponge iron since 1957.

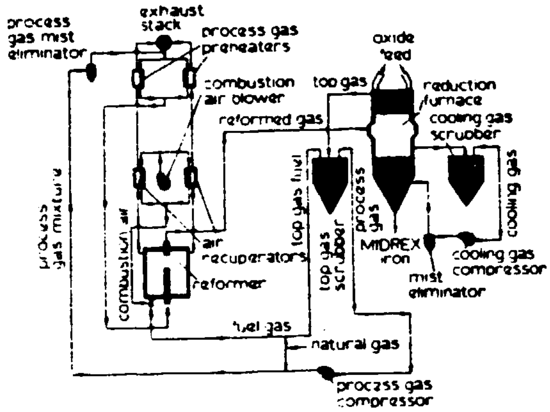
The original HYL I process, offered up to the end of 1980, was discontinuous or intermittent, the iron ore or pellets remained static in each of the four fixedbed reactors or reducing furnaces that each industrial unit has, while being subjected to the passage of different flows of reducing gas. Figure 2a shows a HYL process flow sheet.

In 1980, th HYL III process was developed by HylSA, it is a continuous process with only one vertical reactor comprising two operating zones; a reduction zone and a cooling zone. Ore charged from the top descents counter-current to the flow of reducing gas which ascends through the chamber. Fig 2b shows a diagram of the HYL III process. It is interesting to notice that the gas going out of the top of the reactor after having reduced ore, does not return to the reformer, a fact that has the advantage, it is claimed, of contributing to the protection of the catalyst in this unit.

About the industrial applications of this process see Table 3b, Part I.

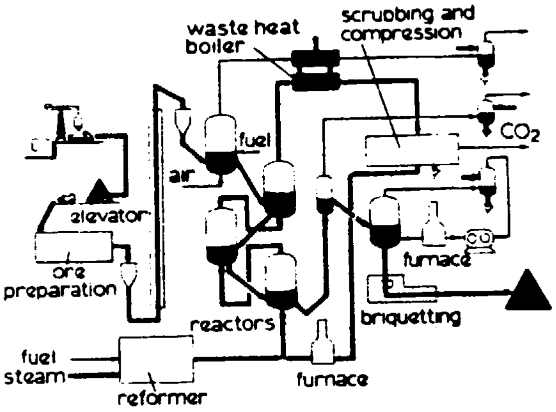
MIDREX: It is the continuous process of natural gas based direct redcution which has the longest experience and which prosses the greatest number of industrial indstallations in production throughout the world.

Fig. 3 is a schematic of the Midrex process. It is worthwhile noticing that in this case, the reducing gas, one passed through the ore and passed out as top gas from the top of the reator is returned to the reforming unit. This characteristic does not entail any problem as long as the top gas is not contaminated with detrimental elements which might poison the reformer catalyst. Currently most Midrex plants have only treated ores of high quality, free of sulphur, chlorine etc.



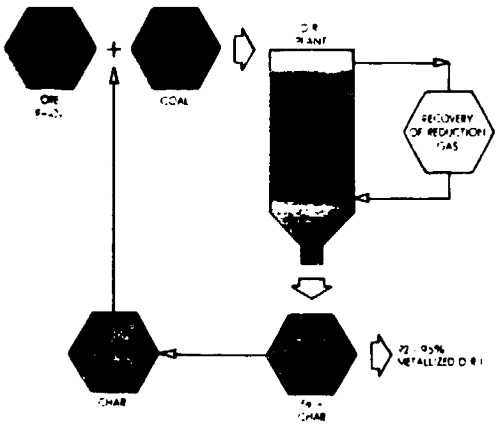
Midrex standard DR process flowsheet.

Fig. 3 *)



FIOR fluid-bed DR process flowsheet.

Fig. 4*)



Reduction

$CO_2 + C \rightarrow 2CO$
$C (S) + Fex\ Oy (S)$
$Fex\ Oy (S) + CO (g)$
$FexO (y-1) + CO (g)$
$FexO (y-1) S + CO2 (g)$

Desulphurization by addition of lime or flux when coals with high S contents (S 0.8%) are used

$FeS + CO \rightarrow COS + Fe$
$COS + CaO \rightarrow CO_2 + CaS$

Fig. 5a **)

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*) Source: US-Steel, 10th edition

**) Source: Reference Nr. 40 and 41

An alternative Midrex process was developed to enable the use of high sulphur ores, thus permitting a choice from a wider range of oxide materials. In this alternative, top gas for reforming is first used as cooling gas in the shaft furnace where sulphur is removed by the hot DRI in the cooling zone.

In view of the present and foreseeable good availability, on the international market, of high quality iron ore and pellets for direct reduction, Midrex plants have no problem in obtaining the requisite quality.

FIOR: Of the DR processes based on natural gas, the Fior process is perhaps the most different. Iron ore concentrates are treated in a fluidized bed. The ore particles are reduced whilst suspended in a current of reducing gas. In the Fior process the ore for reduction passes sequentially through a series of four reactors, counter-current to a reducing gas which is rich in hydrogen. The reducing gas is obtained by steam reforming of natural gas. The pre-reduced fines thus obtained are then hot briquetted. The Fior process was developed between 1960 and 1970 by Exxon. Fig 4 shows a diagramme of Fior process. The first commercial Fior plant was set up at Puento Ordaz, Venezuela, began production in 1976 and is supplied with a mixture of two iron ores of Ferrominera-Orinoco, coming from Cerro Bolivar and El Pao mines. The poportion used is 90 % Cerro Bolivar and 10 % El Pao. The average content of these ores used in the Fior DR plant of Puerto Ordaz, Venezuela:

	Cerro Bolivar	EL Pao
	%	%
Total iron	64.8	66.76
SiO_2	1.5	2.10
Al_2O_3	0.77	0.80
Phosporus	0.102	0.05

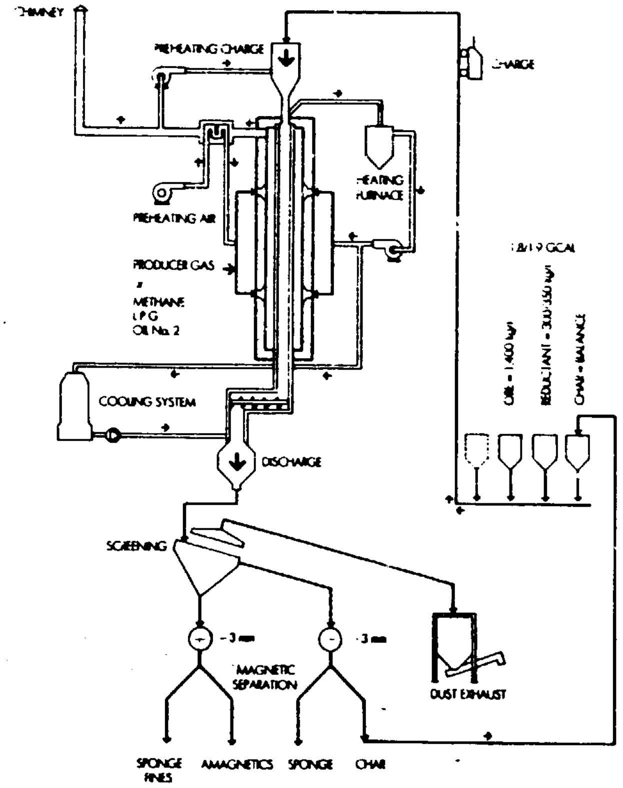
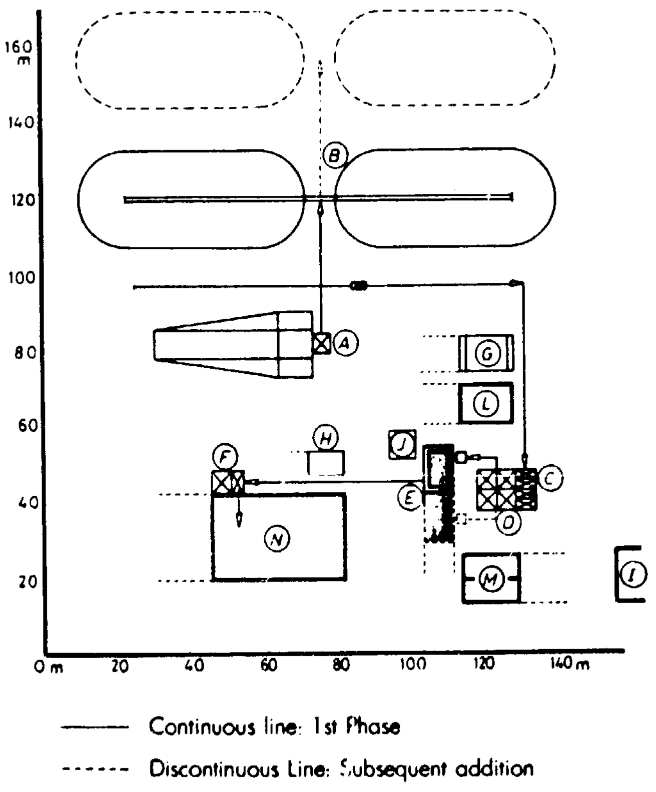


Fig. 5b*)



TYPICAL LAY - OUT for SMALL and MEDIUM PRODUCTIONS

Legend

A - Raw material discharge
B - Raw material stocking yard
C - Reclaiming and screening
D - Raw materials preparation
E - Reduction unit
F - Product dressing
G - Water cooling system
H - Dust suction and collection system
I - Electrical substation
J - Energy recovery
L - Hydraulic unit, compressor and blower
M - Control room and electrical boards
N - D.R.I. storage

Fig. 5c*)

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*) Source: References 40 and 41

The experience of this plant in Venezuela has shown that it is very important that the fines content under 325 mesh (0.05 mm) does not exceed 8 % on average. An increase in these fines provokes difficulties in operation. In regions where abundant and cheap reserves of natural gas are unavailable, but reserves of non-coking coal are, the coal-based DR processes begin to show their merits.

KINGLOR-METOR: Reduction of iron ore as graded lumps or pellets or briquettes with a solid reductant (coal). The raw materials are charged into a series of retorts of rectangular section and the heat is supplied from a combustion chamber in which liquid or gaseous fuel is fired (see Fig. 5 a).

The charge descends through the pre-reduction, reduction and cooling zones. The sponge iron is separated by means of a magnetic separator and the residual charcoal is recycled, while ashes are disposed off. Fig. 5 b shows a diagramme of KM-operation.
One important aspect of the KM-process is the possibility of using "poor" raw materials, such as himonites and liquites, which many countries possess in abundance. Preheating fuels can be either gases, liquids or solids. Operating temperatures 925° to 1090°C; iron ore (input): about 1,45 t (dry basis) for the production of 1 t of DRI; water: 0,4 m^3/t DRI; retorts (purchase cost after the 2nd year of operation): 4,46 US $/t DRI. Fig.5c illustrates a typical layout for small and medium productions (rated capacity range: 30 000 - 180 000 tpy); manpower requirements for the above production range: 24 - 38 (European conditions); A cost-production relation is sown in Fig. 6.

SL/RN: (Progressive Feed/Rotary Kiln) inclined rotary kiln with continuous gravity flow of blended ore, coal and flux; injection of gaseous and liquid fuel through shell burners and central burner at kiln's discharge end; operating temperature 1050° to 1110° C; gross energy input 21.1 6 J/t; maximum commercial plant capacity 385 000 tpy. Figure 7 shows the SL/RN process flowsheet.

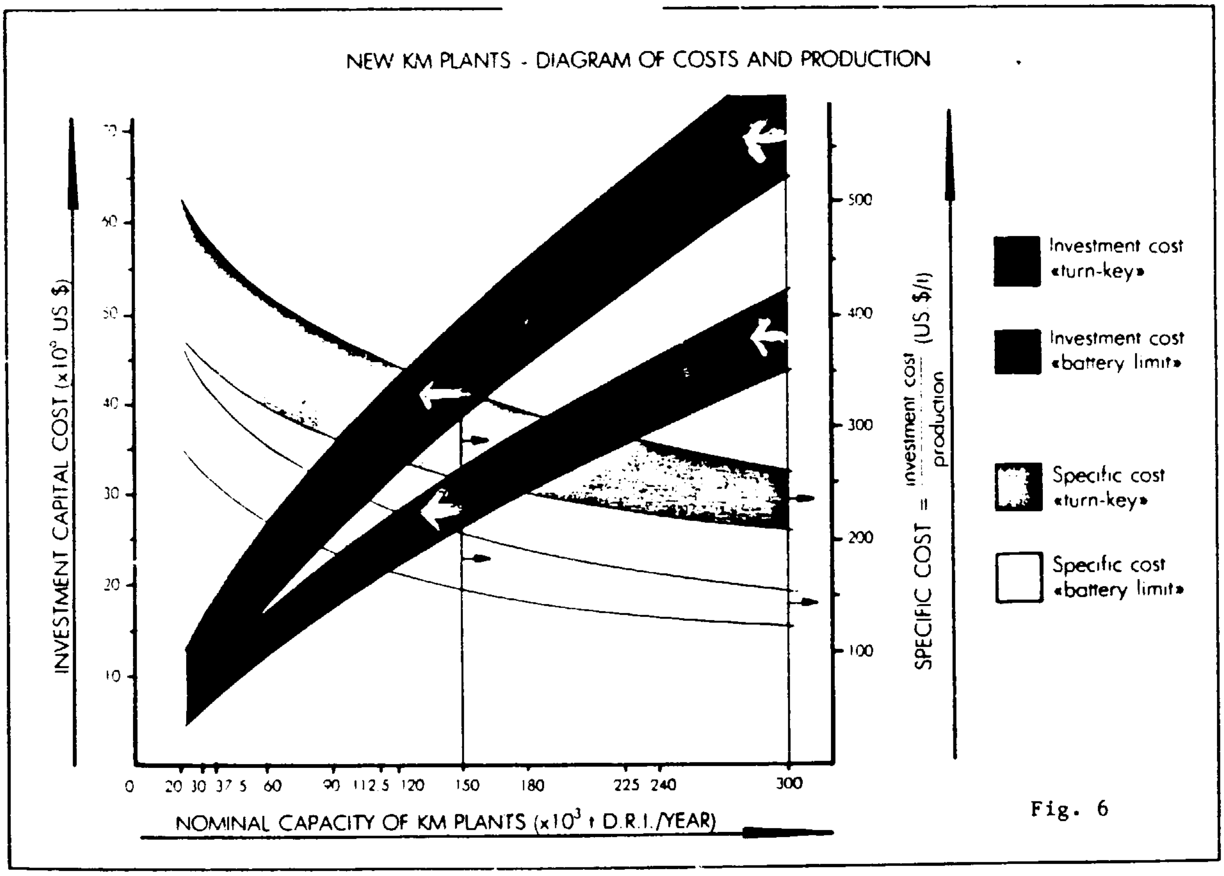
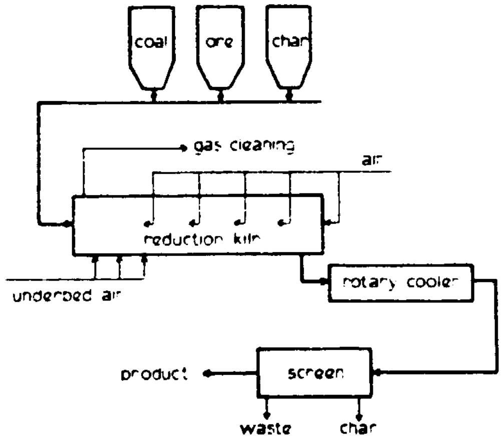


Fig. 6

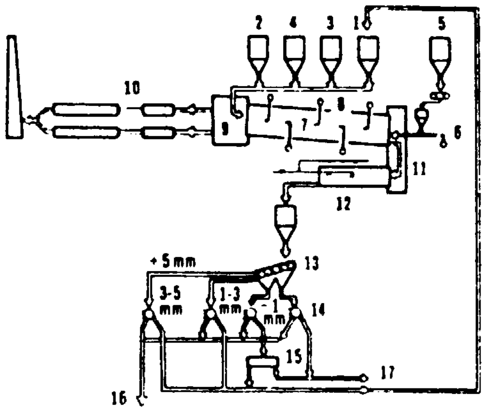
Source: References 40 and 41



SL/RN DR process flowsheet

Fig. 7

Source: US-Steel,10th edit.



Scheme of the Codir process. 1 recycled char, 2 reduction coal, 3 desulphurizing agent (limestone or raw dolomite), 4 lump ore or oxide pellets, 5 injected coal, 6 blower, 7 rotary kiln, 8 air nozzles, 9 dust chamber, 10 waste heat recovery and dedusting, 11 kiln discharge chute, 12 rotary cooler, 13 screening, 14 magnetic separators, 15 pneumatic jig for char-recovery, 16 sponge iron, 17 ash

Fig. 8a

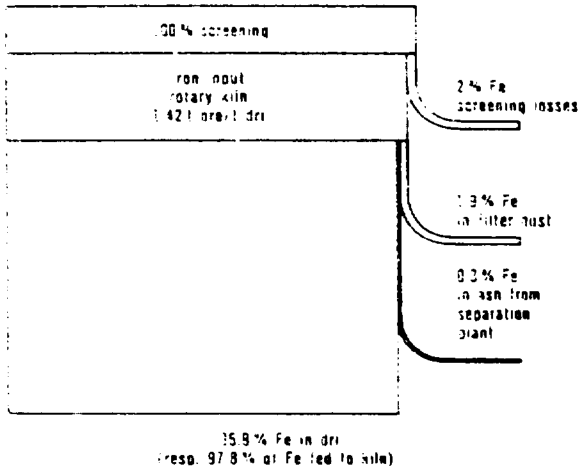
CODIR/KRUPP: (Progressive Feed/Rotary Kiln) inclined rotary kiln with continuous gravity flow of blended ore, coal and flux countercurrent to the flow of hot reducing gases; injection of pulverized coal, gas, or oil through the kiln's discharge and/or feed ends and air blowing through lengthwise shellports; operating temperature 950° to 1050°C; gross energy input 21.1 GJ/t; maximum commercial-plant capacity 165 000 tpy. Figure 8a shows a schematic diagramme of the Codir process and Fig. 8b a typical iron balance. The processes that produce a molten product (similar to blast-furnace hot metal) directly from ore are generally classfied as direct-melting processes.

KR (Kohle-Reduktionsanlage): The plant consists of two reactors. A lower reactor, known as the melter gasifier, serves for melting DRI and gasifying coal with oxygen. It also generates reducing gas; part of it is used for reducing iron ore pellets to DRI in a conventional shaft furnace situated above the gasifier where the coal is coked and partially gasified in a fluidized bed. At the same time, DRI is melted by oxygen injected through the tuyeres and carburized to form molten metal. It is claimed that this process is an alternative to the blast furnace with low investment (because of no coke ovens or agglomeration plants), low operating costs (due to cheap fuel cost) and low specific energy consumption (around 15 GJ/t hot metal). Figure 9 depcits the KR process flow sheet.

In plasma smelting for direct reduction, gases and solids are passed through an arc, much like a welding arc, and are heated. This electric heating replaces oxygen in conventional systems that use oxy-fuel burners.

PLASMARED: The plasmared process developed by SKF, Sweden produces DRI in a shaft furnace with a moving bed. With this arrangement the reducing gas is formed in a plasma gasifier at which one or more plasma generators are mounted in the wall. The plasma generator uses an electric arc that burns any gas that passes through two electrodes to temperature ranging between 3000 to 4000°C. Here the wall powder is gasified with oxygen and steam at temperatures around 1400°C to produce a gas containing 10-15% $CO_2 + H_2O$ in a pregasifier provided with the plasma generator.

Fig. 8b



Typical iron balance: Krupp Codir® process

Iron ores and pellets used in industrial Codir kilns

	Country of origin	Fe_{tot} %	SiO_2 %	S %	other %
Sishen[1]) lump ore	South Africa	66.8	3.0	0.03	-
Postmaasburg[1]) lump ore	South Africa	66.9	2.5	0.02	-
Itabira[2]) lump ore	Brazil	67.8	0.8	0.01	-
Solmine[2]) pellets	Italy	65.6	2.72	0.01	0.28 Pb + Zn
Kromdrai[1]) lump ore	South Africa	67.1	1.20	-	0.10 Sn

[1]) Processed in 74 m × 4.6 m kiln of Dunswart Steel, South Africa

[2]) 110 m × 3.6 m kiln of Borbeck plant, Federal Republic of Germany

Reducing coals used in industrial Codir kilns

Coal type	C_{fix} %	Volatiles %	S %	Ash %	Calorific value MJ/kg
Bituminous coal	58	28	1.0	13	28.8
Semi-anthracite	68	13	1.3	17.7	27.7
Anthracite	78	11	0.8	10.2	30.6
Coke breeze	84.5	4	0.5	11.0	29.5

KR-process
Fig. 9

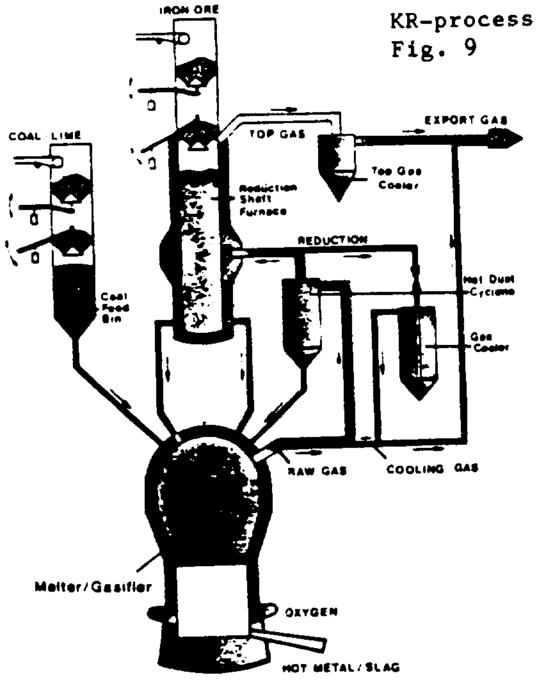
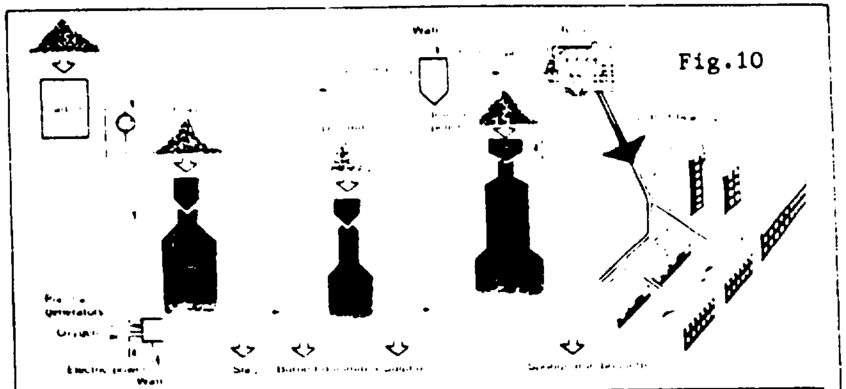


Fig.10



SKF Plasmared for 150 000 tpy sponge iron at Stockholm

Source: References 12,15,23,1; US-Steel 10th edition

Raw gas then passes through a column of hot coke to lower the contents of CO_2 and H_2O, as well as gas temperature. The gas is desulphurized in a dolomite tilter before being used for reduction. Reduction of iron ore takes place in a shaft furnace and the DRI is discharged at the bottom. The top gas, after removal of dust, water and CO_2 is recirculated into the shaft furnace. Benefits of Plasmared process are claimed to include: use of fossil fuel as reducing agent, high total process efficiency (2.2 Gcal/t), low pollution and possibility of using high sulphur fuels. See Figure 10. Unlike the direct reduction process, few smelting reduction processes have been commercialized yet.
Tables 4a to 4c illustrate a comparison of direct smelting processes.

3.3 DRI - Quality/Charging methods

A key factor in producing the highest quality grades is restricting and controlling the levels of residual elements in the steel.
This is the primary reason that direct reduced iron (DRI) is an ideal charge material for the electric arc furnace as being of known composition. While most quality requirements of DRI relate to an optimization of productivity and energy consumption, the absence of contaminating residuals is an important advantage for upgrading steel.

The five major residual elements of concern to steelmakers are Cu, Sn, Ni, Cr and Mo. In DRI, the total level of these five elements typically is around 0.02%. These five elements are present in scrap at levels ranging from 0.10% to over 0.70 %.

As a result of the low residual content of DRI, almost any grade of steel can be produced using it. With a 100 % DRI charge, residual levels close to the lower limit of accurate analysis can be attained consistently. The effect of DRI use or residual levels in steel is illustrated in Fig. 11.

Table 4a Comparison of direct smelting process: Process characteristic and developmental stage

Process	Process characteristic		Present development stage
	Reduction stage	Final reduction/ smelting stage	
Elred	Fluidized bed	D.C. electric arc furnace	Pilot plant (1976-) Pre-red. stage: 0.45 t/h Smelting stage: 25t/charge
Inred	Flash smelting chamber (fluidized bed)	AC submerged arc furnace	Pilot plant (1978-): 5 t/hr Demostration plant (1982-): 8 t/hr
Combismelt	Rotary kiln (SL/RN)	Submerged arc furnace (SAF)	SL/RN: commercial plants & SAF
SKF Plasmasmelt	Fluidized bed	Coke-filled shaft furnace (Plasma)	Pilot plant (1975-): 750 kg/hr (1.5 MW) Semi-commercial plant (planned) 60,000 t/y (15 MW)
KR	Shaft furrace	Shaft furnace	Pilot plant (1982-): 60,000 t/y
Sumitomo	Shaft furnace	Shaft furnace	Pilot plant (1982-): 8 t/d
Kawasaki	Shaft furnace	Shaft furnace	Pilot plant (1970s) Demonstration plant: 100 t/d (planned)
CIG	Fluidized bed/ Shaft furnace	Converter	Feasibility study (1982-)
Krupp COIN	Shaft furnace	Converter	Pilot plant: 3 t/charge
British Steel Corporation	Shaft furnace	Converter	Experimental stage

(Source: Reference Nr. 34)

* Coal net heating value = 6.67 Mcal/kg

Table Energy consumed (per tonne of hot metal) in direct smelting processes (presented on the basis of estimation)

4b

Process	Elred		Inred		Plasmasmelt		COIN		K.R.		Combismelt	
		Gcal		Gcal		Gcal		Gcal		Gcal		Gcal
Coal* (kg)	680	4.55	620	4.14	200-0	1.24-0	440	2.93	1000	6.70	Reduction (SL/RN)	6.2
Electricity (kwh)	617		170 } 680		1100	2.7	-		-			
Oxygen (Nm³)	194		700 } Kwh		130		350	0.67	700	1.20	Smelting (SAF)	2.2
Auxiliaries (Kwh)	136		100 } consumed		-		-		-			
By-product gas (Nm³)			-		-		525	-1.05	2000	-4.20	Energy recovery (CFB)	-3.9
Coke	Power generation credit (300 kwh)	-0.85	Electricity generated } 680 kwh		50 kg	0.34	-		-			
Oil					0-140 kg	0 -1.39	-		-			
Total		3.70		4.14		4.3-4.4		2.55		3.70		4.5
Coal analysis	anthracite, bituminous coal or lignite		Cheap gas coal, anthracite		Coal	Coke	Lean coal 1.0%)				Lignite, sub-bituminous coal, bituminous coal, anthracite, coke breeze	
Fixed carbon %	81		56-51%		75.9	88.0	Lignite coal (0.3% S)		75%		44%	
Ash %	4		14%		8.6	9.0	2-3% Moistue		9.2%		27%	
Volatile matter %	32-37		30-35%		15.5	1.0	Size: -1mm 15% V.M.		14.9%		29%	
Remarks	Sufficient electrical energy generated from off-gas to operate d.c. arc furnace and supply 300 kwh/t of credit		Sufficient electric power generated from off gas to operate electric arc furnace		Plasma ard heater used to super heat portion of process offgas which is injected with coal dust, and iron ore fines at slag-metal interface. Small amount of coke used in the shaft. This process is highly dependent on electricity supply.		A surplus of CO-rich gas (by-product gas) as generated and for gas export/sale. The necessary quantities of oxygen can be generated by internal energy utilisation.				CFB plant allows recovery of energy in the off-gas and from coal discharged at the end of kiln end, this amount to 3.9 Gcal/t.	

Table Comparison of capacity, iron ore, hot metal, capital cost and operating cost for various direct smelting processes.

4c

Process	Elred	Inred		Plasmasmelt	COIN		K.R.	Combismelt	
Capacity	120,000-400,000 t/y	200,000-400,000 t/y		250,000-450,000 t/y	-		300,000 t/y	200,000 t/y	
Iron ore	Fine ore (grain: Size 0.1 mm) Fe 65%	Fine iron ore, calcined pyrite, dust containing Zn & Pb from gas cleaner		Fine ore	Pellet and : 65% Fe lump ore		Pellet : 65% Fe Size : 1/2"-7/8"	Pellet : 65% Fe lump ore	
Hot metal composition (%)		Pyrite	Magnetite		Lean Coal (1.0% S)	Lignite (0.3% S)		High C iron	Low C iron
C	3-4	3.7	2.4	4.0	1.2	2.7-4.4	3.7	2	0.1
Si	0.05	1.2	0.3	1.0	-	-	1-4	0.5	0.01
Mn	-	-	-	-	-	-	0.1	-	-
P	-	-	-	-	-	-	-	0.1	0.03
S	0.5 (high)	-	-	-	0.1-0.2	0.02-0.2	0.05-0.2	0.3	0.02
Capital Cost (in US$) US$	Based on 400,000 t/y $122 M ($305/t hot metal)	Based on 400,000 t/y $92-117 M ($204-260/t hot metal)		Based on 250,000 t/y $51 M ($204/t hot metal)	-		$120-150/t hot metal	$205-225/t hot metal	
Production Cost (per tonnes hot metal)(US$)	$133/t	$125-146/t		$120-140/t	-		$116/t (OS) $150/t (Ruhr)	$133/Fe ($205/t billet)	
Operating Cost (US$)	$31.4/t	$23/t		$1[illegible]2/t	-		$25/t	-	

(Source: Ref. Nr. 34)

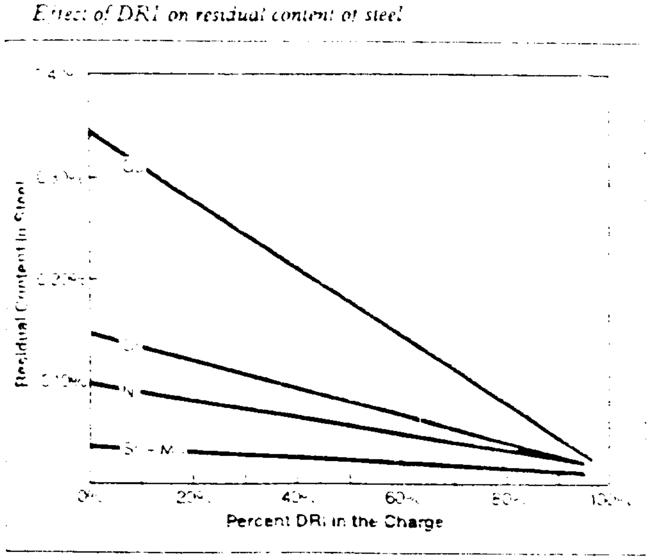


Fig.11 (Source: References 40 and 41)

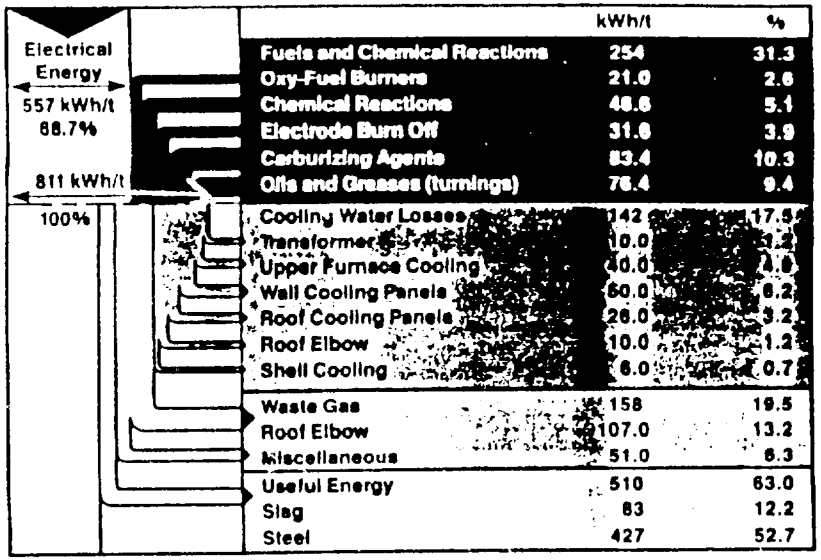


Fig. 13: Energy balance diagramme for electric arc furnace. Excess heat from exothermic reactions and latent fuel sources may be recycled to effect substantial energy savings (Source: Based on references 40&41)

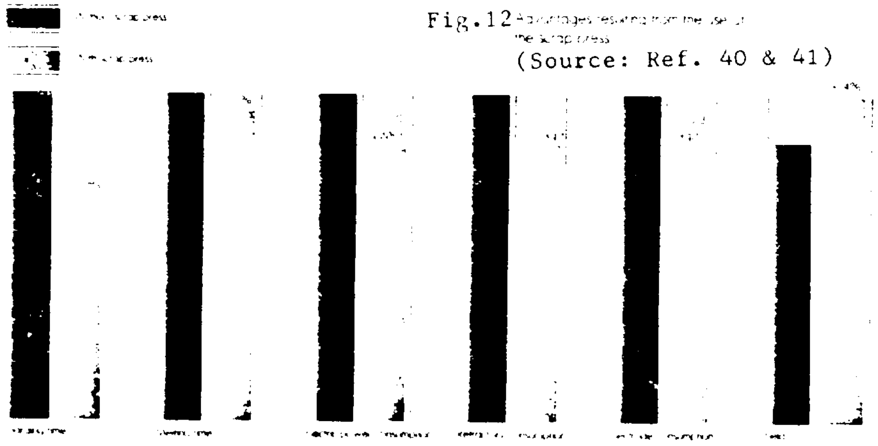
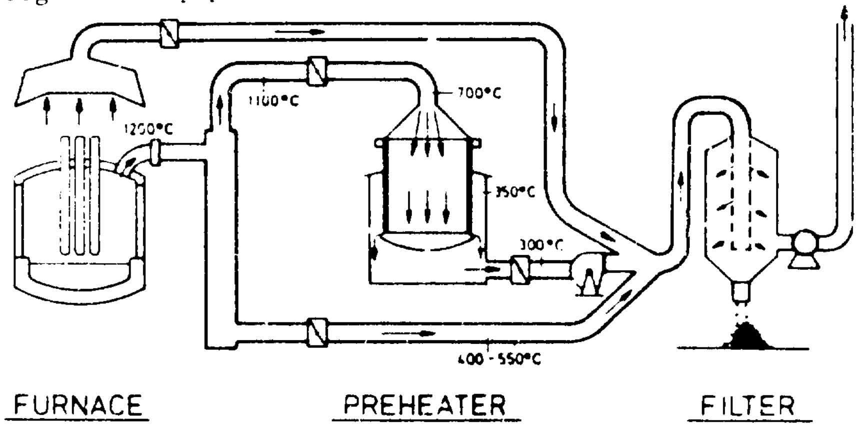


Fig.12 Advantages resulting from the use of the scrap press (Source: Ref. 40 & 41)

Fig. 14 Scrap preheater (Source: Ref.Nr. 10)



The resulting impact of DRI (Midrex process) on some key physical properties of steel is shown below:

Elongation	↑
Fatique	↑
Notch toughness	↑
Hot workability	↑
Heat treatability	↑
Weldability	↑
Isotropy	↑
Yield point	↓
Tensile strength	↓

Continuous charging: The preferred method of using DRI in the electric furnace is to charge it continuously via a feed pipe extending through the roof of the furnace. This is ideal when DRI makes up over 30 % of the charge. The concept of continuous charging DRI into the EAF was developed in the late 1960 to take advantage of the free-flowing characteristic of DRI. Several types of continuous charging systems have been developed; however, almost all melt shops adjacent to direct reduction plants have adopted an overhead system which feeds DRI through a fifth hole in the furnace roof.
The relative cost increase for the building and charging arrangement is about 5 to 10% of the electric furnace cost.

Batch charging: In most cases, EAF steelmakers who purchase DRI on the open market will be using only 20-30% DRI in the charge and will not have a continuous charging system installed in the melt shop. This suggests that batch charging of DRI will be increasingly used as the merchant market for DRI expands. In batch charging, DRI can be beneficial for densifying the charge and controlling tramp element levels.

3.4 Scrap grading according to usage

The bulk of scrap trade takes place close to its sources of generation and points of consumption. All steelmaking processes require a well prepared scrap of defined analysis and having a maximum bulk density. The scrap must also be supplied in a suitable form and size for the available melting units. The types of scrap grades used in the charge is a decisive factor in the production of a heat.

Scrap preparation: The purpose of industrial scrap preparation is to make available to steel plants scrap which is chemically and physically as clean as possible and which is as compact and dense as possible.

i) Scrap Comminution: The purpose of comminution is to achieve the following:

- the manufacture of small sized scrap having a high bulk density.
- the creation of conditions for a possibly necessary grading of the scrap.

There are many facilities available for comminuting scrap, depending on the manner in which the relevant scrap breaks up and on the required finished size.

	Materials capable of shear fracture		Materials capable of brittle fracture	
	thick walled or compact scrap	thin walled scrap	thick walled or compact scrap	thin walled scrap
Coarse crushing		explosion or flame cutting		
inter-mediate size reduction	guillotine shears alligator shears	alligator shears hammer crusher (shredder) hammer mills	skull crackers hydraulic crushers	
fine crushing		rotating hammer mills swarf crushers		drum mills

Research is being carried out into the use of plasma cutting and cutting by means of lasers and water jets. In the field of intermediate size reduction, hydraulic guillotine shears will, for the present, remain paramount because of their favourable energy balance. For thin walled scrap, hammer crushers continue to gain ground as is indicated by the development of shredder plants. Super-cooling of the scrap moreover, with, for instancy, liquid nitrogen prior to size reduction, is still further advantageous.

ii) Scrap upgrading processes have the purpose to remove, as far as possible, the tramp elements (S, Cu, Sn, Zn, Pb, Cr, Ni, etc.) and the nonmetallic materials (rubber, glas, plastic, oil, dirt, etc.) The electrolytic leaching process (Goldschmidt process) is used only for the preparation of tinned, new sheet off-cuts.

Attempts to detin contaminated tin plate scrap, particularly preserve tins from refuse scrap, have not yet led to any satisfactory results.

iii) Scrap compression has always been important in the preparation of light scrap. The purpose is to reduce the volume of the scrap for transportation, to increase the efficiency of steelmaking furnaces and to reduce melting losses. Treatment methods are: scrap baling, scrap briquetting, hot compression of scrap. A distinction is drawn between baling and briquetting, depending on the pressure applied. Figure 12 illustrates the advantages resulting from the use of the scrap press.

Electric Furnace Scrap Requirements: Basically, every type of scrap can be used in the electric furnace. When capital scrap is charged, however, particular attention should be paid to copper and tin contamination as both these tramp elements, nobler than iron, cannot be removed during the melting process. When producing plain carbon steels in the UHP furnace, scrap density is no longer quite so important. Extra subsequent charges of up to three baskets need not adversely affect the output of an arc furnace because the walls are additionally protected by the scrap and the power supply can be increased during this period. In modern furnaces, the cut-off period is reduced to two to four minutes during the extra charging operation.

The maximum length of pieces of scrap depends on furnace size. With 10 t furnaces, it is about 1 m, with 50 t furnaces, about 1.5 m and with 150 t and large furnaces, about 2 m. Heavy ingot scrap should be charged only in limited quanitities and in the first basket in order to avoid electrode breakages caused by slipping and sliding of the scrap, thus leading to down-time and production losses.

The proportion of turnings and shredded scrap charged should be restricted with conventional operation practice as they tend to agglomerate. A 100 % shredded scrap charge can be possible only with continuous scrap feeding. A tendency to explode and the extraction capacity of dust removing plants limit the use of turnings contaminated by oil

Auxiliary equipment for scrap handling: On average, in a steel plant, scrap goes through 3 handling processes before being loaded into the furnace. It is thus essential to diminish the costs of these operations by the use of adequate and reliable systems. It is also important to know the weights of scrap used. Auxiliary equipment suitable for the scrap handling is:

- weighing device
- basket conveying cars
- clamshell or gore charging baskets
- electromagnets
- hydraulic spiders.

3.5 Scrap preheating

Almost 70 % of the total conversion costs in the melt shop are direct or indirect energy costs. It is therefore worth to look at the possibilities to recover waste energy. The energy balance in an electric arc furnace heat helps illustrate the relative magnitude of energy used. It also points out the advantages of recovering the heat available in waste gases, cooling waters and steel, to further optimize operating costs. A close look at the energy balance in Figure 13 and in regard to the energy contained in the flue gas, only the portion extracted through the roof elbow can be utilized. Scrap preheating is one possible application. The heat can be recovered either by passing the fumes directly through the scrap or by using a heat exchanger to heat an intermediate fluid (air) which will then pass through the scrap.

The installation for scrap preheating is shown in Figure 14. The hot waste gases having a temperature of about 600 - 1200°C are sucked through a heating chamber in which the scrap basket is placed. The temperature of the preheated scrap ranges between 250 and 350°C depending on the treatment time and the waste gas temperature. To operate a scrap preheating system, scrap has to be sorted, since combustible componets in the scrap led to partial overheating in the scrap basket and may also create problems in the filter plant. The continuous availability of scrap and regular operation of the electric arc furnace are important conditions for the sufficient operation of a scrap preheating system otherwise scheduling problems would be added to the shop. Operating results of a scrap preheater are as follows:

- decrease of the melting time (by 15-20%) in the arc furnace
- lower electrode and power consumption (by 10-15 %)
- overall productivity increase
- a uniformly low hydrogen content of the steel due to the drying of the scrap.

The scrap preheating equipment consists of:

- Unit for recovery of heat from furnace fumes
- scrap heating hood
- basket carrying cars.

4. Electric Arc Furnace Steelmaking

The electric arc furnace steelmaking has became the pricipal process employed where scrap and DRI are the main raw materials available. One ton of good-quality scrap is required to make one ton of raw steel. At 3 % gangue in the raw ore and 95 % metallization, 1.1 tons of DRI are required to produce one ton of steel. If metallization is 85 % approximately 1.16 tons are needed.

The time required to make a heat of steel depends to a significant degree on the size of the transformer installed with the furnace. During the past 20 years, tap-to-tap times were reduced from three hours to less than one-and-a-half hours.

In Figure 15a the power classification according to IISI proposal 1981 is shown together with the power raiting of different furnaces in USA, Japan and FRG. Precondition for applying high power rates is of course capability of the public grid. The melting time which can be reduced by higher energy input is only part of the total furnace operating. Additional time is consumed for refining, super heating, adjusting of analysis and holding times. However, a series of new developments has permitted a considerably increase in productivity as shown in Figure 15b.

4.1 Electric furnace

Electric furnaces for steelmaking range in size from 5 to 500 tons per heat. The electric arc furnace is the most suitable unit for melting scrap (up to 100 %); DRI or a combination of both. (In comparison BOF converter can accommodate a maximum of about 30 % of scrap in its charge). Two types of furnaces have proven to be practical for melting steel:

a) the three-phase A.C. (alternating-current) direct-arc-electric-furnace
b) the induction furnace

Recently, D.C. (direct-current) direct-arc-electric-furnace has also been developed in smaller sizes (10 to 50 tons) for commercial use. The three phase direct-arc electric furnace is the type most commonly used today. It is primarily a DRI or scrap-melting furnace. A three-phase transformer, equipped for varying the secondary voltage, is used to supply energy to the furnace from the electric-power over a suitable range of power levels.

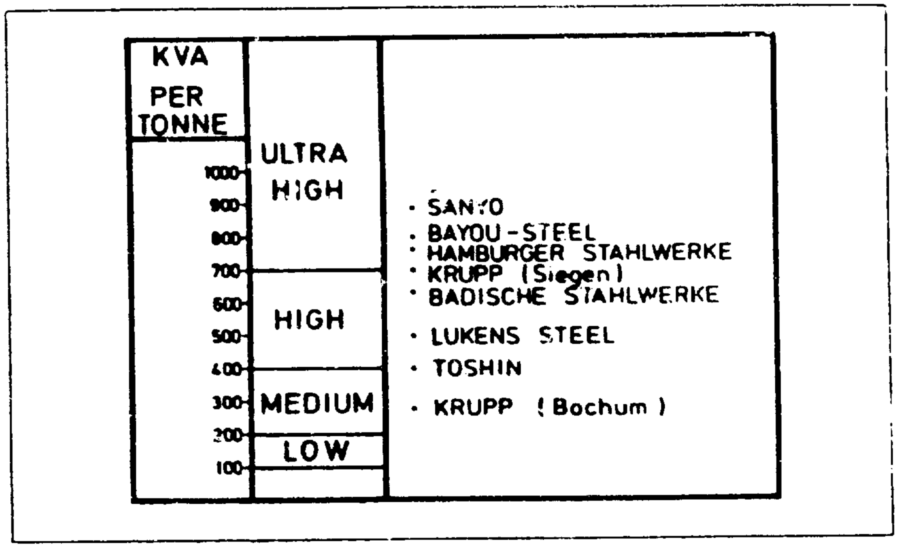
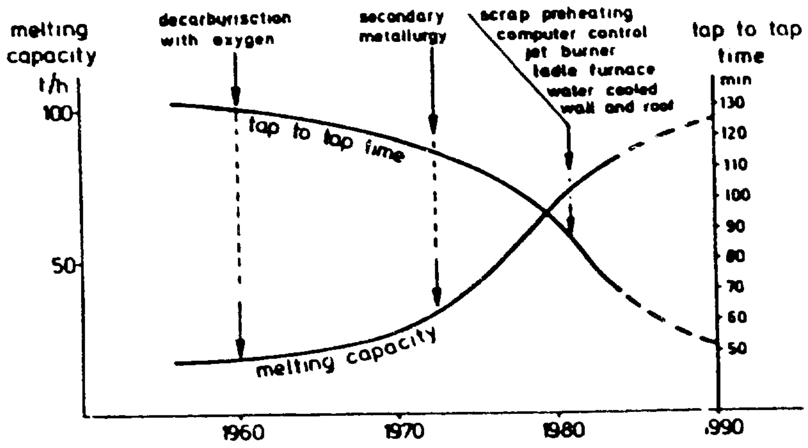
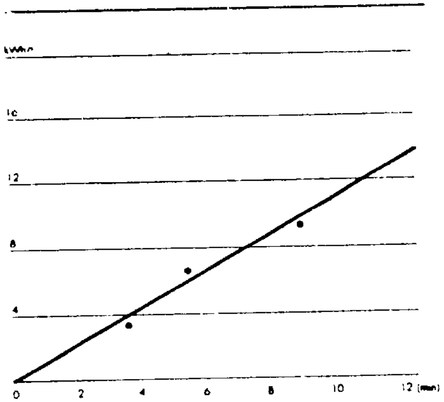


Fig. 15a (Source: Ref. Nr. 10)

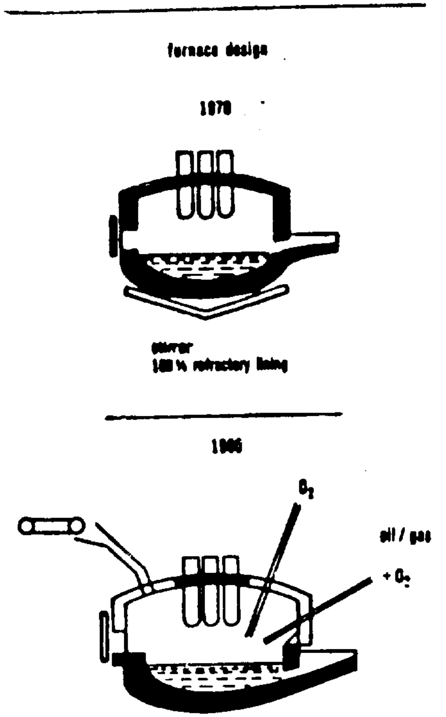
Fig. 15b (Source: Ref. Nr. 10)





Energy loss in relation to the duration of roof opening

Fig. 16
(Source: Ref. Nr. 41)



- water-cooled wall and roof panels
- use of burners
- oxygen lances
- automatic probes for sampling and temperature measurement
- automatic addition of sponge iron, fluxes and alloys
- slag-free tapping
- operation with hot heel

Fig. 17
(Source: References 14 and 45)

Cylindrical solid graphite electrodes suspended from above the shell and extending down through parts in the furnace roof are used to conduct the elctric current inside the furnace shell. The removable roofs enable the scrap to be quickly and easily charged into the furnace, but the duration of the loading operation has to be kept at a minimum due to the thermal losses (Fig. 16). The trend in recent years to ultra-high-power operation (see Fig. 15a) has had a considerable impact on arc furnace design. The term UHP is a relative one and, within current technological limitations, is a function of transformer size and the ability of the furnace walls and roof to provide reasonable life. The structural and mechanical parts of a modern EAF consist basically of: a shell to contain the charge, with a refractory lined hearth, water cooled wall panels and a water-cooled roof. Figure 17 features a comparison of older electric arc furnaces with modern units.
A typical furnace diameter is 5 m for 50 tonnes and 6 m for 100 tonnes. Figure 18 illustrates a consturction diagramme of an EAF (ASEA/Danieli).

4.2. EAF - auxiliary equipment

Auxiliary oxyfuel burners: The use of auxiliary oxyfuel burners is being adopted in many steel plants, since it allows to achieve two important targets:

- Reduction of melting time
- Reduccion of electric power and electrode consumption

The eomplete plant consists of:

- Burner unit, side and piping
- Unit for the distribution and fluid control
- Control panel

A typical layout and distribution system are shown in Figure 19.

Water-cooled panels for furnace shells and roofs: Due to the higher temperatures reached inside the frunace (UHP, oxyfuel burners), there has been an increase in the consumption of refractory material. Traditional furnace coatings have significant shortcomings, so that they are no longer suitable to meet the requirements of more modern operative systems.

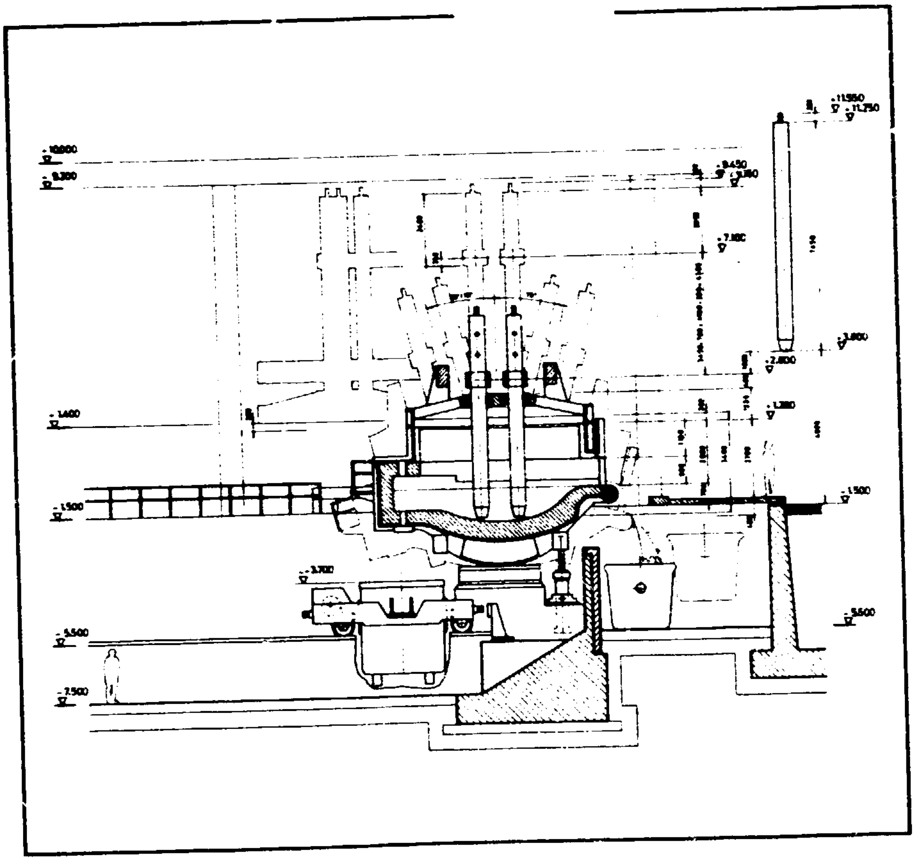


Fig. 18

(Source: References 40 and 41)

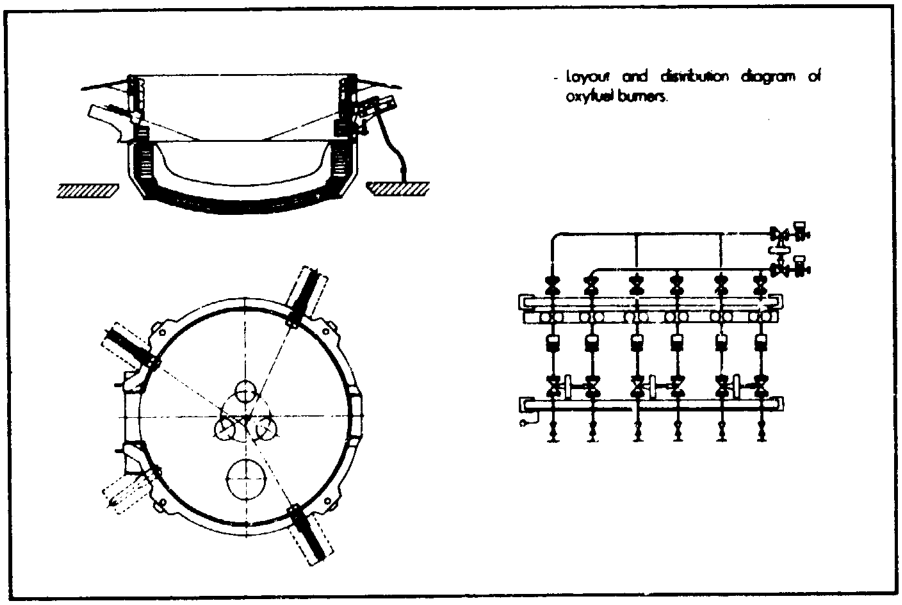


Fig. 19
(Source: References 40 and 41)

Consequently, it is necessary to line the walls and the roof of furnaces with water-cooled panels. The use of such panels not only enables the introduction of the above mentioned technology, but also significantly diminishes refractory consumption, while increasing the utilization factor of the furnace at the same time (heat hours/calendar hours).

Refractories: Modern EAF commonly have a hearth constructed from dolomite blocks. The sidewall, depending on conditions, can also be of dolomite bricks or panels with magnesite or chrome magnesite being substituted in hot spots or where furnace conditions encourage refractory wear. Roofs will normally be lined with silica or alumina bricks. (See Figure 20 a,b and Table 5). Figure 21 a shows a typical installation of a bricked dolomite hearth and profile bank arrangement in a 100 tonne UHP furnace. Figure 21 b illustrates an eccentric bottom taphole arrangement in a 200 tonne capacity furnace. This is the largest arc furnace currently operational in Europe, and was converted to the EBT design August 1985. Figure 21c illustrates the taphole arrangement. No drying or preheating is necessary with the ceramically bounded dolomite hearth; however for the first charge, light scrap should be selected and a lower programme followed. Figures 22 a,b indicate the advantages for the refractory consumption resulting from the use of the water-cooled panels and roof.

Tilting mechanism: Thetilting mechanism has to give a smooth and jerk-free movement to the furnace and especially a slag-free tapping important for all further secondary (ladle) operations.

Electrode holding, operating mechanism and control: The main advantages of the automatic operation of such a system are a) reduction of electrode consumption b) shorter stoppage of the furnace operating time c) controlled fastening.

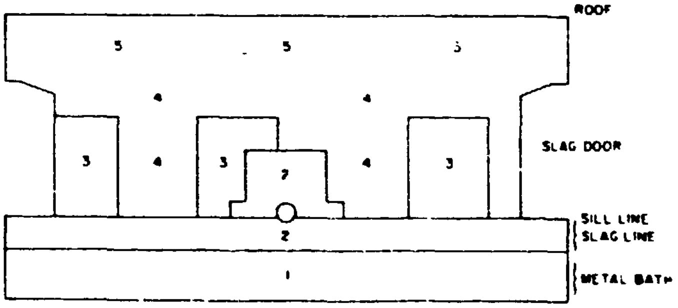


Fig.20a:Various areas of zoned electric furnace refractory lining (see also Table 5)
(Source: Ref. Nr. 45)

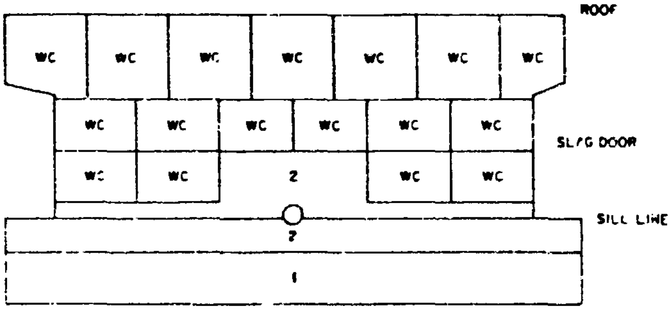


Fig. 20b: Various areas of zoned electric-furnace refractories and water-cooled lining (see also Table 5)
(Source: Ref. Nr. 45)

Table 5: **Refractory Construction in Zoned Electric Furnace** (Source:US-Steel, 10th ed.)

	Typical Refractory in Indicated Zones				
	1	2	3	4	5
Type	Metal-bath area	Slag-line and tap-hole	Hot-spots	Lower walls	Upper walls
A. Conventional lining	Magnesite brick or ramming mix Impregnated magnesite brick	Fused-cast magnesite-chrome brick or magnesite-brick	Fused-cast magnesite-chrome brick	Direct-bonded magnesite-chrome brick—clad	Unburned magnesite chrome brick—clad. Direct-bonded—clad
B Lining using magnesia-carbon brick	Same as A	Magnesia-carbon brick	Magnesia-carbon brick—clad	Magnesia-carbon brick or direct-bonded brick—clad	Same as A
C Lining using water-cooled panels	Same as A	Same as A or B	WC* panels	WC* panels	Same as A or B. WC* panels

*WC = water-cooled

Bricked Hearth and Profiled Banks Arrangement

Fig. 21a*)

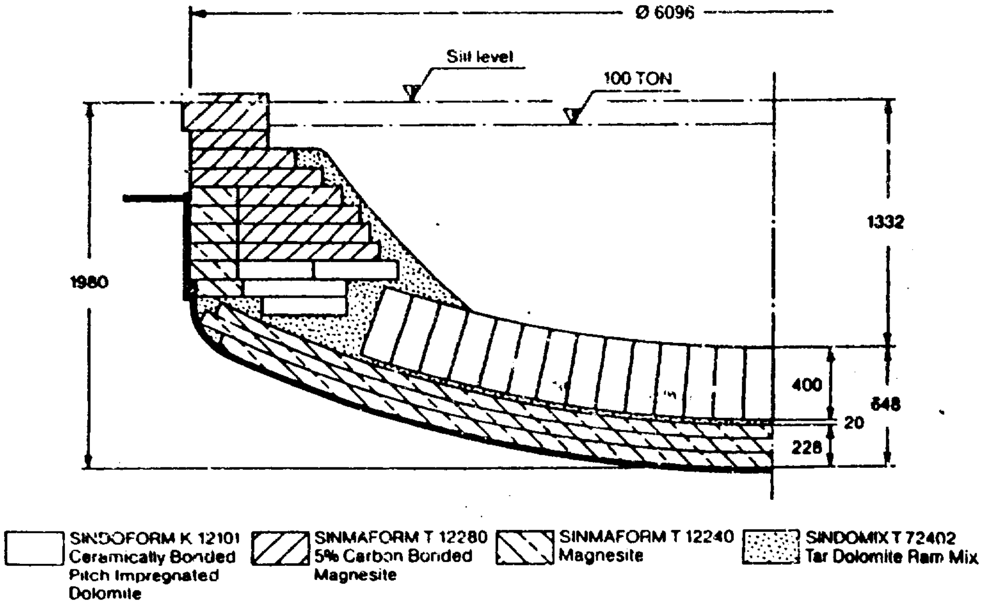
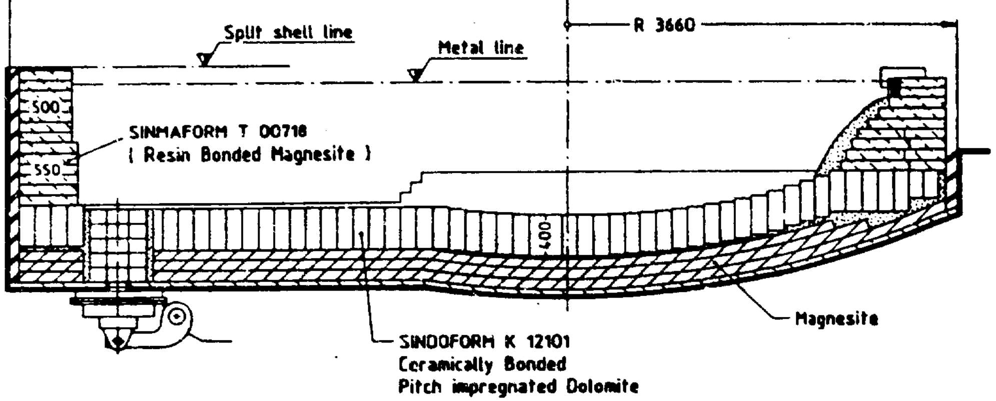
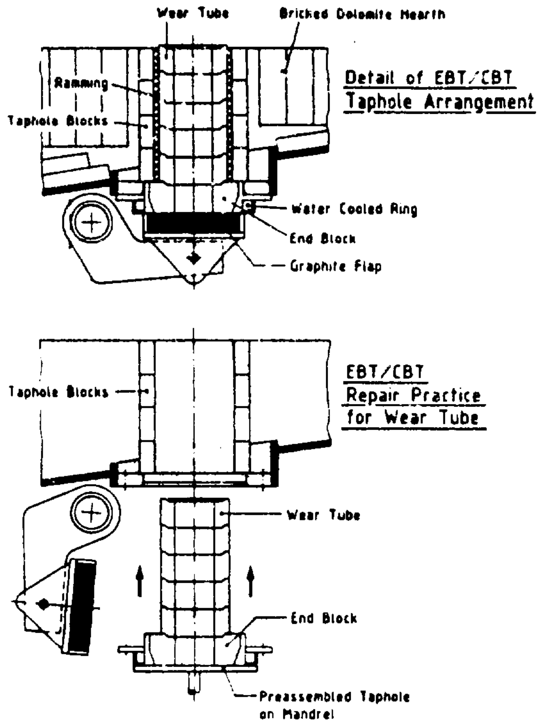


Fig. 21b*)



200 Ton Capacity EBT-Furnace

*) Source: Reference Nr.34



Detail of EBT/CBT Taphole Arrangement

EBT/CBT Repair Practice for Wear Tube

Fig. 21c*)

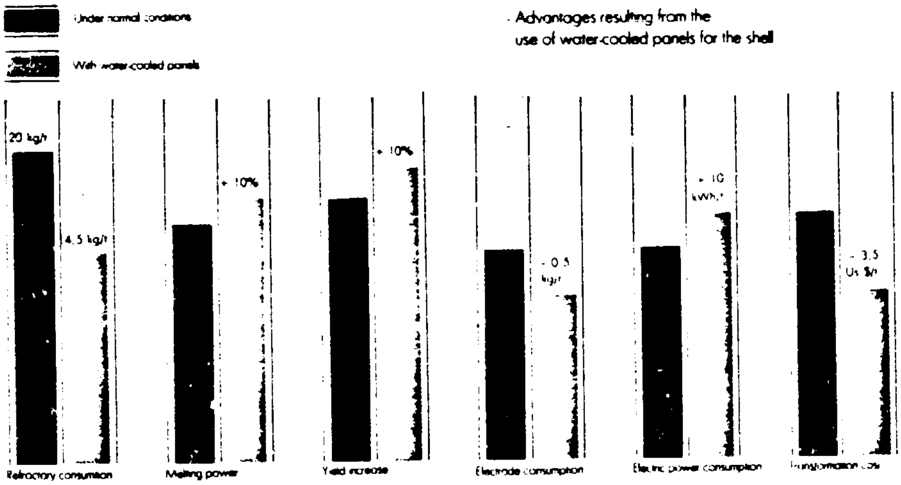


Fig. 22a*)

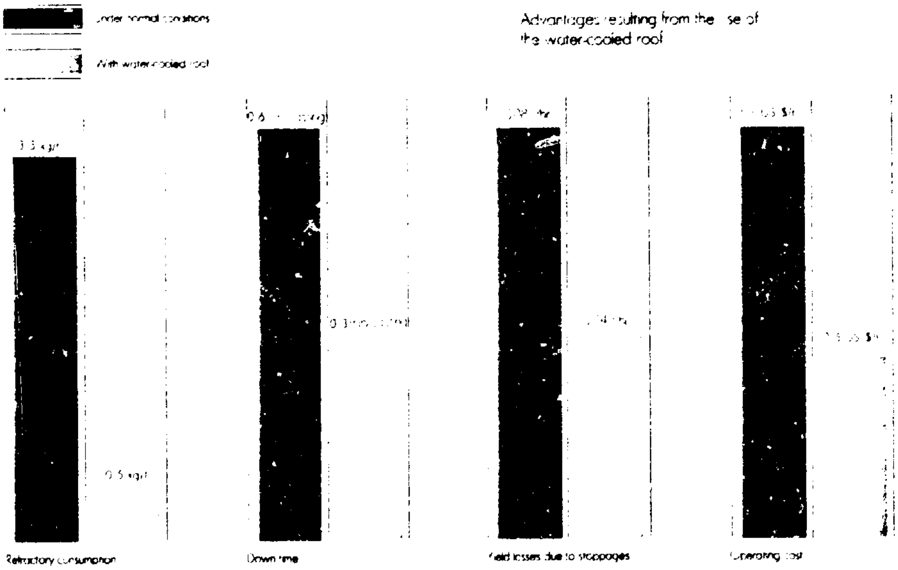


Fig. 22b*)
(Source: References 40 and 41)

Foamy slag: Foamy slags are those which develop a high gas rate while at the same time offer a high viscosity. The basic elements which characterize foamy slags are $CaCO_3$ and C. The main advantages of this technique are: a) shortening of melting and refining time b) reduction of refractory and electrodes consumption c) reduction of electric power consumption d) increased productiity e) improvement of the work conditions for the personnel.

4.3 Secondary steelmaking - ladle metallurgy

One of the recent development that has major impart on mini-plant design and operation is the secondary steelmaking technique. The modern trend in steelmaking is to keep to a minimum the metallurgical work carried out in the EAF. Furthermore, the metallurgical possibilities of secondary steelmaking have changed the role of EAF; it can produce nearly all types of steel if equipped with appropriate processing facilities (see Figure 23). Table 5 shows basic function and processing techniques for various secondary steelmaking processes. Slag free taping is necessary for all secondary operations (see Fig.24). To achieve an optimum service life, along with economical energy consumption, basic lined ladles are used. Table 6 illustrates a cross-section of performances in ladles for both EAF and BOF shops.
The metal refining process MRP developed and designed by Mannesmann Demag Hüttentechnik, FRG is given as an example regarding operating cycle and investment cost.
The MRP converter is a bottom-blown converter which uses oxygen and inert gases to produce high-quality steels. Figure 25a shows the MRP converter profile with a nominal capacity of 8 t, and Table 7 indicates the design data. Figure 25 b shows the process cycle for the steel type 42 Cr Mo 4. Results achieved in about two years of operation are summarized in tabular form, Table 8, Table 9 indicates the total investment cost for different MRP converter capacities.

Table 5

METALLURGICAL & OPERATIONAL PURPOSES FOR THE APPLICATION OF OPERATION ELEMENTS OF LADLE PROCESSES: UNIT

OPERATION ELEMENTS OF LADLE METALLURGY PROCESSES	OPERATION EXAMPLES	HOMOGENISATION	PRECISE ADJUSTMENT OF ALLOYS	DEOXIDATION (AL-FREE)	PERCENTAGE PURITY IMPROVEM.	CONVERSION OF INCLUSIONS	REMOVAL OF				HEATING UP/ TEMPER. EQUALIZ.	[illegible] MELTING FACILITY	[illegible] POWER OF FURNACE	INTRODUCTION OF HIGH AMOUNTS OF ALLOYS	REMOVAL OF PHOSPHORUS	INSUFFICIENT REFRACTORY QUALITY	BUFFER EFFECT	CONTINUOUS/ SEQUENCE CASTING	PROGRAMME EXTENSION	SPECIAL STEEL PRODUCTION LOW CARBON ST.
							CARBON	SULPHUR	HYDROGEN	NITROGEN										
1. RINSING GAS/STIRRING VESSEL																				
A) SIMPLE RINSING/ STIRRING		Y	Y	N	L	N	N	N	N	N	N	N	N	N	N	N	N	Y	L	N
B) UNDER REACTIV SLAG	CAS, SAB, MPE	Y	Y	L	L	L	N	Y	N	N	N	N	N	N	N	N	N	Y	L	N
2. INJECTION TREATMENT																				
A) INJECTION PROCESS	TN	Y	Y	Y	Y	Y	N	Y	N	N	N	Y	N	N	N	N	N	Y	Y	N
B) WIRE FEEDING PROCESS CALCIUM WIRE		Y	Y	Y	L	Y	N	L	N	N	N	N	N	N	N	N	N	L	L	N
BULLET SHOOTING PROCESS	SCAT																			
CALCIUM CARRIER (BEAM)																				
3. HEATING UP OF STEEL (LADLE FURNACE UNDER REACTIVE SLAGS AND INERT GAS)	LF, AP	Y	Y	Y	Y	L	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
4. VACUUM																				
A) TEEMING JET DEGASSING	BV	Y	L	Y	L	N	Y	N	Y	L	N	N	N	N	N	N	N	N	L	N
B) LADLE DEGASSING																				
1. SIMPLE DEGASSING		Y	Y	Y	L	N	Y	N	Y	L	N	N	N	N	N	N	N	L	L	N
2. WITH HEATING UNDER REACTIVE SLAGS	VAD ASEA-SKF	Y	Y	Y	Y	L	Y	Y	Y	L	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
3. WITH OXYGEN BLOWING	VOD	Y	Y	Y	Y	N	Y	N	Y	L	N	Y	N	N	N	N	N	N	Y	Y
C) PARTIAL QUANTITY DEGASSING																				
1 SIMPLE DEGASSING	DH, RH	Y	Y	Y	Y	N	Y	N	Y	L	N	Y	N	N	N	N	N	L	Y	N
2. WITH OXYGEN BLOWING	RH-O, RH-OB	Y	Y	Y	Y	N	Y	N	Y	L	N	Y	N	L	N	L	N	N	Y	Y
COMBINING OF PROCESSES IS USUAL;		METALLURGICAL OBJECTIVES									REASONS FOR OPERATIONAL APPLICATION									

EXERCISE OF INFLUENCE:
Y = YES
L = LIMITED
N = NO

Source: Ref. Nr. 45

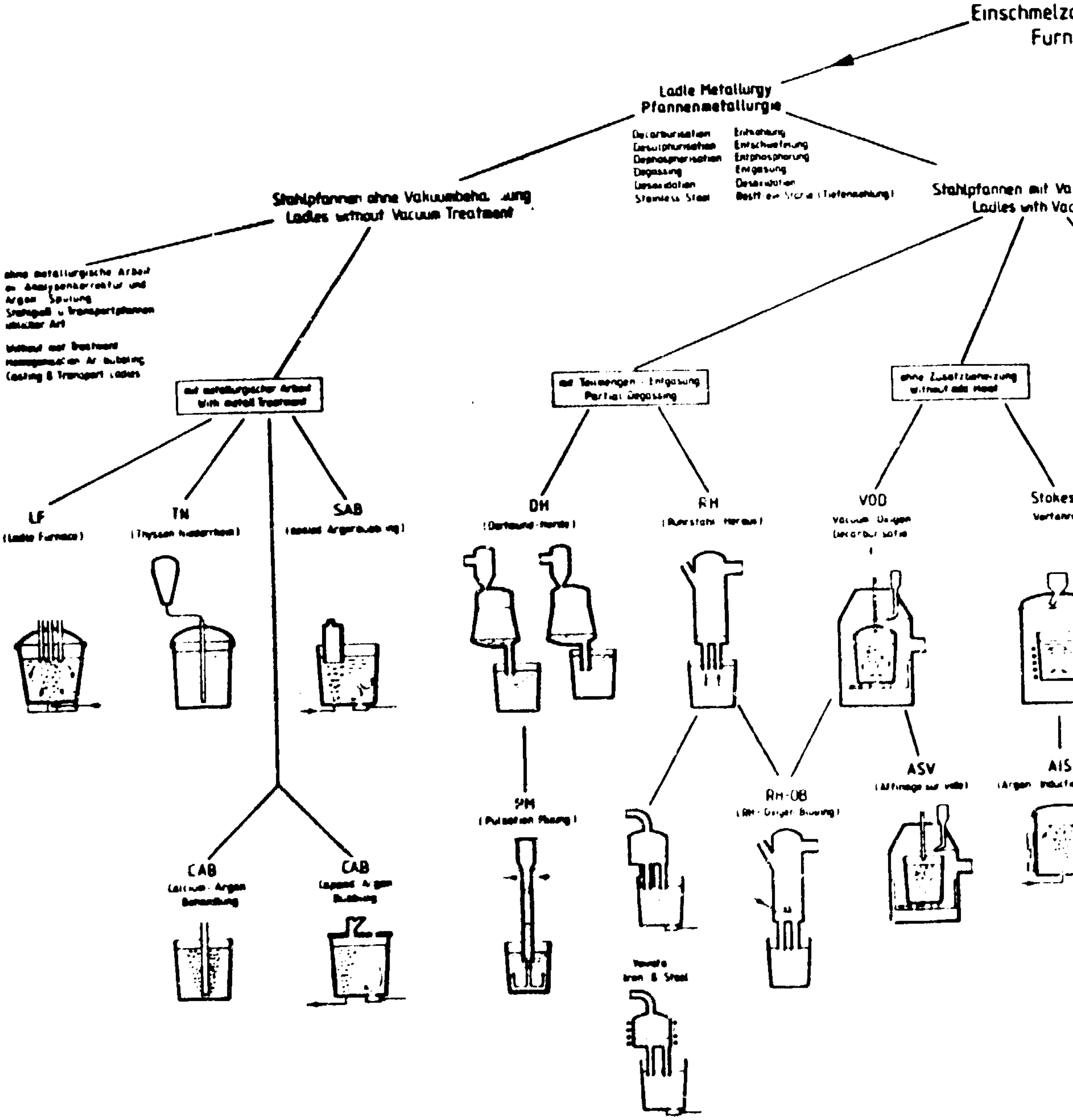
Table 6 (Source: Ref. Nr.34)

PERFORMANCE OF DOLOMITE LINED CASTING & TREATMENT LADLES

Country	Plant	Capacity	Application	Lining Life
W. Germany	A	190 Tonnes	T. N. B.O.F.	50 Heats
	B	130 Tonnes	T. N. Arc Shop	52 Heats
	C	70 Tonnes	C. L. Arc Shop	50 Heats
	D	220 Tonnes	T. N. B.O.F.	38 Heats
	E	285 Tonnes	C. L. B.O.F.	55 Heats
France	A	220 Tonnes	C. L. B.O.F.	65 Heats
	B	105 Tonnes	C. L. Arc Shop	80 Heats
	C	115 Tonnes	T. L. Arc Shop	60 Heats
U.K.	A	100 Tonnes	C. L. Arc Shop	48 Heats
	B	70 Tonnes	C. L. Arc Shop	68 Heats
	C	180 Tonnes	C. L. Arc Shop	45 Heats
Spain	A	100 Tonnes	C. L. Arc Shop	60 Heats
	B	125 Tonnes	C. L. Arc Shop	67 Heats
Italy	A	35 Tonnes	C. L. Arc Shop	48 Heats
	B	120 Tonnes	C. L. Arc Shop	
Sweden	A	65 Tonnes	C. L. Arc Shop	62 Heats
	B	60 Tonnes	C. L. Arc Shop	95 Heats
Denmark	A	120 Tonnes	T. N. Arc Shop	50 Heats
Holland	A	300 Tonnes	C. L. B.O.F.	55 Heats
U.S.A.	A	80 Tonnes	C. L. Arc Shop	48 Heats
	B	60 Tonnes	C. L. Arc Shop	110 Heats
	C	70 Tonnes	C. L. Arc Shop	92 Heats
	D	120 Tonnes	C. L. AOD Shop	65 Heats
Taiwan (R.O.C.)	A	150 Tonnes	C. L./S. L. B.O.F.	55 Heats
Korea (R.O.K.)	A	300 Tonnes	C. L. B.O.F.	54 Heats
Malaysia	A	80 Tonnes	C. L. Arc Shop	50 Heats
N. Zealand	A	50 Tonnes	C. L. Arc Shop	72 Heats

C. L. = Casting Ladle
T. N. - Thyssen Niederrhein
S. L. = Scanlance
T. L. = Transfer Ladle

SECONDARY ST
VERFAHREN DER SEK



SECTION 1

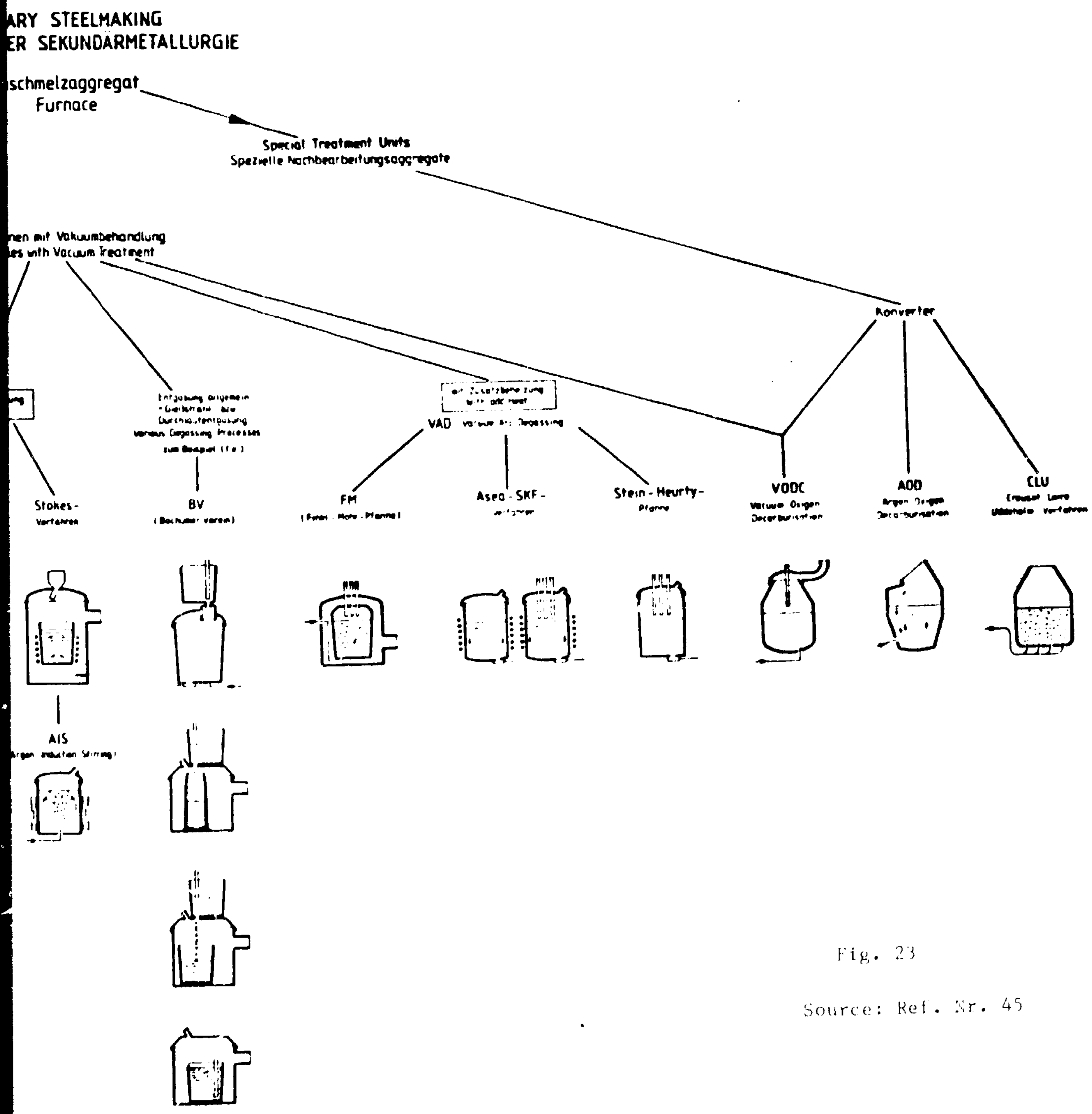
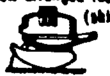
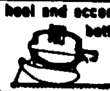


Fig. 23

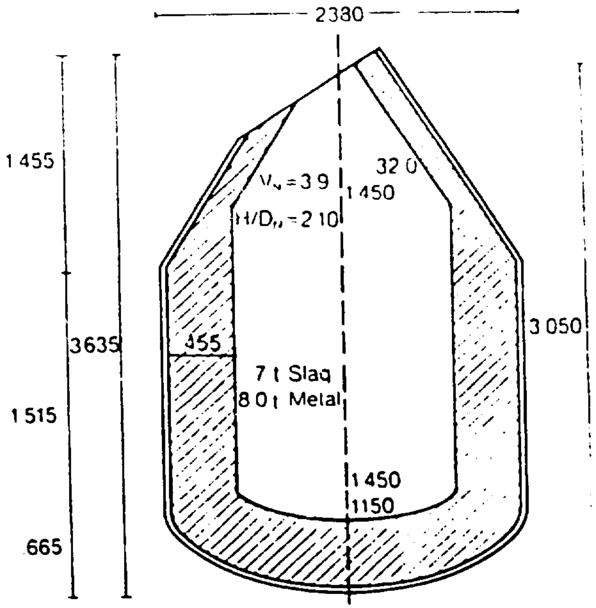
Source: Ref. Nr. 45

SECTION 2

tapping technique	slag running off before steel	with steel	after steel
1 without slag retaining 	5 to 10 %	40 to 70 %	20 to 80 %
2 closing taphole 	none	yes	yes
3 low-arranged taphole (skimmer) 	none	little	little
4 gate or stopper 	none	little	little
5 previous slagging off 	none	none	none
6 bottom taphole 	none	little	yes
7 heel and low-arranged taphole (SBT) 	none	none	little
8 heel and eccentric bottom tap (EBT) 	none	none	little

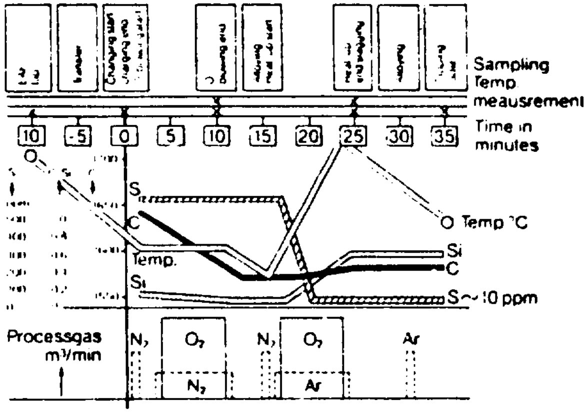
Tapping techniques to avoid slag entrainment.

Fig. 24
(Source: Ref. 14 & 45)



Converter profile (8 t)

Fig. 25a
(Source: Ref. 1 -16)



MRP-process operation for GS 42 CrMo 4

Fig. 25b
(Source: Ref. 1 - 16)

Table 7 Design data

Vessel dimensions		
Rated capacity	approx	8 0 t
Overall height	approx.	4 000 mm
inside the plate shell		
Volume	approx	11 2 m³
Cylindrical section dia (d)	approx	2 360 mm
Inside height (h)	approx	3 635 mm
inside new lining		
Volume		3 9 mm³
Cylindrical sec dia (d)		1 450 mm
Inside height (h)		3 050 mm
Tilting drive		
Static tilting torque (nominal)		50 000 Nm
(maximum)		150 000 Nm
	Normal operation	Emergency operation
Converter		
Tilting speed (rpm)	0 1–1 2	0 1
Angle of tilt (°)	360	
Motors		
Type	electric	air
Number	1	1
Rated speed (rpm)	720	1 500
Brakes		
Type	double shoe brakes	
Number	2	

Operational data

Operational data	A	B		
Year of commissioning	1983	1983		
Vessel size	8 t	8 t		
Trunnion ring size	8 t	8 t		
Refractory life per campaign				
Vessel	70–95	50		
Blowing nozzel change	50	30		
Gas consumption			C-start	
Oxygen m³/t	10–15	16–20	above	0 20 %C
		20–24	up to	0 20 %C
Nitrogen m³/t	4	up to 3	above	0 20 %
		up to 6	up to	0 20 %C
Argon m³/t	4–5	up to 3	above	0 20 %C
		up to 6	up to	0 20 %
Heating aluminium	10–12	10–40		
Lime consumption	30–40	40–60	above	0 20 %C
		50–70	up to	0 20 %C
Treatment time	25–30	30–35		

Table 8*)

Capacity of MRP-Converter	10 t	15 t	20 t
- Complete mechanical, electrical instrumentation, gas cleaning system, service media, supervision of erection and commissioning	3 700 000.-	4 700 000.-	5 800 000.-
- Total capital cost	3 700 000.-	4 700 000 -	5 800 000.-
- Production (minimum) t/year (300 working days/year)	30 000	45 000	60 000
- Useful life (years)	10	10	10
- Calculatory depreciation (linear depreciation) DM/year	370 000.-	470 000.-	580 000.-
- Calculatory interest (10 % of 1/2 purchasing value) DM/year	185 000.-	235 000.-	290 000.-
- Total fixed costs DM/year	560 000.-	705 000.-	870 000 -
- Total specific investment costs DM/t liquid steel	19 0	16 0	15 0

Table 9: Total investm. cost*)

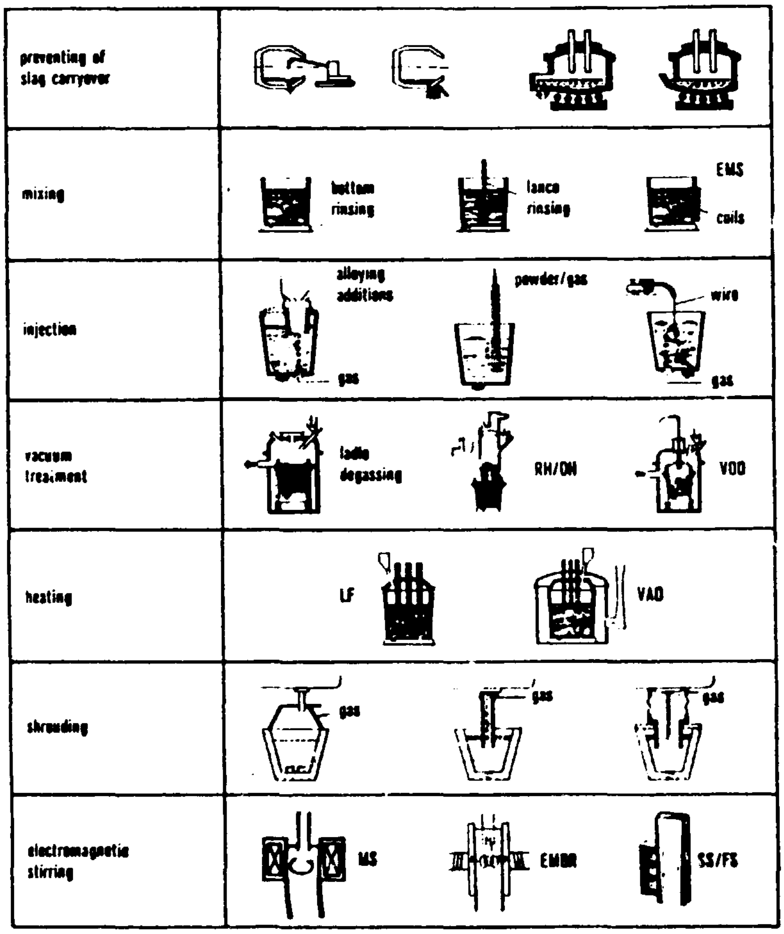


Fig. 26: Objectives in secondary metallurgy*)

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*) Source: Ref. 1 - $\frac{16}{45}$,

4.4 Continuous feeding of the furnace and ladle

The continuous feeding of the furnace and ladle offers advantages such as:

- shorter break down due to feeding by means of baskets
- continuous feeding of sponge iron (in case of DRI) at a high melting and refining power, thanks to the constant covering of the electric arc with foamy slag
- shorter down time during the refining process
- higher thermal output of the furnace

4.5 Synchronization of EAF Steelmaking and Caster

With respect to continuous casting processes the main advantages resulting from the steel processing outside the furnace are:
Metallurgical advantages: optimal degree of oxitation (deoxitation, degassing, desulphurization, alloying and temperatur control and adjustment).
Industrial advantages: Improvement of the steel plant yield rate, reduced consumption of the furnace refractories, better all-round utilization of power, better yields for ferroalloys, improved yield in continuous casting process, widening of the range of steel produced at reasonable costs, decrease of the percentage of castings which do not comply with analytical requirements. *)
One morepoint should be added, that the ladle serves as a buffer between the working cycles of the furnace and the downstream casting facilities. Minor troubles, unfavourable chemical composition, and fluctuations in casting periods from different tap weights can force variations in furnace tap-to-tap times. These factors can be balanced by extending the retention time of the liquid steel in a ladle metallurgy station. Figure 26 shows the measures taken in process technology and their conversion into metallugical processes

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*) Today it is possible to achieve contents of $(C+S+P+O+N+H) < 70$ ppm and lower contents of these accompanying elements down to the limits of analytical determination.

4.6 Fume collection and sound proofing in steel plants

Research is constantly carried out to improve furnace productivity. There has been a progressive increase in the specific installed electric power (kVA/t), (see Figure 15a, b), leading to today's extremely high UHP values.

This implies not only the generation of more fumes, but also a significant increase in the noise level during the melting stage. Thus it has been necessary to take steps to lessen noise diffusion. It is possible to distinguish two different trends:

- soundproofing of the furnace bay to limit the diffusion of noise towards the outside and setting up of sound proofed cabins to protect the operators.
- complete enclosing of the furnace by means of sound deadening walls.

The soundproofing of the furnace area involves a higher investment as the surface to soundproof is greater than the one involved for a furnace enclosure. However bay sound proofing is preferable in some cases, as it does not require any change in the furnace operation (see Figure 27). There is a widespread fear that enclosing the furnace may affect and delay its operation, thus negatively influencing productivity.
But in fact, if the enclosing of the furnace is examined in all its details and the necessary measures are taken to allow for an easy furnace management, the problems can be solved. Besides preventing noise diffusion inside the plant, as well as, outside, the enclosing of the furnace makes it easier to collect the secondary fumes generated by the furnace. In the case of furnaces with a lower capacity it is even possible to eliminate the section system for the collection of fumes from the 4th hole, so that the costs of the fume cleaning system are further reduced (see Figure 28).

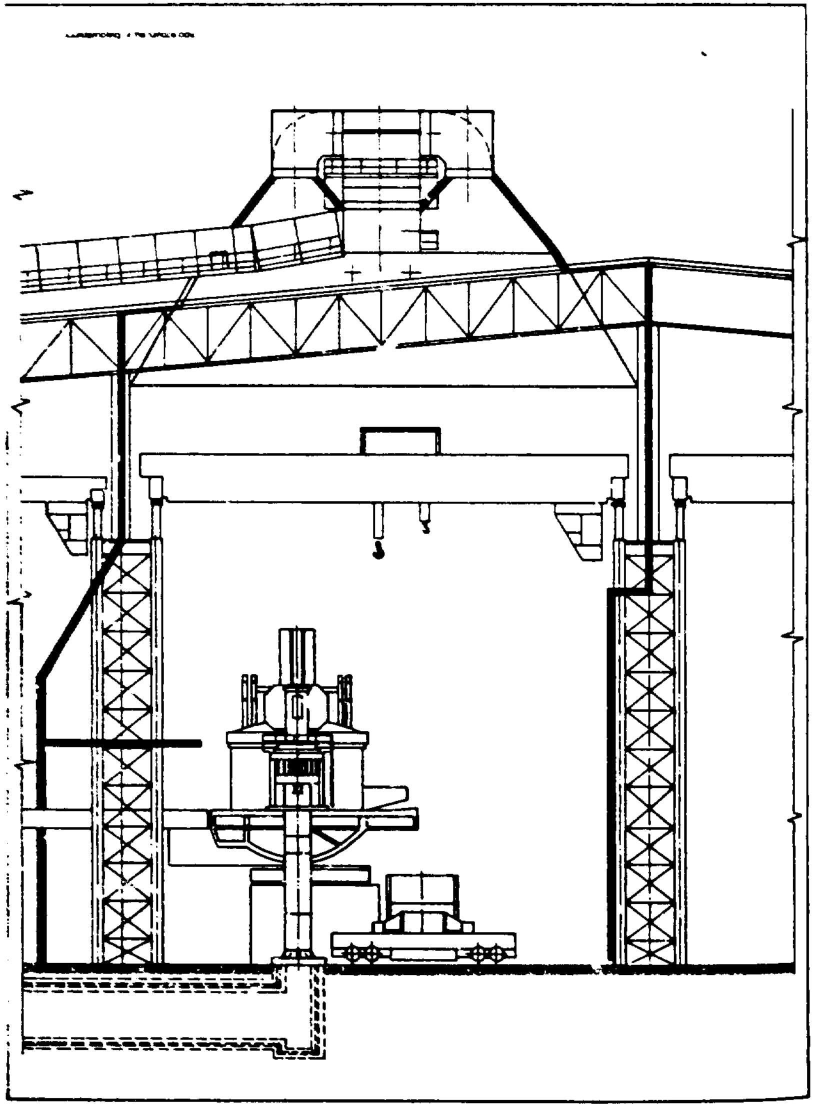
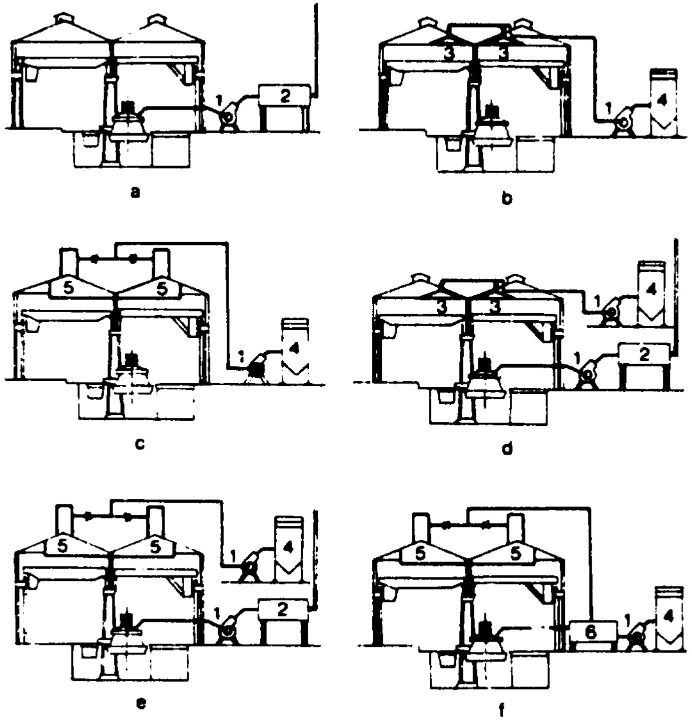


Fig. 27
Source: References 40 and 41



(a) Furnace extraction system. (b) Canopies without furnace system. (c) Roof hoods without furnace system. (d) Furnace system with partial roof extraction from canopies. (e) Furnace system with full roof extraction from hoods. (f) Combined furnace extraction with full roof extraction.

Fig. 28
Source: Ref. Nr. 51

5. Process stages and facilities after the EAF-steelmaking

Selection of casting process: Two routes can be adopted for casting liquid: a) conventional ingot casting, and b) continuous casting. Conventional Ingot Casting: In conventional ingot casting, liquid steel is poured into ingot moulds: the ingots are stripped, heated and then rolled in primary mills to produce semis such as blooms and slabs.

Continuous Casting: In continuous casting, liquid steel is directly cast into semis like blooms, billets and slabs. During the last 15 years the total world crude steel production remained firmly constant at a level around 650 million tonnes/annum. During this period, however, the tonnages and percentages of continuously cast steel continued to increase, and in average world wide, the continuous casting percentage is now close to 4o %, Figure 29 a.

5.1 Advantages of continuous casting

The rapid progress of continuous casting is mainly due to the many advantages it offers over ingot casting. There are:

- lower investment cost
- smaller space required
- continuity of operations and possibility of complete automation
- improved product (consistent quality)
- except for some high alloy and special steels, all grades of steels may be continuously cast.
- high yield ratios between liquid steel and semis (see Figure 29 b)
- lower consumption of inputs and energy
- less handling of materials
- lower transformation costs
- increased output in the production process down-stream from casting (rolling etc.) see Figures 29 b,c.
- more comfort and safety for the personnel which work in the steel plant and a better work environment.

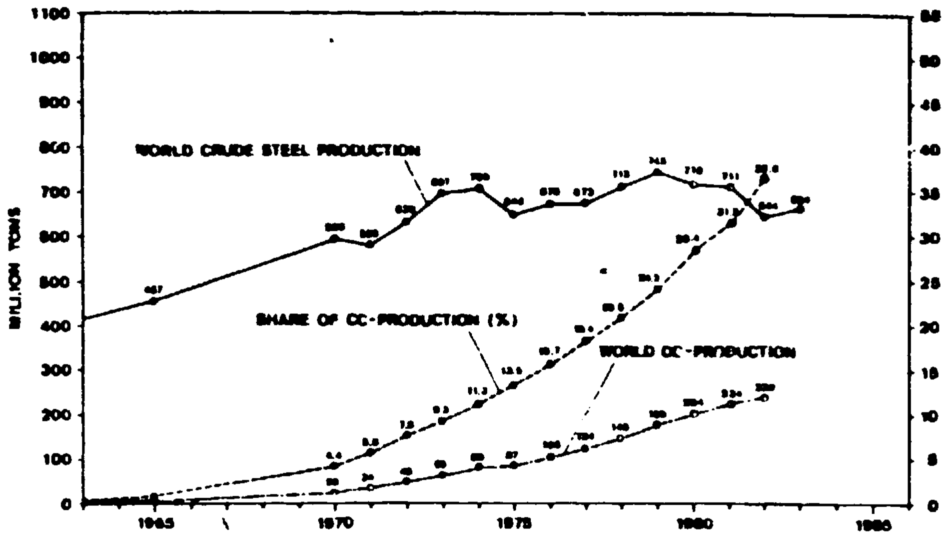


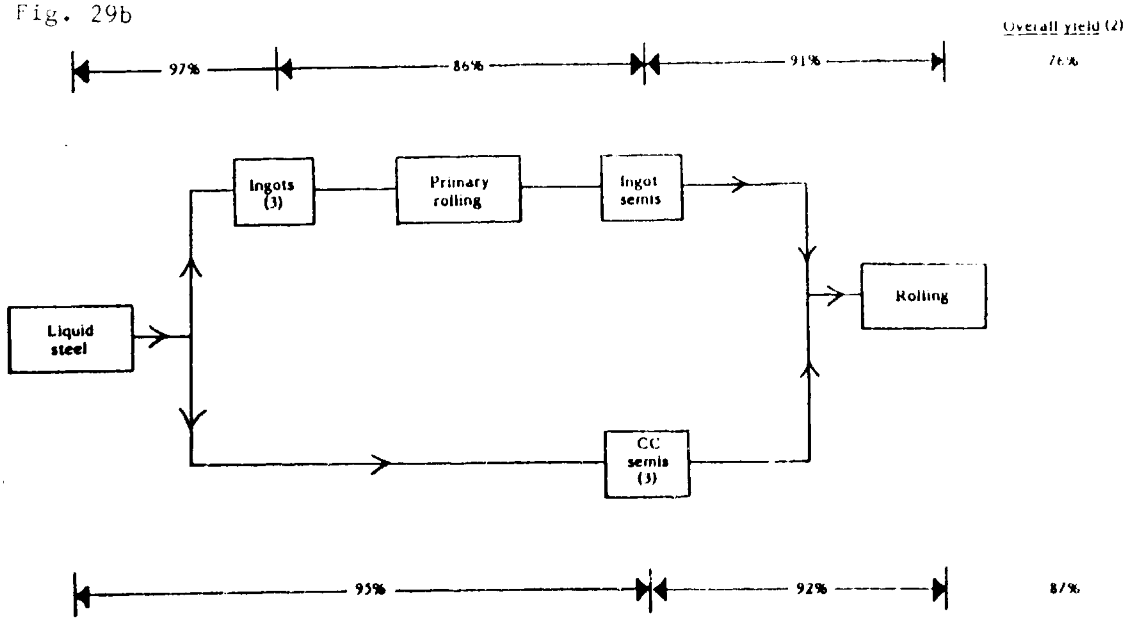
Fig. 29a

WORLDWIDE PRODUCTION OF CRUDE STEEL AND SHARE OF CONTINUOUS CASTING

(Source: Ref. Nr.45)

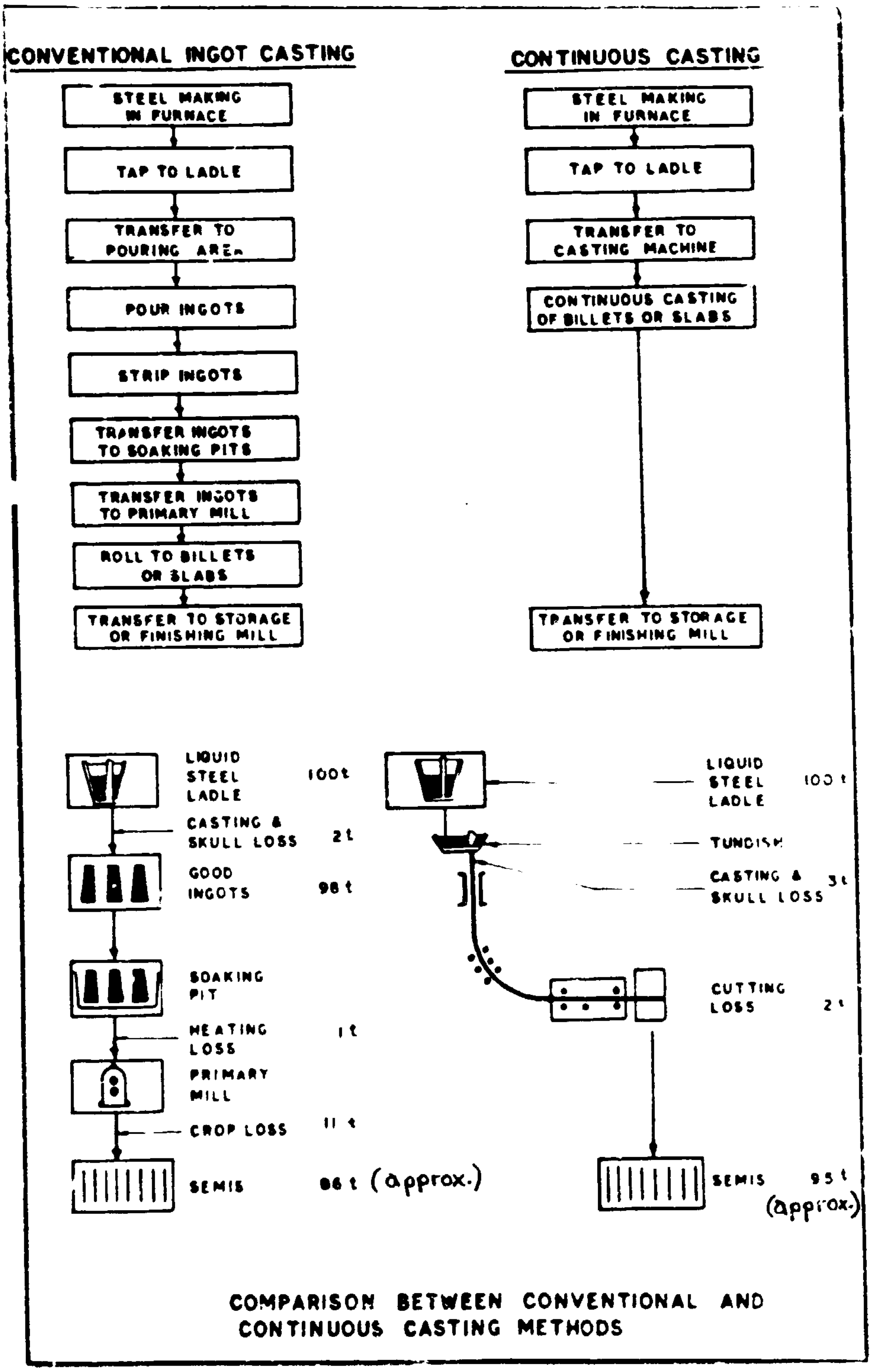
Relative yields of ingot and continuous casting (1)

Fig. 29b



(1) Typical yields based on Japanese practice.
(2) Overall yields for ingot casting and continuous casting are 76% and 87%, respectively.
(3) Sum of ingots plus continuous casting semis is crude steel as defined by IISI.

Source: IISI.



COMPARISON BETWEEN CONVENTIONAL AND CONTINUOUS CASTING METHODS

Fig. 29c
(Source: UNIDO)

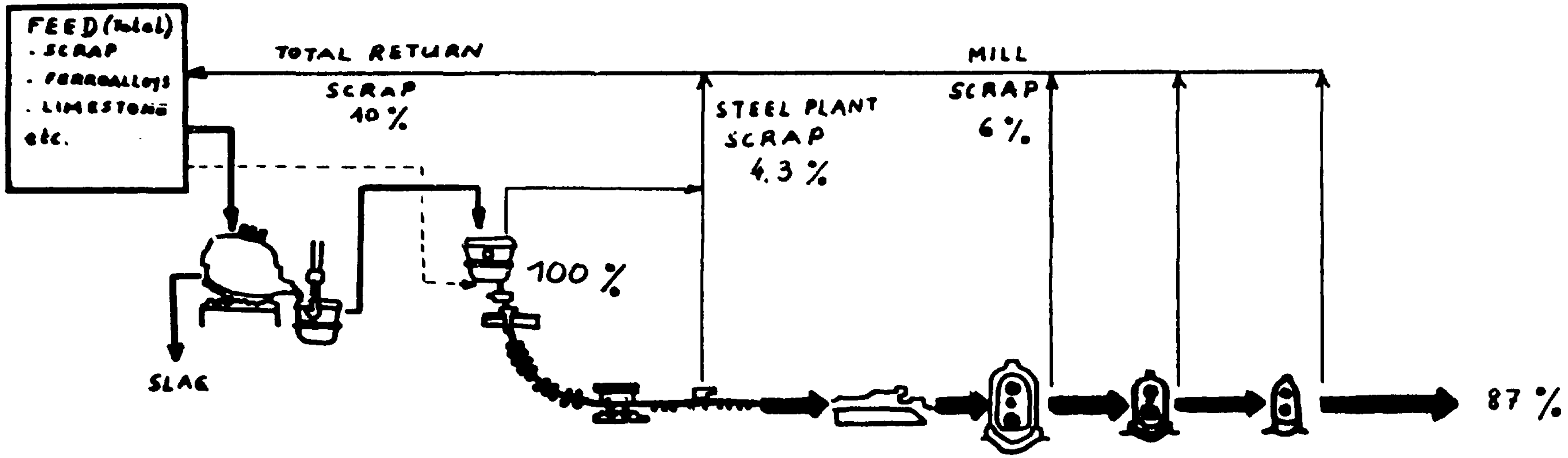
In the case of mini steel plants, the adoption of continuous casting enables production of good-quality billets (blooms and slab production can basically be included by the mini plant concept too) in the place of conventional pencil ingots or small size ingots. It also obviates the need for a breakdown mill for rolling the ingot to billet.

5.2 The impact of continuous casting on scrap demand

The introduction of continuous casting is having, and will continue to have, a profound effect on the availability of circulating scrap since continuous casting of steel involves one step fewer than ingot casting (see Figure 29 c).
The total effect is to increase the yield of finished steel from liquid steel by effectively reducing the amount of metal which is scrapped; it is widely held belief that the increased use of continuous casting will result in an increased demand for purchased scrap. In the case of continuous casting the lower generation of circulating scrap is exactly balanced by the increase in yield of semi-finished steel from liquid steel (see Figs. 29 c,d).

5,3 The impact of continuous casting on Work's planning

Because of the quality demand and the international steel market situation, it is necessary to improve the yield of steelmaking facilities. The continuous casting machine has a key position in this position. The controlability of the factors influencing the desired quality of the product being poured is the major concern of the continuous casting technology. Because of its nature, the continuous casting machine demands the central position in the work's planning, on the one hand in relation to the melt shop (upstream) and on the other, with regard to rolling (downstream). The scheduling of the production through the works based on continuous casting must involve sufficient attention to the co-ordination of the steelmaking operation and also that of the steelmaking operation and also that of the rolling mill with the casting machine itself.



FACILITY	ELECTRIC ARC FURNACE	LADLE	CONTINUOUS CASTING MACHINE	HEATING FURNACE	ROUGHING MILL	INTERM. MILL	FINISHING MILL	
PRODUCT	FEED → LIQ. STEEL, SLAG	LIQUID STEEL	STRAND (solidif. steel)	BLLETS				BARS, ANGLES, etc.

Fig. 29d: RETURN SCRAP, APPROXIMATE VALUES IN %.

(Source: Based on UNIDO material and references 35,36,37 & 45)

5.4 Technical considerations

5.4.1 Process principle - machine type

When molten steel comes into contact with the walls of the water-cooled mould, a thin solid skin forms. Due to thermal contraction, the skin separates from the mould shortly after solidification. The rate of heat abstraction from the casting being slow, molten steel persists within the interior of the section for some distance below the bottom of the mould. The thickness of the skin increases due to the action of water sprays as the casting moves downward and gradually becomes completely soldified.
The mass of solid steel is supported as it descends by driven pinch rolls that also control line speed by controlling the rate of withdrawal of the casting from the mould. Oscillation of the mould up and down for predetermined distances at controlled rates during casting helps to prevent the casting from sticking in the mould.
During the development of the continuous casting technology different types of casting machines were established especially with the intention to reduce machine heights and consequently investment costs. The machine types with corresponding general characteristics are summarized below:

Machine type	general characteristics	
vertical	straight mould	height no bending high ferrost, pressure limited length limited casting speed
bending/ straightening	straight mould	height high ferrost, pressure
bow machine (curved mould)	reduced height	curved mould
oval bow	minimum height	curved mould varying machine radius
bow machine (straight mould)	straight mould reduced height	beding with liquid core
horizontal	straight mould no bending	for small sections (under development)

The tapping temperature of steel is generally 1650° - 1690° C for concast installations, depending on the life of the furnace refractory and the taphole condition.

5.4.2 Technical Characteristics

The successful application of the continuous casting process in a steel plant is dependant upon many factors, some of which are given below: i) General data

1.1 Size of the furnace

1.2 Tap-to-tap time of the furnace

1.3 Possibility of programming the tapping time

1.4 Total tons of steel to be cast per day

1.5 Shape of the cast product (see Figures 30 a,b)
Billets, blooms, Round Bars, Slabs.

1.6 Metallurgical length, [m] (solidification coefficient K, Table 10)

1.7 Casting speed [m|min] (see Figure 31)

1.8 Cast size [mm x mm]

1.9 Number of strands

1.10 Design (bow type, vertical, vertical with bending, horizontal)
Length of vertical section, m;
Radiis of curvature, m;
Straightening (1 point, several points, progressive)

ii. Before the Caster

ii. 1 System protection between ladle and tundish; sampling

ii. 2 Tundish (size, lining type; baffle|dam; stopper rod| slidegate|metering nozzle; covering powder; automatic bath level control|system; possibility of tundish change during casting; special treatments; preheating|reheating, additions)

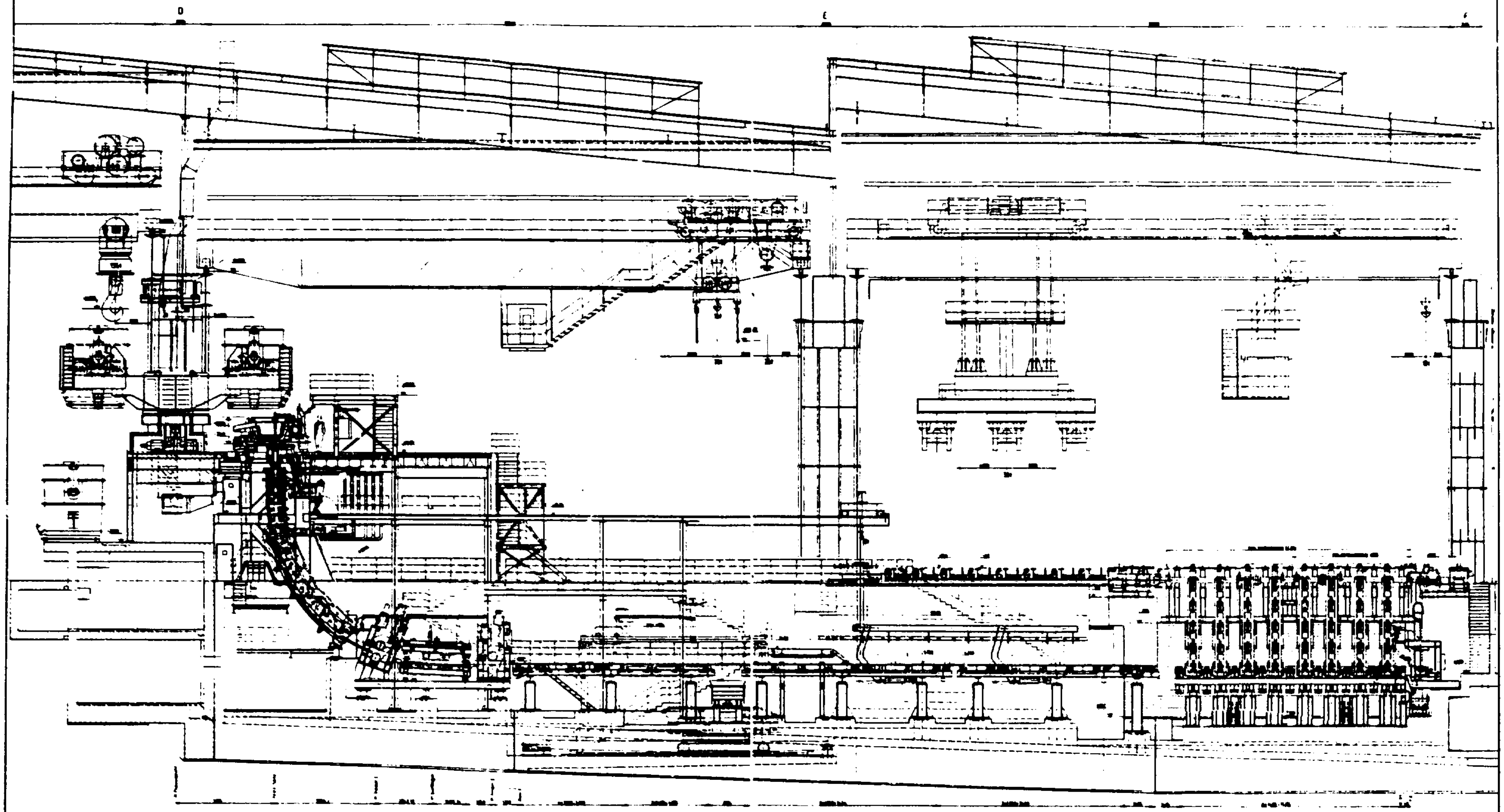
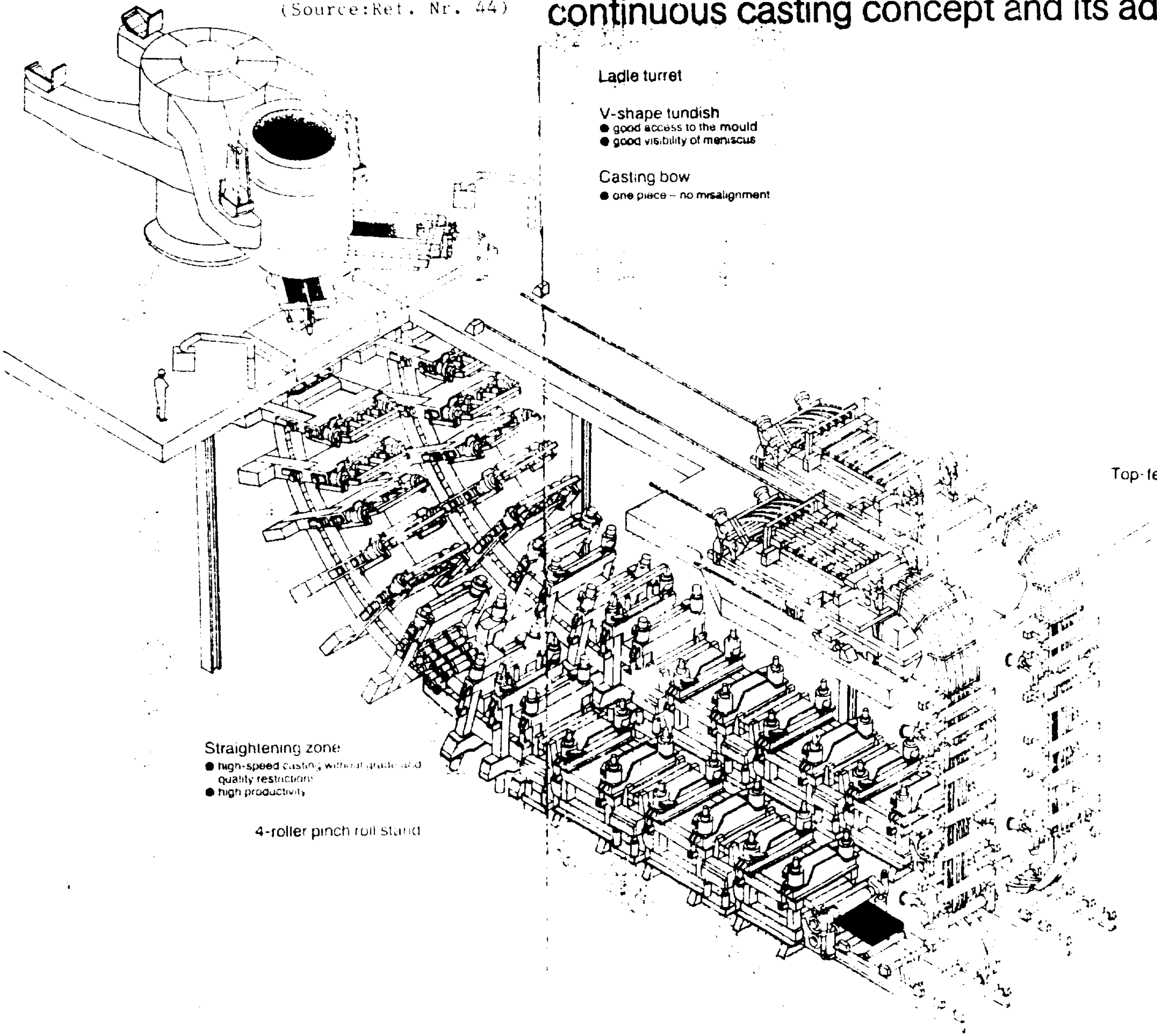


Fig. 30a: Longitudinal section of a cont. casting machine for billets (Source: Reference Nr.44)

Fig. 30b
(Source:Ref. Nr. 44)

Slab casting machines: continuous casting concept and its advantages



Ladle turret

V-shape tundish
- good access to the mould
- good visibility of meniscus

Casting bow
- one piece – no misalignment

Straight mould
- uniform distribution of inclusions
- uniform shell growth
- ease of maintenance

Bending zone

combines
- low head machine profile
- metallurgical advantages of straight mould

Top-fed dummy bar system

Straightening zone
- high-speed casting without grade and quality restrictions
- high productivity

4-roller pinch roll stand

Strand guide
- modular design
- small rollers with intermediate supports
- small-dia driven rollers to minimize bulging
- long roller life – high availability – low maintenance
- high-speed casting – high productivity – excellent quality

	K [mm x min$^{-½}$]				
	28	27	26	25	24
SLABS insensible to cracking (deep drawing quality, austenitic stainless steels etc.)		X			
sensitive to cracking (pipe grades, St37, St42, ferritic stainless steels, etc.)			X		
electric sheets (Si-alloyed, 3%)					X
BLOOMS insensible to cracking	X				
sensitive to cracking		X			
BILLETS insensible to cracking	X				
sensitive to cracking		X			

Solidification coefficient (straight mould)

Table 10*)

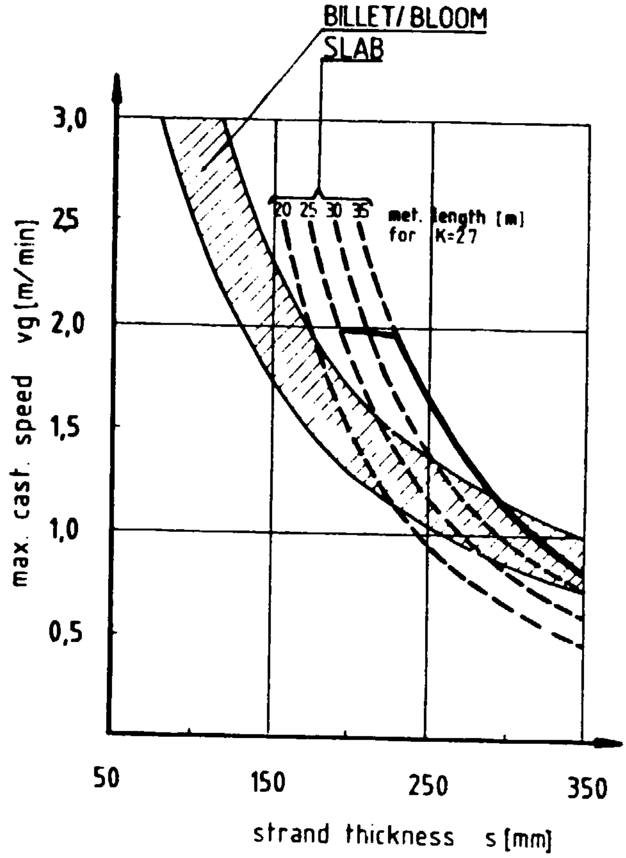
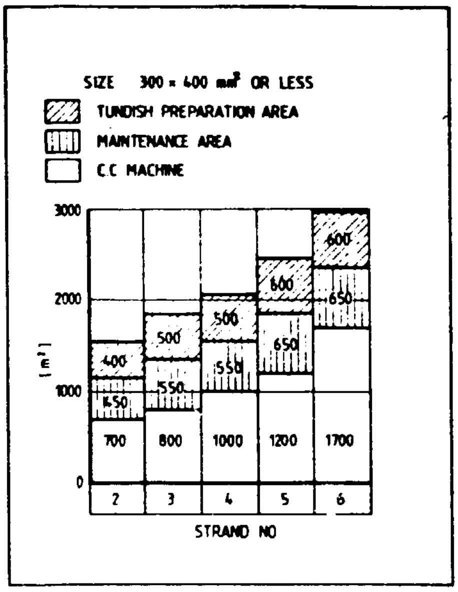


Fig. 31: Max. casting speed depending on shape, strand thickness and metallurgical length *)

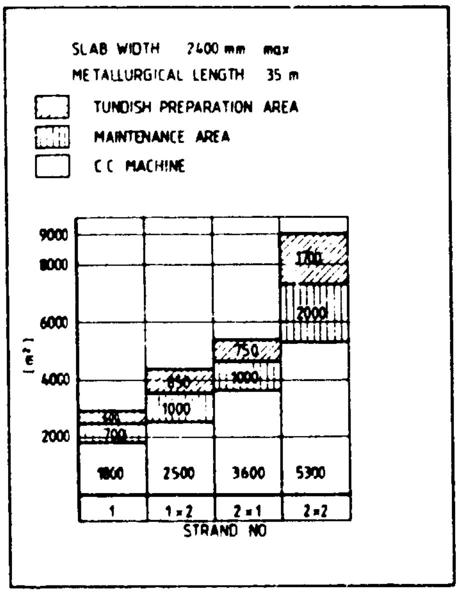
(straight mould)



Space requirements for bloom casters

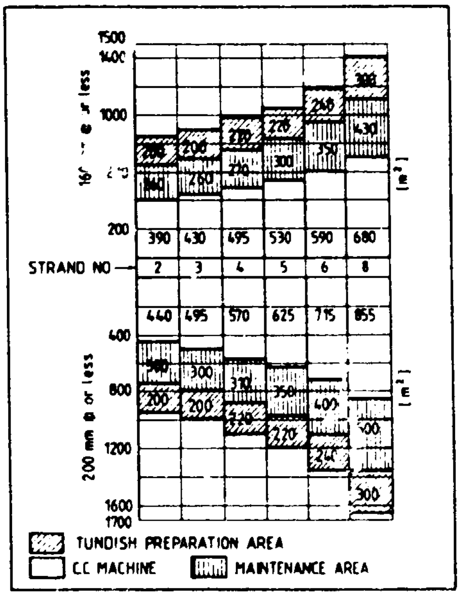
Fig.32a *)

Fig.32b *)



Space requirements for slab casters

Fig. 32c*)



Space requirements for billet casters

*)Source:Ref. Nr. 44

iii. Continuous Casting Machine

iii.1 Mould (length; material/alloy; coating; automatic bath level control/system; breakout warning system; variable width adjustment during casting; oscillation mechanism; additional control equipment).

Mould lubrication (casting powder/type of supply mechanism; powder grade/casting speed range)

iii.2 Dummy bar, loading of dummy bar

iii.3 Strand support (support system below the mould, dimensions); support rolls (size; type; one piece, divided, solid or hollow, with internal cooling; type of cooling; coating)

iii.4 Secondary cooling (types of cooling: water, air-water/ratio; types of nozzles: flat, square, round, horizontal, multinozzle system; water flow rate/control method)

iii.5 Control devices

Electromagnetic stirring - EMS (type; location: mould, secondary cooling, end of liquid pool)

Process computer (continuous casting machine control; continuous casting operation control; roll gap control; size control of cast product; automatic control of cut off; preventive maintenance, quality control)

iii.6 Area required for casting machines (see Figrue 32, a, b, c)

5.5 Financial aspects

5.5.1 Capital investment

Examination of the capital costs of continuous casting plant installted by the British Steel Corporation shows that the capital cost per tonne of installed capacity increases with the size of the cast section, but there is a modest reduction in cost per tonne as the capacity of the plant increases and that continuous casting plants are not cheap, prices ranging from £ 54 to £ 200 per annual tonne. As machines of necessity become more flexible, designs based on current concepts will become more complicated and both capital and maintenance costs will increase. Significant reductions in cpaital charges per tonne of steel cast will only be achieved by increasing machine utilisation.

5.5.2 Operating Costs

It has proved difficult to obtain operating costs comparing ingot and the concast routes. A survey costs for the ingot vs the concast route for billet and slabs has provided some illustrative figures. For billets, the cost of the concast product may be in the range of 88% to 96% of the cost via the ingot route depending on the capacity of the steel plant, the caster and the throughput. The lower figure was for steel supplied from a 50 tonne BOF to a 4 strand curved mould caster, with product sizes 89, 117 and 140 mm square. Fore slabs, the cost of the concast rpoduct was as low as 81% of the ingot route. There are thus very significant savings in operating costs.

The figures presented above include the cost savings of increased product yield and the yield saving is over-riding in operating cost reduction.

5.6 Product quality

At the level of the semi-finished products the product quality evaluation can be carried out by examining the severity of inspection and the extent of conditioning. The cleanness of the metal is mainly obtained by careful preparation in the ladle, effectively preventing reoxidation of the metal, and by developing techniques making it possible to maintain the bath level in the mould at a constant value, with high accuracy. At the same time it is necessary to install high-capacity equipment (a computer) to monitor and control casting conditions in order to predict product quality and downgrade if necessary.

Fig. 33 a shows the three main dressing routes applied to slabs, depending on product type, product mix, the ability to predict quality by monitoring and controlling the casting operations etc.

Fig. 33 b shows optimum process routes evaluated for the production of high grade bars and wires.

Due to the substantial improvements having been achieved as regards cleanness of the steel most steel grades can now be continuously cast. The operating factors which determine cleanness with respect to inclusion are summarized in the following table:

Operating factors affecting SLAB SURFACE QUALITY	
Cleanliness	Ladle Treatment Stream Protection Mould Level Control No disturbance in the mould: - Weir and dams in the tundish - Large tundish - Metal flow rate (small oscillation stroke)
Cracks	Steel composition (C. Nb, Va, Ni, N_2) Mould taper Alignment of the mould with the machine Machine geometry conditions Secondary cooling (homogeneous cooling) Mould flux Mould plating

Factors affecting BLOOM AND BILLET QUALITY	
Inclusions and blow holes	Ladle treatment Stream protection Mould level control
Surface Defects	Mould powder Machine conditions
Segregation	E. M. S. *) Steel composition
Internal Cracks	E. M. S. Casting speed Secondary cooling

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*) E.M.S. = Electromagnetic stirring

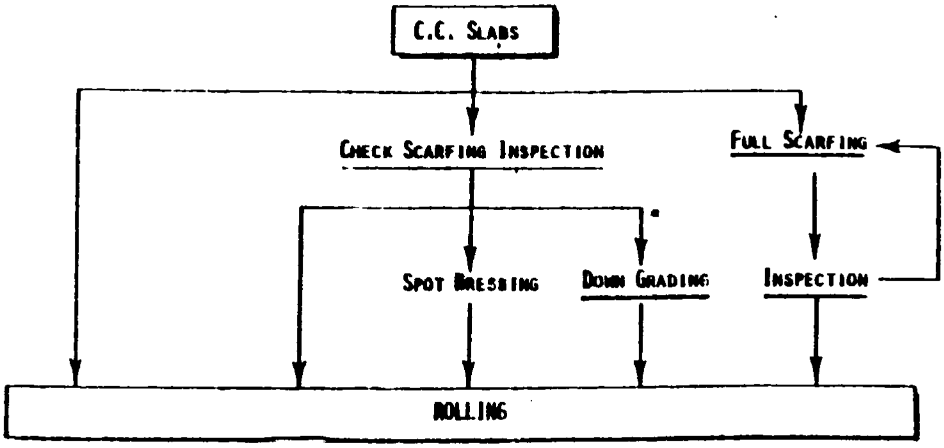
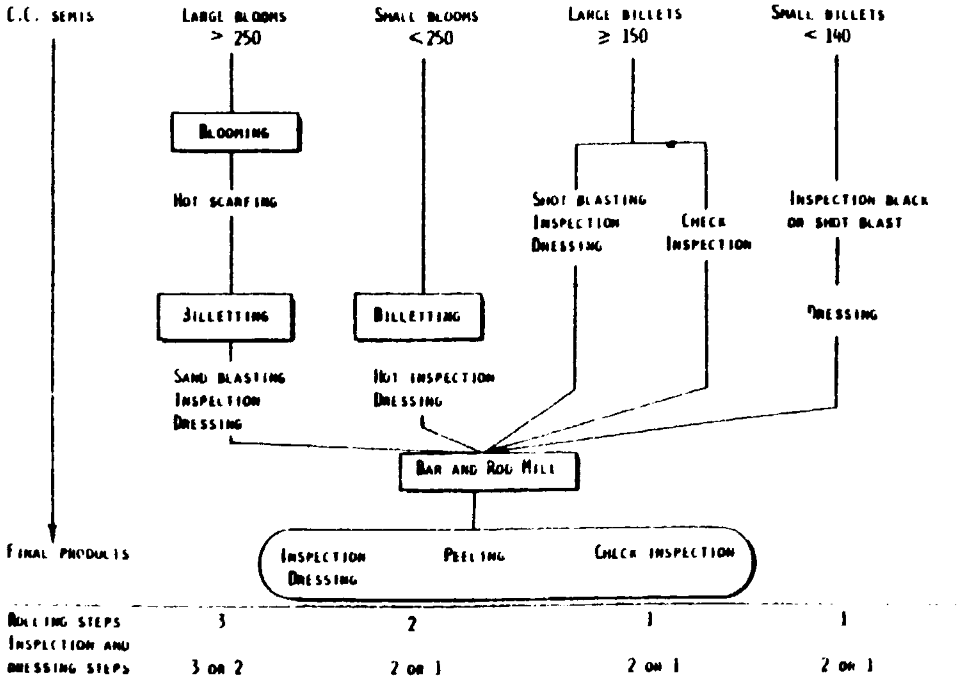


Fig. 33a ALTERNATIVE DRESSING POLICIES APPLIED TO SLABS *)

Fig. 33b*) DRESSING POLICY AND ROLLING STEPS FOR HIGH GRADE BARS AND RODS



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*) Source: Ref. Nr. 46

6. Build-up and size of the "mini-steel" concept

6.1 Build-up "route"

The complete build up of mini-mill and/or integrated mini-mill is shown in Figure 34. In many cases, the extension of the plants to a final integrated mini mill takes place in individual steps. In these cases, in principal, the rolling mills represent the first step (upstream). Consequently, this area is of particular importance because it later determines the total production capacity of the plants. Additionally, account must already here be taken of matching up with possible future expansion plans. At this step the initial billets are purchased. In the second step the semi-integrated mini-mill, or in accordance to our basic definition mini-mill, has its own steel production in electric arc furnaces based on scrap (also possible the additional purchase of prereduced sponge iron) and continuous castng plants for the production of billets.

Finally and in addition to the second step the third step consisting of a direct reduction plant on an ore basis completes the extension to an integrated mini-mill.

An emphasis has also to be given to the build-up procedure of a steel plant under the perspective of co-operation and industrial as well as productivity links among various developing countries. Similar perspectives and development trends can support a build up procedure in a complementary sense regarding the location of the possible stages mentioned above and the respective products. *)

The approximate comparative cost, site area, required energy, electrical supply capacity, oxygen and water consumption, these three types, as compared to an integrated steel plant of economic size are indicated in Table 11b.

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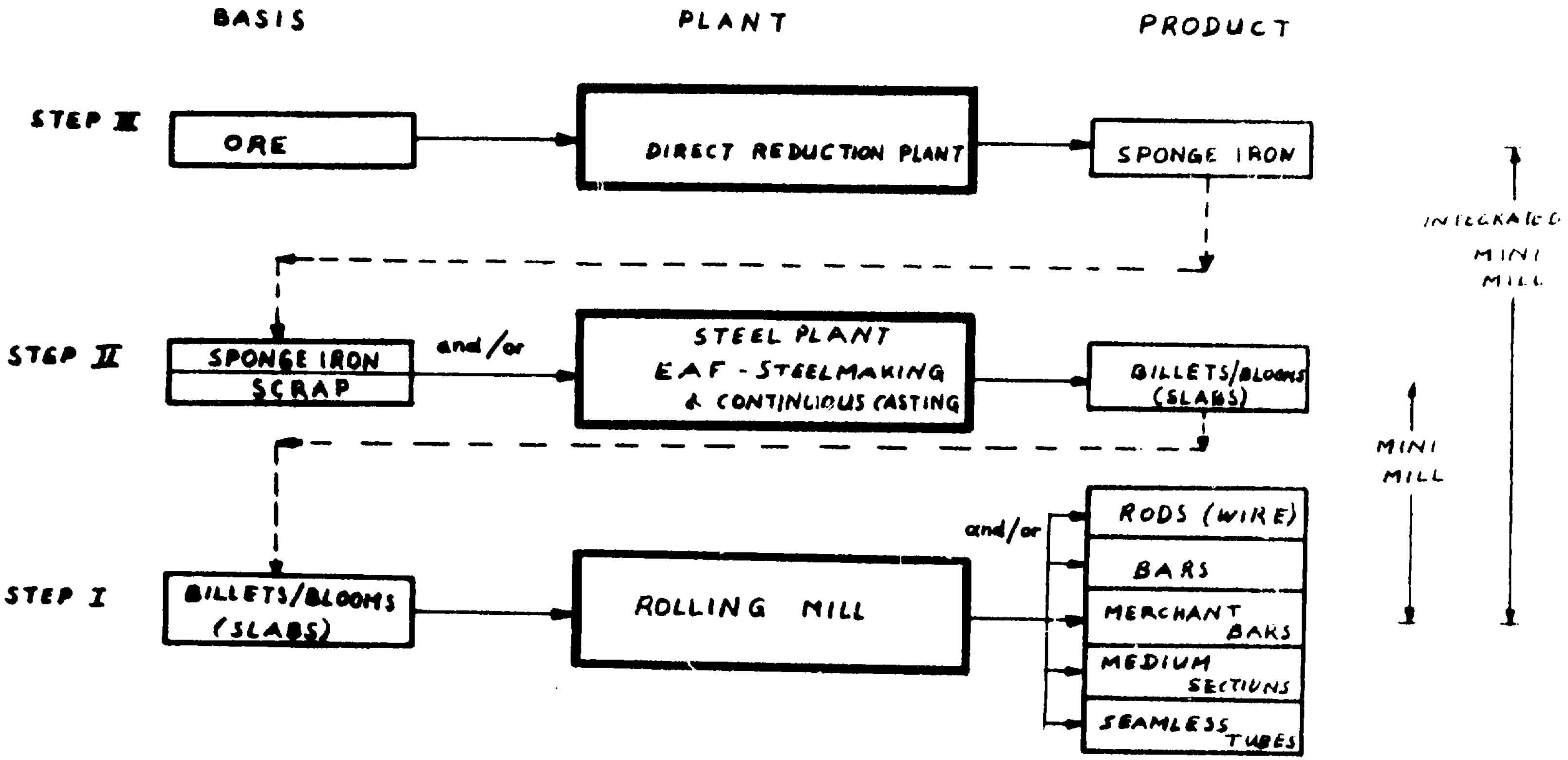
*) all Table 11a



STEP - BY - STEP ARRANGEMENT
OF MINI-MILLS OR INTEGRATED MINI-MILLS
Fig. 34 (Source: Based on references 17,34,40,41,44 & 45)

Table IIa
(Source: UNIDO)

Suggested iron and steel making processes

Sl. No.	Country	Suggested process route
1.	India	Market - very large; iron ore and reductant - available in plenty; hydro power potential good, steel development through large integrated steel plant; iron production route blast furnace/direct reduction route.
2.	Republic of Korea	---
3.	Iran	Market - very large; iron ore available; reductant natural gas plenty; hydro-power potential very good; possible iron production route direct reduction/BF with imported coking coal; steel development - normally through large integrated plant.
4.	Afghanistan	Market - very limited; reductant - not sufficient; hydro-power potential - good; production of hot metal/sponge iron not planned; steel through EAF on scrap/purchased sponge iron
5.	Bangladesh	Market - limited; reductant enough natural gas, hydro-power potential - exists, production of sponge iron planned; steel through EAF on sponge iron feed.
6.	Burma	Market - limited; iron ore - available; reductants - non-coking coal and forest reserves, hydro-power potential - very good; possible iron production route - small capacity blast furnace/direct reduction; steel through converter/EAF; integrated mini-steel plant
7.	Indonesia	Market - large; iron ore available; reductant natural gas plenty; non-coking coal available; possible iron-making route direct reduction by 1985 and BF by 2000 AD with enlarged market; steel through integrated mini steel plant at initial stage possible.
8.	Malaysia	Market - fairly large by 2000 AD; iron ore - available; reductants - natural gas plenty and forest reserve; hydro-power potential good; possible iron production route - direct reduction initially, blast furnace when market enlarges; steel through integrated mini steel plant to start with
9.	Nepal	Market - limited; no natural resources except small quantity iron ore; steel - through EAF on scrap/purchased sponge iron to start with; iron ore may be utilized later for hot metal production and steel through integrated mini steel plant.
10.	Pakistan	Market - fairly large by 2000 AD; iron ore - available; reductant - natural gas/non coking coal; iron making route - blast furnace/direct reduction; steel - through integrated plants based on hot metal/pre-reduced material; mini steel plant possible.
11.	Philippines	Market - large; iron ore - fairly large; reductant - non-coking coal/forest reserve; hydro power potential - very good; steel development - normally through large integrated steel plant, mini steel plant possible through DR-EAF route.
12.	Singapore	Market - fairly large; no natural resources; possibility of steel development through large integrated plants based on purchased raw materials - planned after 1985.
13.	Sri Lanka	Market - limited; natural resources - non-except small quantity iron ore; hydro power potential good; steel through EAF on scrap/purchased sponge iron.
14.	Thailand	Market - large; iron ore small quantity; reductant - non-coking coal; hydro power potential good; steel development possible through integrated mini steel plant or large capacity one on hot metal route, future possibility mini steel plants on direct reduction route.

Table - 11b

Particulars	Unit	Rerolling Mill	(scrap based) Mini Mill	(DRI route) integrated Mini Mill	Integrated Steel
i) Capacity	tonne/ year	50,000	250,000	500,000	3,000.000
ii) Site area	Hectares	2.5	16	35	330
iii) Engery (including electricity, solid liquid & gaseous fuels	GJ/day	400	4500	30,000	300,000
iv) Rated capacity of electrical supply	MVA	3	75	120	300
v) Water	m^3/day	100	2,000	5,600	65,000
vi) Oxygen	t/day	0.2	25	25	750
vii) Capital (for works only)	Million US $	10.0	70.0	300.0	3000.0

Source: Proceedings of SEAISI Conference held in Singapore in Sep.1980.

6.2 Ranges of sizes and products

Whilst in many mini-mills (or simple rolling mills) where the development remains restricted to the first or the second stage the output is in the region of around 50 000 to 200 000 tpy, the sizes above are increasing moe and more in the progress of full integration. Taking the production units of the DRI plants into account, these are in the size range of 250 000 to 700 000 tpy. On account of the jump in investment costs with the transition from single-strand to multistrand operation the specific investment costs are most favourable for production quantities that can be produced on a single-strand rolling mill.

In accordance with the production programme, i.e. percentage distribution of the types of product to be rolled, the qualities and sizes, these production limits can be defined as follows for the modern types of rolling mills to be considered:

Table 12 a

- wire rod mills	approx.	400 000 tpy
- bar and/or merchant bar mills	approx.	600 000 tpy
- conbination mills (wire rod- bars and/or merchant bars	approx.	500 000 tpy
- Medium section mills (with continuous fimishing trains)	approx.	600 000 tpy
- Tube mills (seamless tubes)	approx.	700 000 tpy

The most important new product area for mini-steel producers is the flat products (coils, sheets, plates). The Steckel mills have considerable potential for allowing mini-plants to get into the flat rolled products.

Mill products form mini-steelplants usually include rounds, rebars, wire rods for many industries (e.g. nails, screw, fencing material, mesh), small squares, angles, flats and channels.

Hence, the first build up stage of a mini-mill can also include the following finishing stages: cold rolling, drawing machines, welded mesh plant. These possible extensions of the mini-mill route are in accordance with the present process trends required by the market demands and quality improvements achieved.

Tab.12b. tabulates the general range of sizes produced on themills (listed in table 12 a) with the initial cross-sections that are necessary for economical rolling.

While the sizes for the various process routes are indicative of optimum sizes, it is possible to install substantially lower capacity units and operate them at reasonably economic levels if local conditions dictate this.

6 .3 Principle demands on rolling mills

- Lowest possible specific investment cost, taking under consideration the fact that the overall output level largely governs the general mill layout that is likely to be the most cost effective. The types of mill lqyout may approximately be broken cown as follows:
  cross-country mills - tonnages upto say 50 000 tpy
  semi-continuous mills - tonnages 50 000 - 200 000 tpy
  continuous mills - tonnages over 200 000 tpy

- Lowest possible specific opeating costs
- Low maintenance costs
- Low labour cost
- High qualified operating personnel
- Fast operatinal rediness of the rolling mill
- Amortization of capital cost over the shortest possible period
- High yield and good efficiency
- Using the advantage of secondary metallurgy rolling of high quality steel is possible
- Possibilities of a stage-wise expansion.

PRODUCT GROUP	INITIAL SECTION	FINISHED PRODUCT
ROD	100 - 150 mm □	5.5 - 16.0 (18.0) mm dia
BARS	100 - 130 mm □	8.0 - 40.0 mm dia
MERCHANT BARS	100 - 150 mm □	8.0 - 80.0 mm dia (squares & hexagons) 20x4 - 150x50 mm flats 20x20 - 90x90 mm angles (equal & unequal) 20-70 mm ⊥-shape 30x15 - 100 mm channels 80 - 100 mm beams
SEAMLESS TUBES	180 - 450 mm □	25 - 400 mm outer dia 2 - 85 mm wall thickness
MEDIUM SECTIONS	130 mm □ - 250x350 mm ▭	20 - 180 mm dia (squares & hexagons) 50x5 - 300x30 mm flats 50x50 - 200x200 mm angles (equal & unequal) 30 - 300 mm channels 80 - 400 mm beams

Table 12b: Examples of products and initial cross-sections of different rolling mills (STEP I)
(Source: Reference Nr. 34)

The stage-wise increse fo the production programmes include the following advantages:

- Lower cost in the first construction stage not only for the basic investment but also for the training of personnel in less industrially developed areas.
- A good trained personnel important for the next stage of expansion is thus already available
- Better adoption of the required additional personnel
- Better build-up of the regional sales (and possibly the export) of the manufactured products.

6.4 The rolling-mill continuous casting interface

The present metallurgical developments have been simulated by

- quality improvement and
- cost reduction

Although the practice of hot-charging a semi-finished shape into the reheating furnace of the finishing mills is not necessarily a productivity improvement attributable to continuous cast, it is, nevertheless receiving wide attention because of the potential fuel savings. By charging hot continuously cast product into the finishing mills, the sensible heat of the product is utilized with significant energy savings. The practice may avoid reheating altogether or require some intermediate reheating. However, it demands some close co-ordination between the caster and finishing area. It also demands excellent surface quality.

In Japan hot charging has become a standard practice, and over 40 % of the continuously cast semis are hot charged. Kobe Steel at Kobe and Kakogawa practice hot charging of 100 % of the blooms produced which are transferred directly to the reheat furnace by covered transport to an assigned site.
For long products, hot charging mainly relates to blooms which undergo intermediate roughing or are rolled directly into beams. In these cases, 100 % hot charging is achieved.

6.5 Heating of the steel for rolling

The design of reheating facilities depends primarily on form factors:

1) the maximum required heating rate
2) the quality or qualities of steel concerned
3) the cross-section of the steel to be heated
4) the type of fuel available (normally oil or gas)

Basically a reheating furnace is a refractory-lined box through which steel passes to raise its temperature evenly to a suitable rolling temperature. When reheating a furnace care must be taken for a correct balance between a low capital cost and an acceptable fuel cost.

Typical sizes range from 10 to 65 tonnes/hour. For heating billets the furnace could be of the walking beam type or the pusher type. The walking beam furnace has the advantages of providing better quality product, greater flexibility of operation and lower scale losses. On the other hand, pusher furnace is lower in capital cost, simpler to operate and easier to maintain. The refractories used in a typical reheat furnace are illustrated in Fig. 35.

6.6 Rolling mills for mini-steel plants

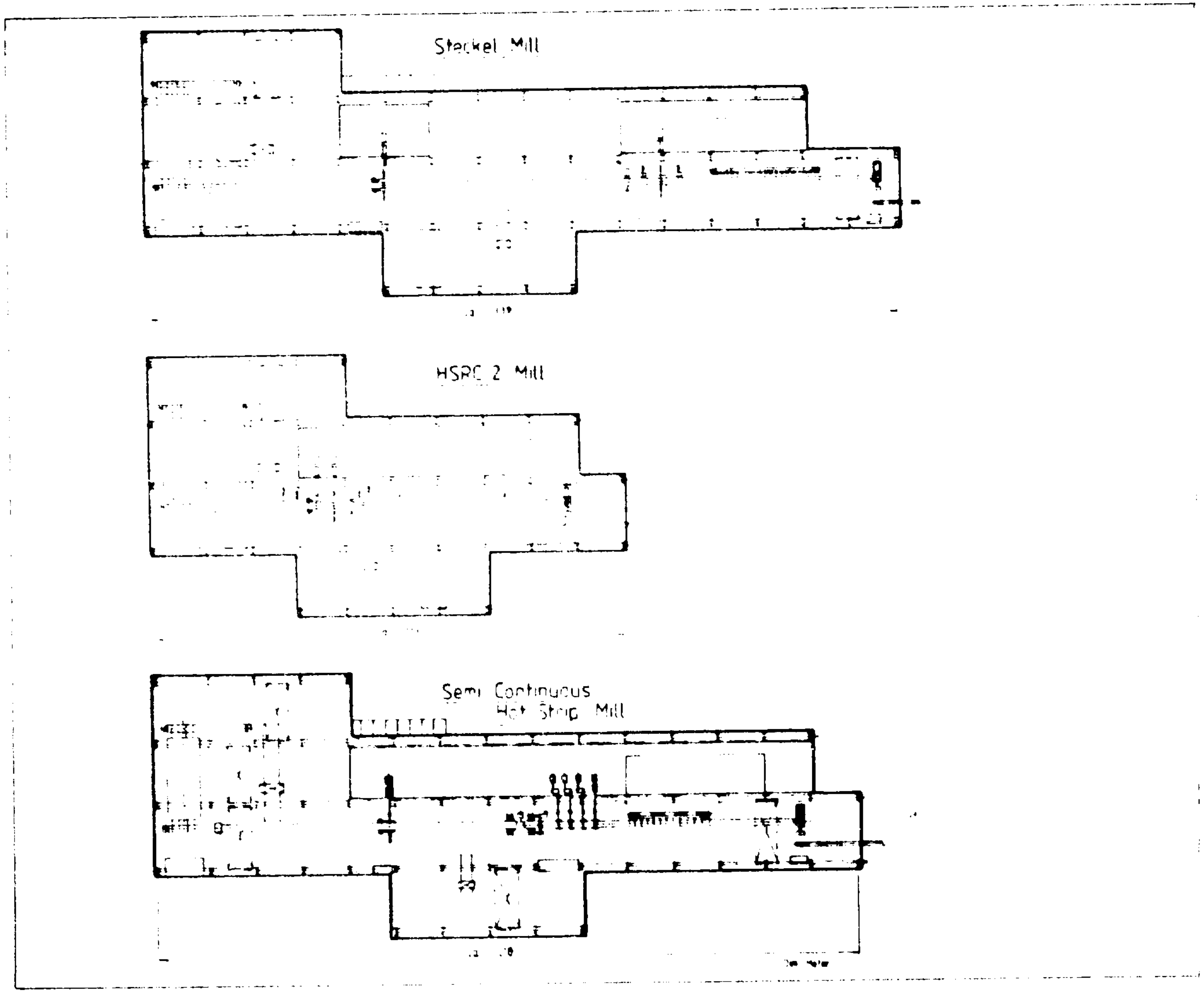
The Table (see next page) illustrates the main features introduced for improvement in euqipment and operation of rolling mill for bar and wire rod.

Development	Feature	Benefit
Billet conditioning	- Surface defect inspection using magnetic particle method and internal defect inspection using ultrasonic system	- Labour savings
	- Surface conditioning using high efficiency billet grinder or pinch rolls	- High efficiency
Reheating furnace	- Walking-beam furnace	- Less oxidation, greater flexibility homogenerly of temperature
	- Use of waste-gas jet for preheating optimization of heat patterns and extraction temp, adoption of waste gase oxygen content control, in-furance partition walls and heat insulation, introduction of hot charge rolling	- Energy saving
Rolling mill and its operation	- H-H type (horizotal stands only) - V-H type (alternative vertical and horizontal stands)	- Permit simultaneous Multistrand pass - High rolling speed no interstand twisting and less surfache defects
	- Using tiltable stands moveable stand - Cantilever stands (small diameter rolls)	- High speed rolling reduced capital cost and mill down time due to ease of maintenance, lower operating cost

cont./. page -118-

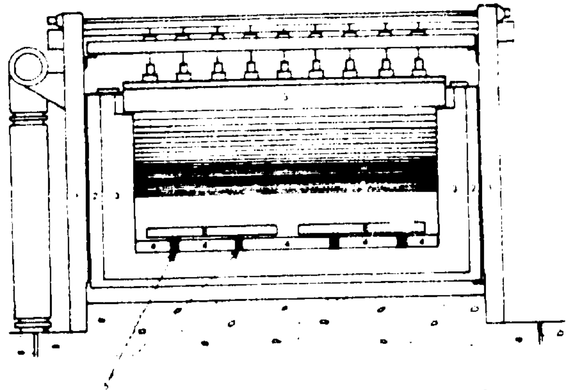
Development	Feature	Benefit
	- Block mills (compact cantilever stand)	- High rolling speed, exact dimension and good surface finishes.
	- Cartridge-type (housingless) stand	- High reduction ratio, low elastic deflection, easy removal and insertion of rolling stand
	- Improvement in rolls, pass design and guides, standardization of draft control, improvements in trouble shooting and other maintenance techniques	- Increase operation rate and sharp reduction in cobbles.
Controlled cooling and finishing	- Stelmor process (for high carbon steel)	- Eliminating the patenting operation
	- Retarded Stelmor process (for low carbon steel, scrap steel etc.)	
	- EDC (Easy Drawing Converyor) system	- Uniform structure throughout the coil
	- Slow Cool System (SCS) for medium-carbon and low alloy steels	- Omitting the softening annealing operation
	- Direct quenching (DQ) techniques	- For high strength steel wire rods
	- Tempcore process (for rebars)	- Surface hardening
	- Direct solution treatment (DST) for austenitic stainless steel	- Free from grain boundary carbon percipitation
	- Automation of terminal processing, automation sampling and inspection	- Labour savings.
	- Tempcore process (weldable high quality rebars)	- High yield strength

(Source: Ref.Nr.47)



Comparison of the layout of a Steckel, HSRC and semi-continuous hot strip mill for a barrel length of 66" and a specific coil weight of 15 kg/mm

Fig. 36
(Source: Ref. Nr. 22)



Section through billet reheat furnace 1 Steel structure 2 supporting brickwork and tiles 3 insulation brickwork 4 high temperature brickwork 5 fusion cast alumina skids 6 billets

Fig. 35
(Source: Ref. Nr. 51)

With regard to rolling technology the following additional trends can also be recognized:

- Slit rolling: two or four bars are produced from one billet by rolling and slitting with special grooves in the finishing line. Low temperature loss, high production rate, low finishing rolling speed, low investment costs.

- Grooveless rolling for billet: Use of flat rolls, as in the case of plate rolling, in a rolling sequence except the final pass. Significant redcutions in roll changing, set-up and dressing time. (about 5 % increase in mill productivity 6 % savings in energy, higher yield).

- High reduction mills like kocks swing forge, triple-mill, cycloidal mill, planetary rolling mill, Schloemann-Siemag mill, GFM forging-rolling system. They are particularly suitable to demands for flexibility in producing small and varied quantities of round bars. Relatively slow rolling speed.

- Three roll planetary mill (PSW = Planeten-Schraeg Walzwerk) by SMS in FRG. Here the cross-sectioned reduction is affected by three conical mills, arranged at 120^{o} to one another and rotated around the stock so that a tapered shaping zone is formed between their surfaces. The wall thicknesses of the blanks can be varied by roll adjustment and the use of different mandrel diameters.

Several attempts have been made to design a mini-strip mill such as Sendzimir planetary mill and hot strip reversing compact (HSRC) mill developed by VOEST-ALPINE. Both represent small flat products plant with economic advantage. See Fig. 36. Furthermore, economical method of slitting hot rolled strip into two or three narrow ones has been developed and this would reduce the capital and manifacturing costs for welded pipes, tubes, structurel shape etc.

7. Computerized production process

Three levels of computer control are necssary for the control of steel plant and rolling mill as an integrated unit, they are (Fig. 37 a)

- production planning
- production control
- process control

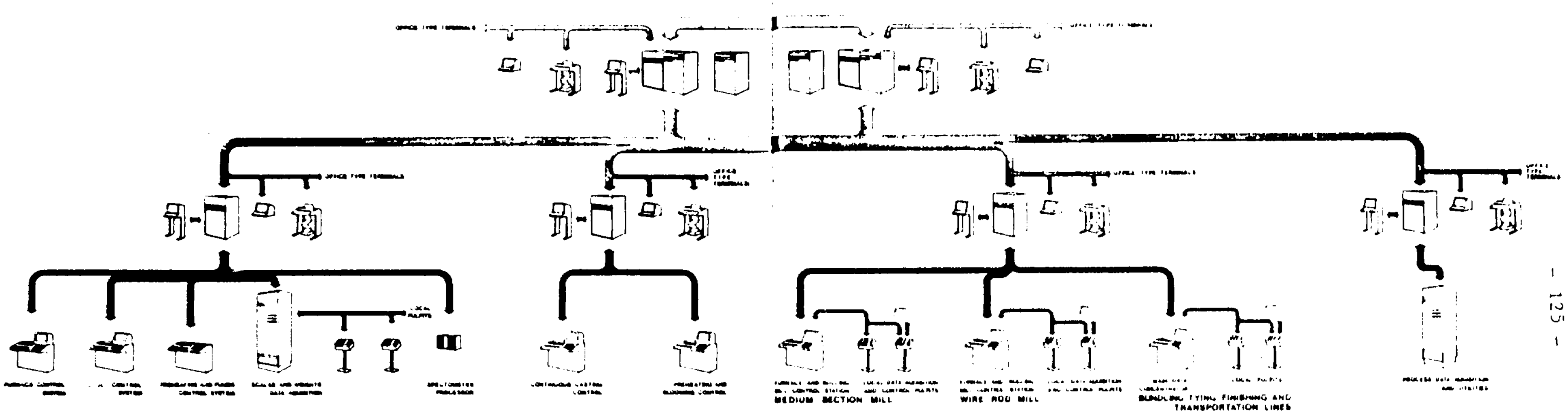
Data logging and reporting, including all steps, are important parts of such an integrated system. As far as automation is concerned such a target is supported by using process control characterized by the following features:

- optimum process control and evaluation
- high degree of availability
- easy maintenance
- simple man/machine communication

The improvement of electronic systems together with the reduction of their cost and their increased reliability, even in the most unfavourable environment, make it possible to create extremely sophisticated systems with relatively low and quickly recoverable investment costs, due to the direct or indirect economic advantages of automation. Such systems are able to fulfill one or more of the following functions

- co-ordination of the activities for casting preparation
- management and co-ordination of activities in the scrap yard
- operative control of castings (melting and refining)
- programming of melting energy relative to weight and of charging materials
- control of the "melting stage" and temperature gradient on the wall
- best possible use of electric power in relation to the power supply contract

COMPUTERIZED PRODUCTION PROCESS



STEEL MELTSHOP

CONTINUOUS CASTING

ROLLING MILLS

ENERGY MANAGEMENT

(Source:References 40, 41,44 & 45)

- control of burners
- supervision of water cooled panels
- control of analysis results and calculation of additive and ferroalloys
- recording of significant events and operative times
- operation reports per casting, shift, day, etc.
- interface with higher operative systems (supervision or management)

Advantages of such automation systems:

- The specific energy consumption is reduced by 30-35 k t/hr
- The specific consumption of raw materials and alloys is reduced by 5 %
- The melting time is reduced by ca. 5 %
- The quality of the end products is improved.

7.1 EAF - Computerization

Process control computers are critically important in shortening tap-to-tap times.
Adding computerized process control omptimizes furnace power usage in melting operations. It also facilitates automatic tap charging and the monitoring of water-cooled furnace elements.
Depending on the level of sophistication required, the control system may include thermal and metallurgical models (see Fig. 37 b).

7.2 Automation of continuous casters

Generally the continuous casting process is very suitable to automation so that automation devices are increasingly gaining importance. The major objective of automation for continuous casters is the improvement of economy. This is achieved by improved utilization of facilities and by an increase of productivity and product quality (Fig. 37 c).

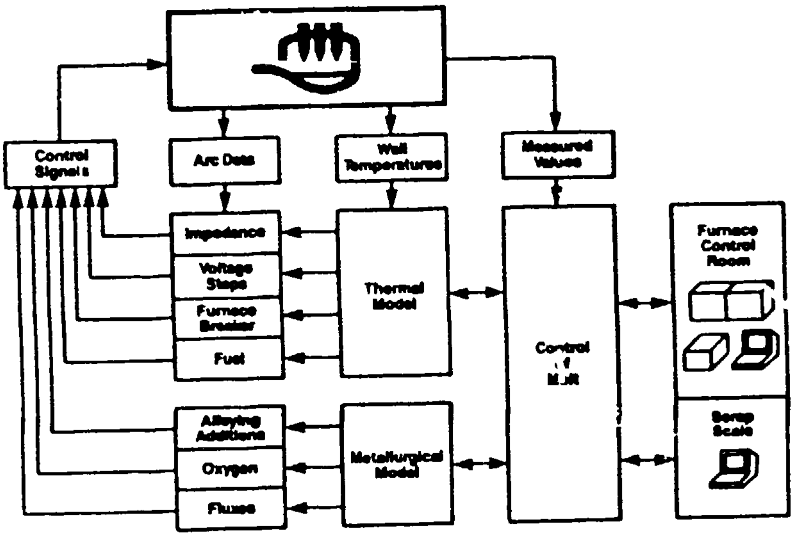


Fig.37b: Schematic of process control system
(Source: References 1 - 16, 40,41,45)

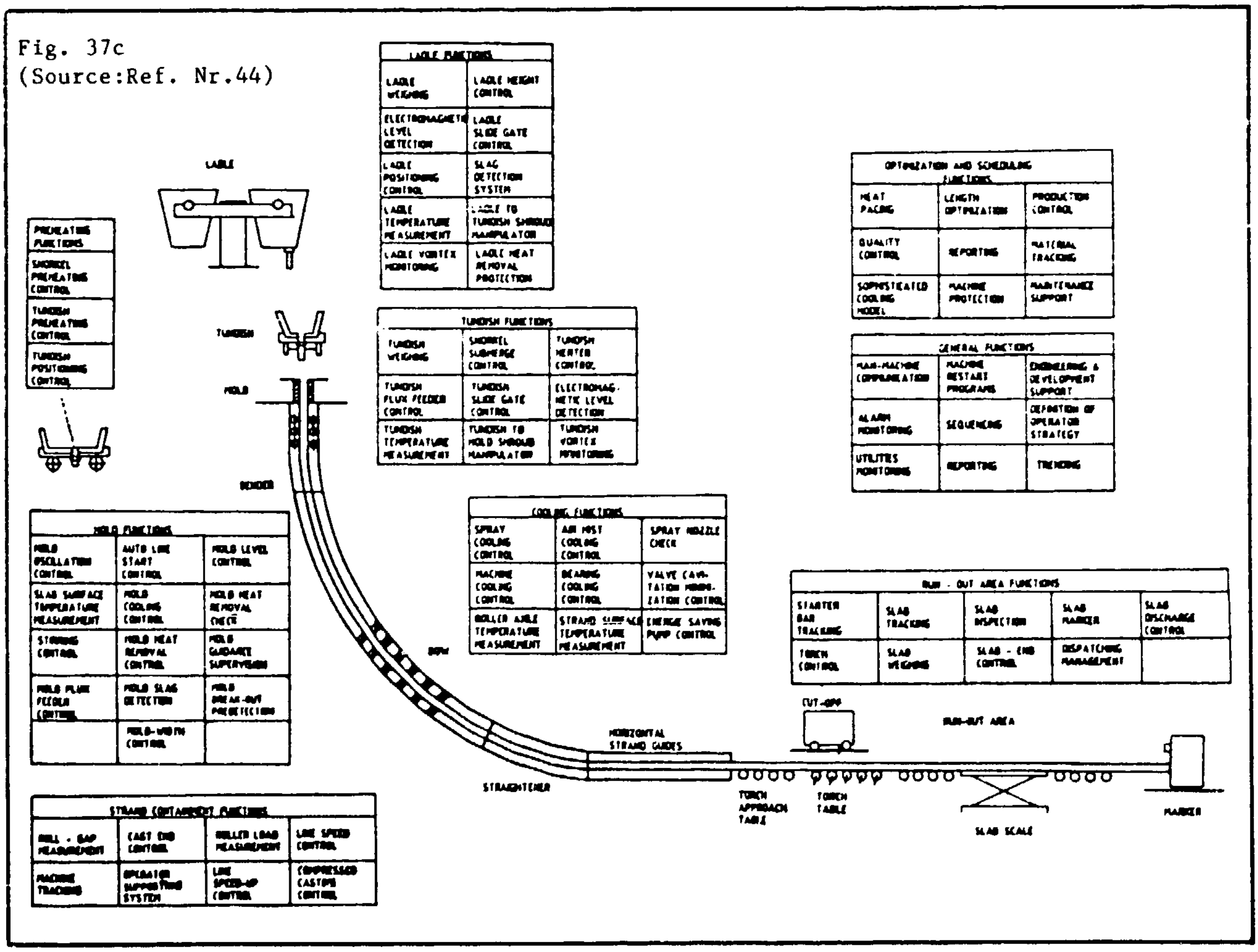


Fig. 37c
(Source:Ref. Nr.44)

Automation functions on a continuous caster

Practically all steps from the steel flow out of the ladle to the marking of the cut product can be performed automatically. In addition automatic machine inspection and computerized maintenance are available.

7.3. Automation in rolling mills

Controlled rolling techniques which eliminate additions of expensive alloying elements and heat treatment in the subsequent process have been developed to provide steels with such customer requirements as higher formability, higher toughness, higher weldability, and higher quality.

8. Plant location

The important locational factors to be considered are the availability of adequate area of suitable land, proximity to existing transport network, sources of prower and water (during consturction and operation time) nearness to the developed areas of the country, which also normally are the major market centres, and availability of contruction materials. Further, the shape and technology of the land should not impose constraints on the development of the most desirable layout features for the complex as a whole. The topography should be as flat as possible to reduce site development costs, but should drain well. The sub-soil conditions should be good enough to bear the loads of equipment.

A coastal location of the plant involves advantages especially in conjuction with the transport of the raw materials (or energy) as well as the finished goods. In case of making the selection between a sales-oriented location and a raw material optimized location the question of cost degression by larger transport valumes of the input materials would mean an advantage to the sales orientated location.

The main criteria for the proper plant location can be summerized as follows:

Raw mnaterial assembly cost, product distribution cost, availability of land availability of electric power, availability of water, port, road transport facilities, availability of housing and social amenities.

9. Energy Requirements based on two Reference Plants

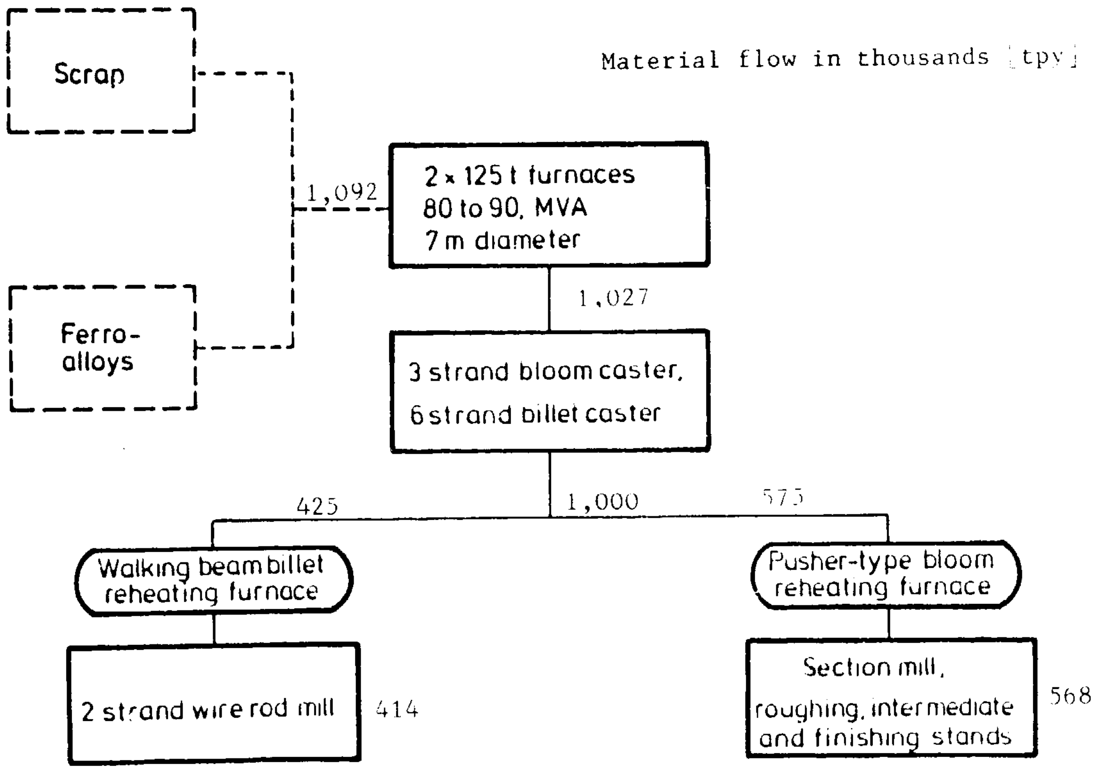
The following survey is based on a study worked out by Krupp AG (FRG) and presented during a IISI - Seminar on Steel and Energy held in Brussels (Belgium) in the year 1983.

Basic assumptions: The two reference plants incorporate proven, energy efficient technologies and operating practices which should be considered economically viable in the majority of steelmaking countries.

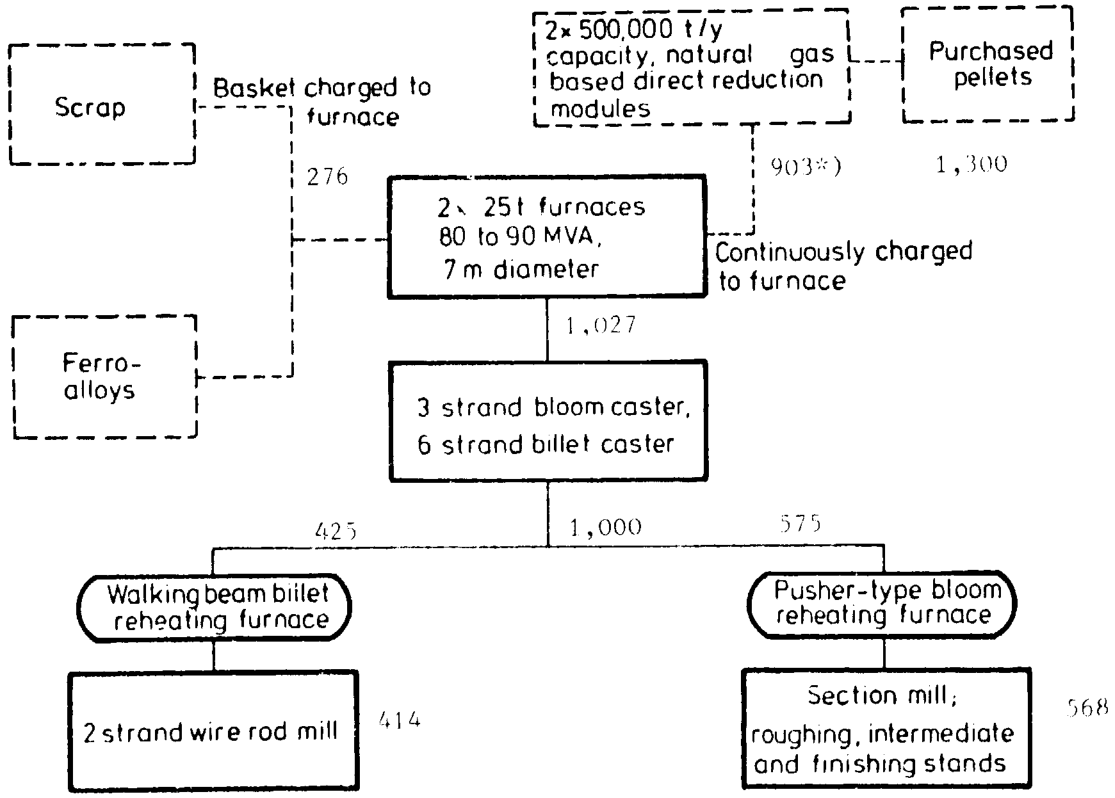
The variations of the reference plants were chosen as follows:

	Reference Plan 1	Reference Plant 2
Production Capacity (tpy)	1 million	1 million
Type	Mini-mill: all scrap EAF ↓ Cont. Casting machine ↓ Rolling Mill	Integrated mini-mill: DRI plant ↓ 75% EAF ← 25 % (Scrap) ↓ Continuous Casting Machine ↓ Rolling Mill

Figures 38 a and b show the equipment configuration and material flow. The respective energy consumptions are listed in the Tables 13 a and b The hot cooling system is depicted on Figure 38 c.



Reference Plant 1
Fig. 38a (Source: IISI)



Reference Plant 2
Fig. 38b (Source: IISI)

*) 91,7 % Fe

Energy balance for Reference Plant 1

Plant Product: Annual production (t/year)		CONSUMED ENERGY						
		Added carbon	Natural gas	Electric power	Oxygen	Electrode	Total	Cumulative total
		8,078 Kcal/Kg	9,000 Kcal/Nm^3	2,300 Kcal/KWh	1,610 Kcal/Nm^3	8,006 Kcal/Kg		
Electric arc furnace	Unit consumption	8	3.2	414*	25	3.4**		
Liquid steel:	Mcal/tp	65	29	952	40	27	1,113	
1,027,000	Mcal/tcs	67	30	978	41	28	1,144	1,144
Continuous casting		0	1.8	25	5	0		
Bloom, billet:			16	58	8		82	
1,000,000			16	58	8		82	1,226
Section mill		0	34.5	117	0	0		
Sections:			311	270			581	
568,000			177	153			330	1,556
Wire rod mill		0	25	130	0	0		
Wire rod:			221	299			520	
414,000			91	124			215	1,771
Others							50	1,821
TOTAL	Mcal/tcs							1,821 *

* Electric power saving (a) through scrap preheating: 40 KWh/tls - 92 Mcal/tls
(b) through hot steam cooling: 46 KWh/tls - 106 Mcal/tls.

** Reduction in electrode consumption of 0.6 Kg/tls by scrap preheating.

*) consumed energy before scrap preheating
& hot steam cooling: 2,028 Mcal/tcs

Table 13a (Source:IISI)

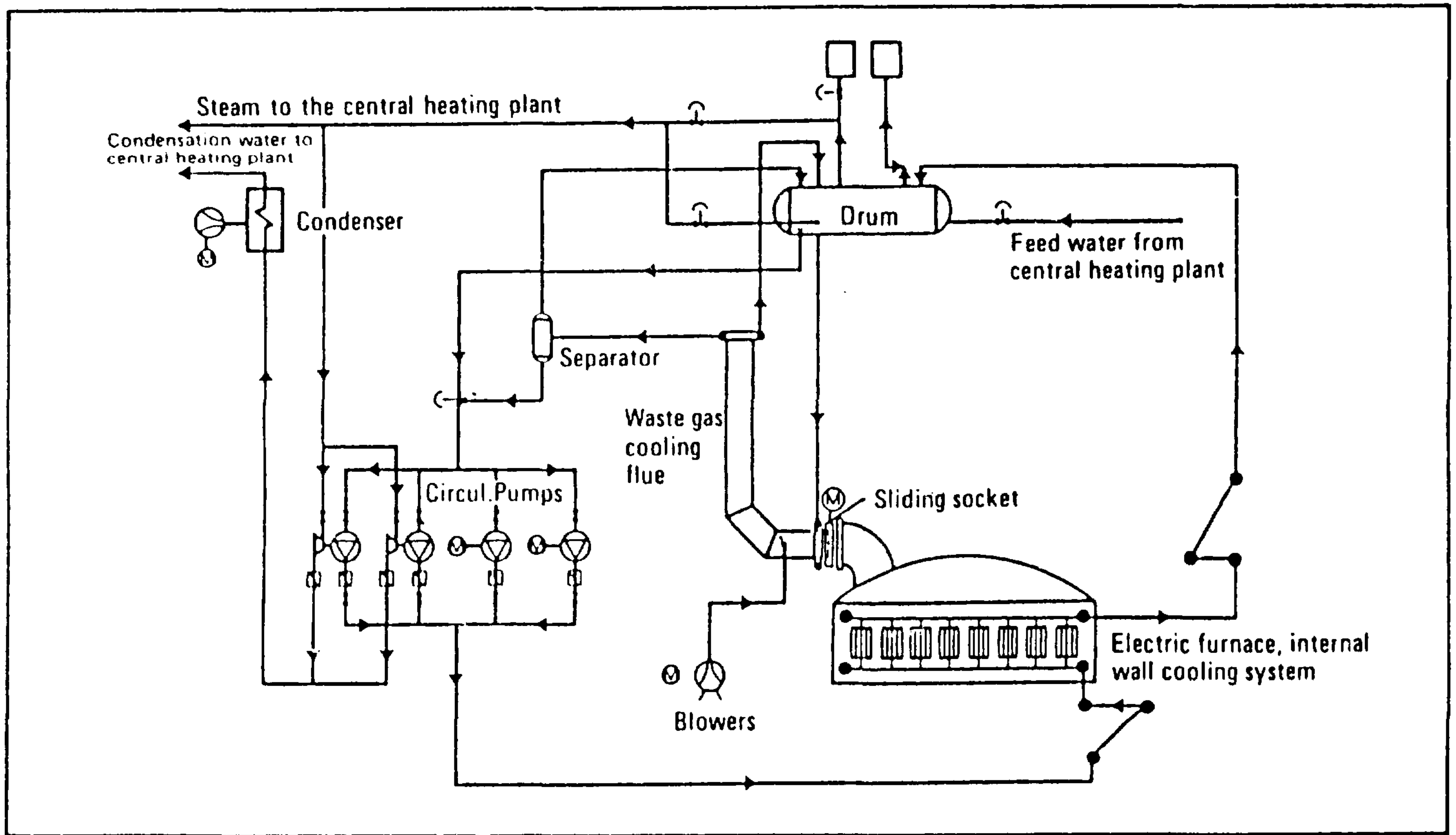
Energy balance for Reference Plant 2

Plant Product: Annual production (t/year)		CONSUMED ENERGY							
		Added carbon	Natural gas	Electric power	Oxygen	Electrode	Energy required to produce pellet	Total	Cumulative total
		8,078 Kcal/Kg	9,000 Kcal/Nm^3	2,300 Kcal/KWh	1,610 Kcal/Nm^3	8,006 Kcal/Kg	300 Kcal/Kg pellet		
Direct reduction plant	Unit consumption	0	272	100	0	0			
Sponge iron:	Mcal/tp		2,446	230			432	3,108	
903,000	Mcal/tcs		2,209	208			390	2,807	2,807
Electric arc furnace		1	3.2	504*	25	4	0		
Liquid steel:		8	29	1,159	40	32		1,268	
		8	30	1,190	41	33		1,302	4,109
Continuous casting		0	1.8	25	5	0	0		
Bloom, billet:			16	58	8			82	
1,000,000			16	58	8			82	4,191
Section mill		0	34.5	117	0	0	0		
Sections:			311	270				581	
568,600			177	153				310	4,521
Wire rod mill		0	25	130	0	0	0		
Wire rod:			221	299				520	
414,000			91	124				215	4,736
Others								50	4,786
TOTAL	Mcal/tcs								4,786 *)

* Electric power saving through hot steam cooling: 46 KWh/tls - 106 Mcal/tls

*) consumed energy before hot steam cooling: 4,892 Mcal/tcs

Table 13b (Source:IISI)



KRUPP

Hot cooling system for UHP furnace
at Krupp Stahl, Work Bochum

Fig. 38c

Source: IISI

1.1. Resources - General view

The geographical distribution of the major natural resources essential to steel production are important determinants in the global iron and steel trade situation.

Four of these resources relate to energy - total coal, natural gas, oil, and electric energy - and the others relate to raw materials or are combined fuel and reductants - iron ore, coking coal, charcoal, and manganese ore - as well as fluxes.

Identified reserves of the major resources are shown in Figure 1; Figure 2a identifies those developing countries where the availability of resources may be designated favourable (five resources present) less favourable (three resources), or least favourable (less than three resources).

Source UNIDO/ICIS.25.

1.2. Iron-Ore

1.2.1 Deposits-Minerals

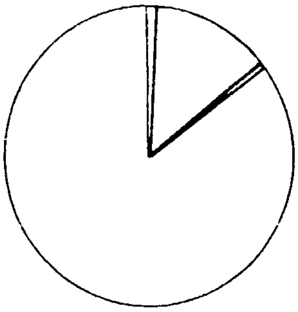
Global reserves of iron-ore are estimated at approximately 700 billion tons, with positively identified deposits totalling 250 billion tons.

A large portion of common ores and rockforming minerals contain appreciable amounts of iron, but there are only six minerals containing sufficient amounts of iron and available in sufficient quantities to serve as potential sources from which iron may be economically obtained. The six iron bearing minerals and the iron content of each pure mineral are given below:

Iron-bearing material	Iron content (per cent of Fe)
Hematite	69.9
Magnetite	72.4
Goethite	62.9
Chamosite	42
Siderite	48.2
Pyrite	46.6

Figure 1. Distribution of resources of raw material for the iron and steel industry

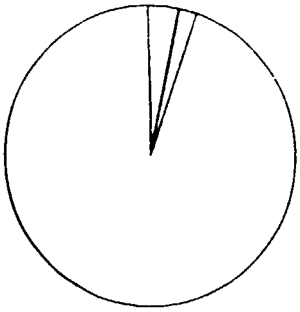
TOTAL COAL



Developing Countries	14.6 %
Africa	0.7 %
Asia	13.5 %
Latin America	0.4 %

World total: 8,100 billion tons

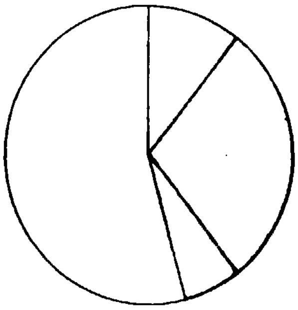
COKING COAL



Developing Countries	5.2 %
Africa	0.0 %
Asia	4.6 %
Latin America	0.6 %

World total: 430 billion tons

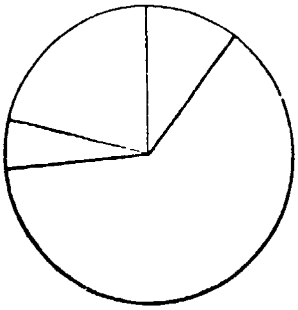
NATURAL GAS



Developing Countries	45.8 %
Africa	10.8 %
Asia	31.3 %
Latin America	3.7 %

World total: 63,000 billion nm³

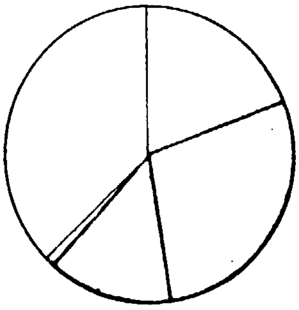
OIL



Developing Countries	79.0 %
Africa	10.3 %
Asia	63.3 %
Latin America	5.4 %

World total: 74 billion tons

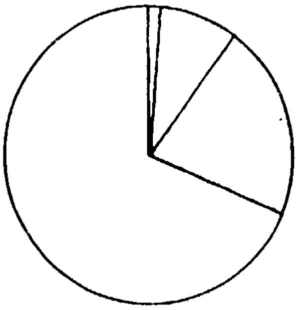
POT. HYD. RES.



Developing Countries	62.7 %
Africa	19.1 %
Asia	28.3 %
Latin America	14.5 %
Oceania	0.8 %

World total: 2,261 GW

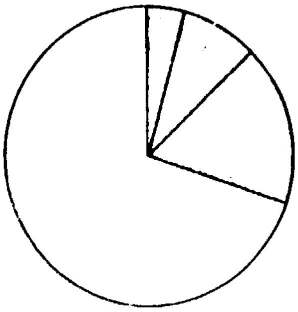
GROWING STOCKS IN FORESTS



Developing Countries	30.2%
Africa	1.2%
Asia	8.2%
Latin America	20.8%

World total: 400 billion m³

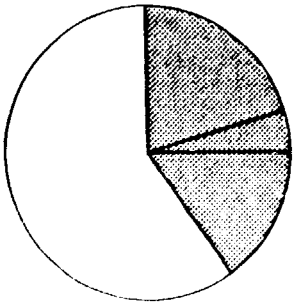
IRON ORE



Developing Countries	30.4 %
Africa	4.2 %
Asia	8.6 %
Latin America	17.6 %

World total: 689 billion tons

MANGANESE ORE



Developing Countries	40.2 %
Africa	20.4 %
Asia	4.7 %
Latin America	15.1 %

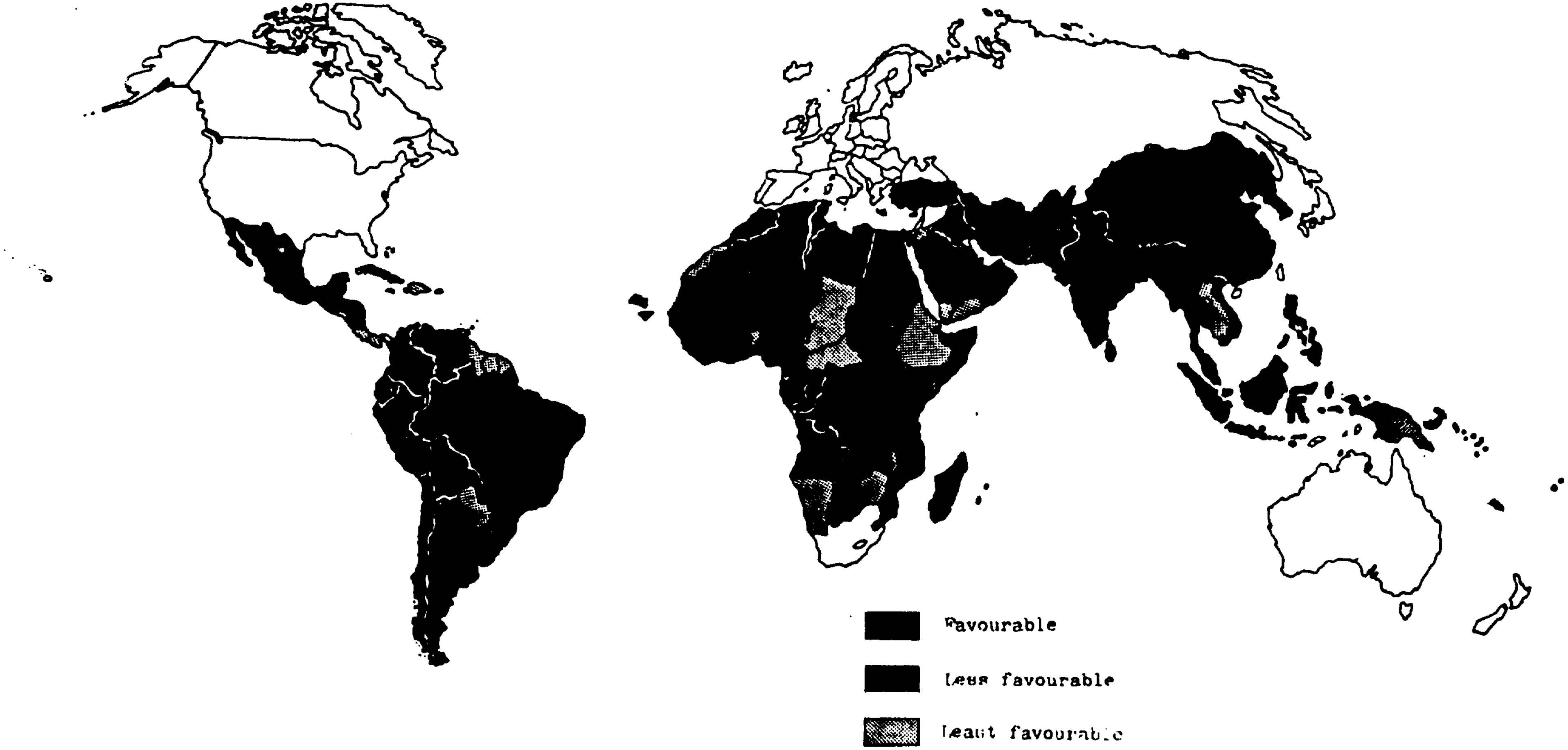
World total: 3 billion tons

Percentage of world resources: Developing countries
Developed countries ☐

(Source: Ref. Nr. 4)

Figure 20: Assessment of developing countries' natural resources for establishment of an iron and steel industry

(Source: Ref. Nr. 4)



The peculiar characteristics of each deposit are basically result of the mineralogical and geological environment and the complex concentration process of iron in ore deposits.
A world distribution of iron ore reserves according to iron content is given in Table 1.
Fig. 2b illustrates world's principal sources of iron ores.

1.2.2 Beneficiation - Agglomeration

Different beneficiation techniques are employed to suit a particular ore, depending upon its mineralogical and petrological characteristics. The techniques include crushing, grading sizing, washing and wet screening, gravity treatment, magnetic separation, froth flotation, reduction rosting, thickening and drying. The overall beneficiation flow sheet may include the use of one or more of the different methods, but its finalizing is primarily governed by the mineralogical characteristics of the ore under study.

Ores that contain 60-65 % iron are generally considered of good quality. The presence of the total gangue minerals consisting of oxides of silicon, aluminium and titanium up to a level of 8 % is acceptable. The phosphorus and sulphur contents of the ore should be as low as possible.

Pelletizing: This agglomeration technique is resorted to where the ore particles are in very fine form either as a beneficiated product or a naturally-occuring minerals like blue-dust. The process consists of two principal steps, normaly balling and induration. A development in recent years has been the introduction of cold induration processes (cold-bonded pellets). Pellets can be made in drum, disc or cone type of pelletizer. World pellet production in various regions using different induration systems is given in Table 2.
The three most important pelletizing systems are the travelling-grate, the grate kiln, and the shaft furnace.
The charging pattern of iron-ore requirements is shown in Table 3.
Figure 3a shows the growth pattern of consumption of lumpy ore, sinter and pellets in different regions of the world, and Fig. 3b depicts the individual products of two agglomeration processes, pelletizing and sintering.

Table 1

WORLD DISTRIBUTION OF IRON-ORE MINERAL RESOURCES

(C: chamosite; F: hematite; G: goethite I: ilmenite, M: magnetite; P: pyrite; S: siderite)

Country or area	F	M	G	S	FM	FG	CS	FS	MP	MS	FMP	MSP	MG	SP	FMG	FMS	Unclassified	Others
	Total resources and potential reserves[a] (millions of tons)																	
Africa	17 056 (2 405)	2 718 (373)	1 297 (262)	6 (6)	4 254 (603)	1 358 (127)	92 (20)	168 (168)		55 (15)	41 (41)		46 (46)		1 419 (1 250)	1 427 (432)	42 (42)	P 1 (-), FP 1 (1), FMI 279 (28), FMC 1 000 (1 000)
Asia (including India)	19 427 (8 310)	7 751 (2 673)	3 206 (655)	41	12 824 (4 206)	566 (317)	2 545 (508)	129 (29)					4 (2)		275 (108)		24 758 (88)	GSC (450)
India	15 516 (6 982)	2 332 (620)			8 547 (419)	52 (52)	2 540 (508)								53 (53)		12 (12)	
Australia and New Zealand	(1 630)	(660)	(5 951)		(35)	(7 953)		(322)	(144)		(2)				(120)			
Canada and the West Indies	12 235 (2 025)	32 411 (8 164)	(1)		55 875 (20 898)	8 370 (4 320)		600	20 (10)	1 000		1 675 (40)		735 (420)		6 020 (20)	1 500	P (8), FFI 350 (350), FMI 320, FSC 2 000, FMC 25, GSC 1 500
Europe (including Sweden)	777 (457)	3 122 (3 103)	1 264 (794)	1 900 (1 680)	2 498 (1 778)	839 (139)	9 460 (4 840)	775 (675)	50 (10)	50 (50)					440 (100)	2 240 (2 120)	1 116 (10)	MI 50 (50), GC 5 148 (5 048), SC 10 (2), FSC 50 (30), MSC 680 (250), GSC 1 853 (1 048), FGSC 1 740 (1 640), MGS 38 (38)
Sweden		2 895			475													
South America	84 869 (32 262)	788 (251)	1 948 (301)		2 610 (411)	2 304 (929)							8					
United States of America	3 561 (396)	12 969 (789)	907 (745)		65 555 (3 227)	6 139 (2 267)	343 (343)	50					313 (113)		1 742 (272)	10 254 (4)	3 (3)	FGS 30 (30), FMGS 4 426 (28), others 2 (2)
USSR	29 025 (20 875)	38 325 (21 648)	106 363 (13 894)	1 258 (1 195)	36 255 (29 421)		522 (447)	9 316 (9 316)								300	82 937 (13 687)	

[a] Figures without parentheses indicate total resources and those with parentheses show potential reserves.

Source: Reference Nr.5

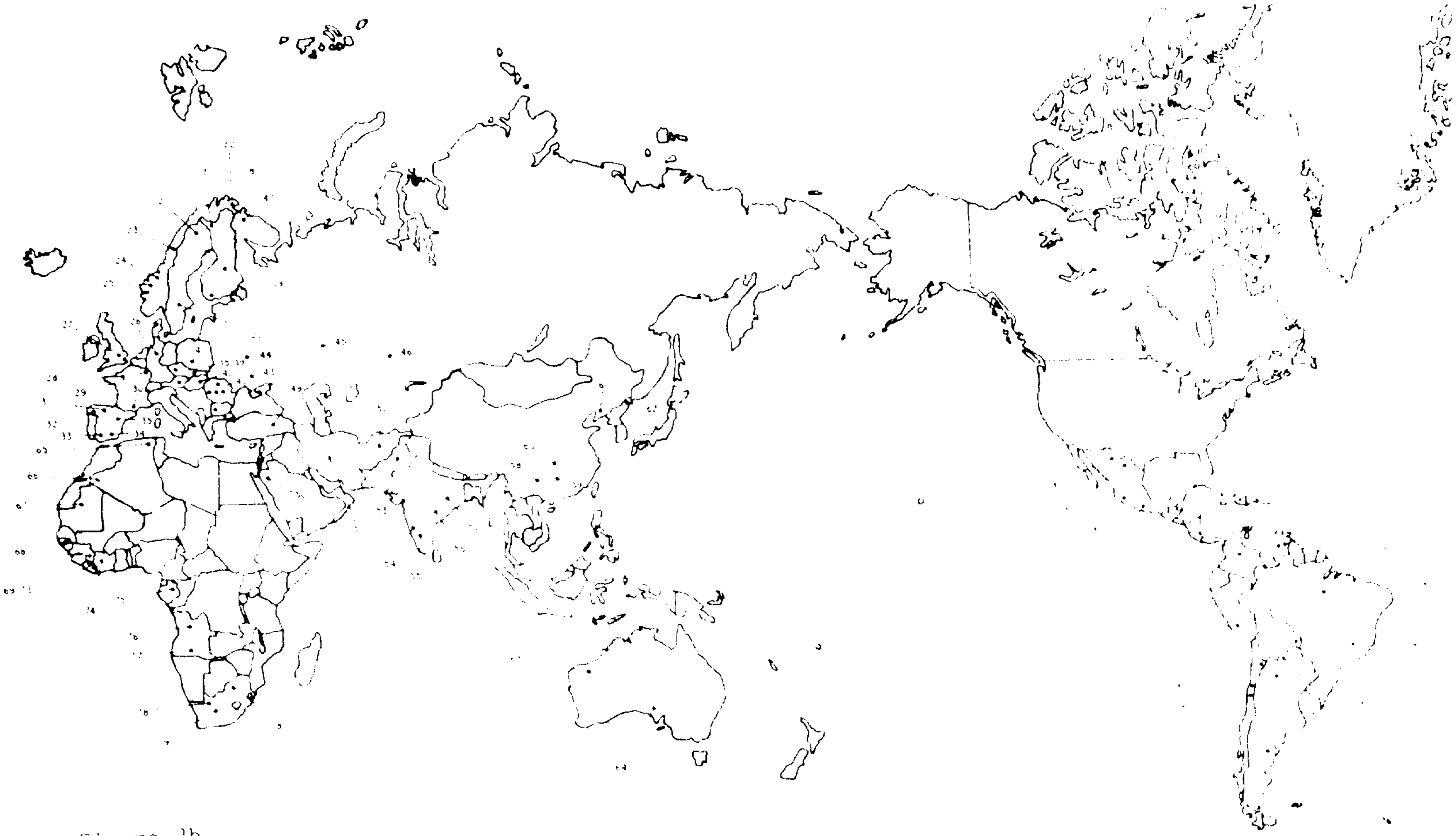


Figure 2b

Outline map showing locations of world's principal sources of iron ores.

(see next page for site identification)

Location Names of Sites Indicated on Preceding Page.

South America
1. Cerro Bolivar, Venezuela
2 El Pao, Venezuela
3 Carajas, Brazil
4 Quadrilatero Ferrifero, Brazil
5 Mutun, Bolivia
6 Zapla, Argentina
7 Sierra Grande, Argentina
8 El Romeral, Chile
9 Algarrobo, Chile
10 El Laco, Chile
11 Marcona, Peru
12 Paz de Rio, Colombia

Central America
13 Las Truchas, Mexico
14 Pena Colorado, Mexico
15 Hercules, Mexico
16 La Perla, Mexico

Western Europe
17 Jussaro, Finland
18 Otanmaki, Finland
19 Rautuvaara, Finland
20 Grangesberg, Central Sweden
21. Kiruna, etc., Northern Sweden
22 Svdvaranger, Norway
23 Rana, Norway
24 Fosdal, Norway
25 Rodsand, Norway
26 Salzgitter, Gifhorn, Peine-Ilsede, Federal German Republic
27 Frodingham-Northhampton-Lincoln-Wales, United Kingdom
28 Lorraine, France
29 Normandy, France
30 Pyrenees, France
31 Santander and Viscaya, Spain
32 Leon, Spain
33 Huelva-Sevilla, Spain
34 Granada-Almeria, Spain
35 Teruel, Spain
36 Erzberg, Austria

Eastern Europe
37. Kremikowtzi, etc., Bulgaria
38 Barrandienne, Czechoslovakia
39 Spiss Hemer, Czechoslovakia
40 Rudabanya, Hungary
41 Czestochowa Klebuck, Poland
42 Romania (see text)
43 Ukraine, USSR

Eastern Europe (Continued)
44 Kursk, USSR
45 Urals, USSR
46 Kazakhstan, USSR
47 Kulo, USSR
48 Vares, Yugoslavia

Middle East and Asia
49 Divrigi, Turkey
50 Wadi Sawawin, Saudi Arabia
51. Choghart, Iran
52 Hajigarh Pass, Afghanistan
53. Chichali, Pakistan
54 Goa, India
55 Kudremukh, India
56. Mahya-Pradesh, India
57. Bihar-Orissa, India
58 Chichiang, Peoples Republic of China
59 Tayeh, Peoples Republic of China
60 Ninghsiang, Peoples Republic of China
61 Anshan, Peoples Republic of China
62 Musan, North Korea

Oceania
63 Hamersley Ranges, Australia
64 Middleback Range, Australia

Africa
65 Ouenza, Algeria
66 Gara Djebilet, Algeria
67 Kedia d' Idjil, Mauritania
68 Nimba, Guinea
69 Wologisi, Liberia
70 Mano River, Liberia
71 Bie Mountain, Liberia
72 Bong Range, Liberia
73 Nimba (Lamco), Liberia
74 Mont Klahoyo, Ivory Coast
75 Mekambo, Gabon
76 Cassala, Angola
77 Cassinga, Angola
78 Sishen, South Africa
79 Beeshoek, South Africa
80. Thabazimbi, South Africa
81 Bahariya, Egypt

Philippines
82 Santa Ines
83 Mindanao

Source: US-Steel, 10th edition

Table 2

WORLD PELLET PRODUCTION IN 1975

Induration system	*Production level (millions of tons)*						
	Africa	*Australia and New Zealand*	*Europe*		*Latin America*	*Northern America*	*Total*
			Eastern	*Western*			
Shaft furnace	0.85	3.00	–	1.25	1.50	17.30	23.90
Travelling grate	2.00	6.70	21.10	7.43	10.60	37.65	85.48
Grate kiln	2.00	9.85	-	7.50	–	42.25	61.60
Lepol furnace	-	0.30	–	0.45		-	0.75
Circular grate	–	–	–		0.75	-	0.75
Grancold process	–	–	–	1.60	–	–	1.60
Total	4.85	19.85	21.10	18.23	12.85	97.20	174.08

Source: United Nations Economic and Social Council, Economic Commission for Europe, "Structural changes in the iron and steel industry" (STEEL/GE.3/R.3/Add.1), p. 9.

Table 3

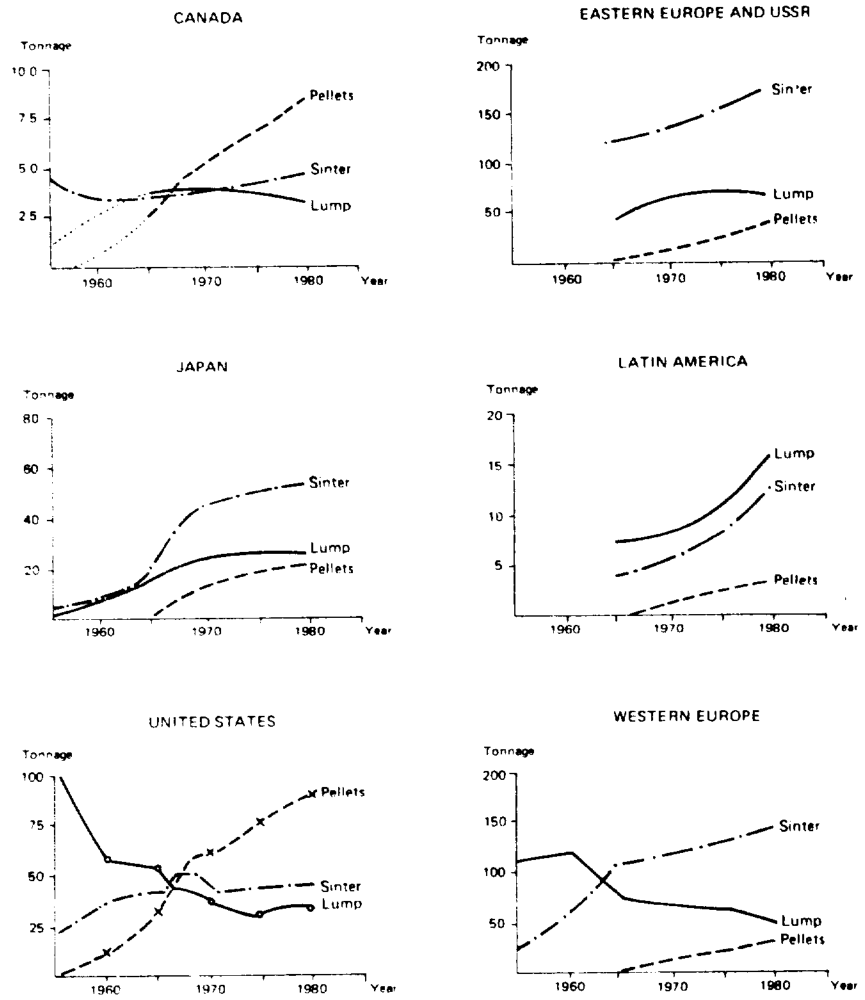
CHANGING PATTERN OF IRON-ORE REQUIREMENTS

Type of feed	*Iron-ore requirements (percentage of total)*			
	1965	*1970*	*1980*	*1985*
Lumpy ore	39.4	33.4	22.0	20.0
Sinter feed	53.0	50.3	48.0	48.0
Pellet	7.6	16.3	30.0	32.0
Total	100.0	100.0	100.0	100.0

(Source: Reference Nr.5)

Projection of iron-ore consumption by physical form

(Millions of tons)



Source: Jack R. Miller, "On-site processing of iron ore in developing countries through the stage of prereduced agglomeration" (ID/WG.146/67), p. 17.

Figure 3a

Figure 3b

Appendix - 2

1. <u>Scrap</u> is solid and utilizable old and waste material having an iron content and is intended for remelting being used in all forms as a feedstock for steelmaking furnaces. Scrap is not a uniform product regarding its form, composition and economic value. Since problems of the protection of the environment, the securing of raw materials, and energy conservation have come to the fore on a world wide scale, scrap is having an increasingly important part to play in solving these problems.

i) Available scrap is generally classified in two groups; unalloyed and alloyed scrap.

a) <u>Unalloyed scrap</u> coming onto the market is graded into a varying number of types of scrap depending on the country of origin. The types of scrap defined in the scrap terminology usually include only carbon steel scrap. The grades of scrap supplied must be absolutely clean and free from all harmful components including, for instance, nonferrous metals, alloys, castings, plastics, oils and grease, and textile residues.

b) <u>Alloyed scrap</u> segregation is difficult due to the diversity of grades of special alloy steels. Plants producing special steels usually either collect the works' own scrap arising in groups or alternatively scrap of each individual quality is collected together and held ready for when a charge of the same or similar composition is to be melted.

Stainless steel scrap or discards are classified in four groups:

First group: Cr-steels containing Ni 0,5 % maximum
Cr-steels containing Ni 2 % maximum

Second group: Cr-Ni-steels containg Mo 0,5 % maximum

Third broup: Cr-Ni-Mo-steels

Fourth group: Cr-Ni-steels (no limit to nickel)

Low alloy structural steels, should also be separated on the basis outlined above when optimum reuse is possible.

Scrap or discards of high speed steels are classified in three groups:

First group: W- steel (traces of Mo and Co)
Second Group: W-Mo-steel (traces of Co)
Third Group: W-Mo-Co-steel.

ii) Scrap to be used as feed-stock for metallurgical processes can be classified according to its origin as:

a) Internal Scrap (home scrap, circulation scrap) is which necessarily arises in steelplants during steelmaking and hot and cold working and is supplied to the furnaces as feedstock. This scrap is distinguished by its high bulk density and the fact that it is particularly free from impurities.
Separation iron obtained by preparation (crushing, magnetic separation) of steelworks slags.

b) Producer Scrap(manufacturing scrap) includes scrap arising during the subsequent processing of steel products. The availability of this type of scrap must be seen as a function of steel consumption. The various steel processing industries have a scrap output, which depending on the particular manufacturing process used, varies from 6 % in the construction industry to 28 % in the motor car industry. Producer scrap from the steel construction and engineering industries is a valuable iron carrier for the steelmaker. On the other hand, scrap from small undertakings may give rise to some uncertainty and doubt in the melting process.

c) Capital scrap is scrap which on termination of the service life of the various steel products, is returned to the steel plants as feedstock. The availability of capital scrap depends on steel consumption during earlier periods. The life span of a steel product decreases with progressive industrialization, the increasingly short life of consumer goods, and the rising standard of living.

Scrap which arises from the wrecking of large units (ships, steel structurs, heavy machinery) and in large quantities (rails) is a good feedstock for the steelmaker as the chemical composition is fairly uniform and the density is usually suitable.
The use of so-called trade scrap has to be faced carefully.

Refuse Scrap is a term used to include scrap arising in household refuse and which is recovered from rubbish dumps, refuse incinerators, and composting plants. The metallic part of this scrap is found in the form of commodities such as bicycles, kitchen utersils,etc. in household and bulk refuse, the greater part of the metal found in household scrap, however, being tin cans. Since these cans are coated with a thin layer of tin for protection against corrosion, the tin content of refuse scrap may be many times more than the actually permissible level for the steelmaking charge materials and such scrap, therefore, can be used only in limited quantities.

2. DRI (Sponge iron): Various terms have been used to describe the product of direct reduction. The most pertinent term comes from France: prereduced iron ore. In Germany and in the English-speaking world, the expression "sponge iron" has been adopted, based on the physical state of the product. In its modern usage, sponge iron is referred to as direct-reduced iron (DRI). As a feedstock for direct reduction plants, ores rich in iron content and having a low gangne content are required. Recently, DRI has gained an importance as a substitute for scrap, and has a particularly higher degree of purity and a uniform particle size. A disadvantage of using DRI for steelmaking as ompared with scrap, is that it has only about one tenth the thermal conductivity of scrap and this means that additional heat is required.
The relative contribution of the various DRI manufacturing process into the 9.21 million tons produced in the world in the year 1984 was as follows:

Shaft furnace process - MIDREX	53.64 %
retort process - HyL I	31,05 %
HyL III	4.23 %
Fluidized bed process - FIOR	3.58 %
Rotary kiln process SL/RN	4,89 %
PLASMARED, KM, DRC, CODIR, ACCAR	2,61 %

Appendix - 3

Environmental Control

The iron and steel industry produces gaseous, liquid and solid contaminants. The gaseous contaminants include sulphur and nitrogen oxides, ammonia, and carbonoxides and particulates such as iron, silica, and lime stone. The liquid contaminants are tars, oils, phenols, cyanides, ammonia, heavy metal ions, low pH, suspended solids and some BOD (Biochemical Oxygen Demand - a measure of the biologically degradable portion of the waste loading). The solid contaminants are largely fines of the raw materials such as carbon, iron, silica and limestone.

Table 1 summarizes the envirnmental problems outlined above and indicates those sectors of the industry in which they are of importance. Figure 1 also shows sources of each polutant in the process of iron and steel production. Table 2 indicates the amounts of pollutants emitted.
The United States Evironmental Protection Agency has suggested the following tratment technology: *)

Production process	Treatment:
Coke	Cooling water recirculation; dilution of still waste with cooling water system blow-down; biological oxidation of combined still waste blow-down stream
Iron manufacturing	Polyelectrolytes, classification, sludge thickener, vacuum filtration of thickener under-flow, cooling and recycle
Steel manufacturing	Thickener
Hot-forming	Scale pit and oil flotation skimming
Cold-finishing pickle rinse water	Neutralization and settling
Cold Rolling	Chemical coagulation and dissolved air flotation

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*) Source: UNIDO/ICIS.25.

Table 1 Typical pollutants from an integrated steel plant

	Water	Stack emission	Fugitive or secondary	Solids
Transport	Suspended solids Run off water		Dusts: iron oxide, coal, limestone	Spillage muds
Blending and bedding	Suspended solids. Run off water		Iron oxides, coals, recycled dusts	Baghouse dusts
Sinter and pellet plants	Scrubber waters. Suspended solids. Lime, acids	SO_x, NO_x, F^-, (CO?), particulates	Dusts from sinter plant coolers, noise	Baghouse dusts with Zn, (Pb), alkalies, filter cake
Coke ovens	Phenols, cyanides, tars, ammonia	Smoke, SO_x, NO_x, steam, gas flare	Coal or coke dusts, sulphurous or carcinogenic emissions, smoke, benzene,, BaP, steam	Carbonaceous solids from baghouses, pitch, tar, refractories
Blast furnace	Suspended solids. fluorides, lead and zinc compounds. Chlorides, heat	H_2S, SO_2. Steam from slag cooling beds	Iron oxides, H_2S, casthouse fume, CO coke dust, noise	Baghouse dusts, blast furnace slags, refractories, filter cakes
Hot metal treatment	Alkalies. Suspended solids	Particulates, alkalies, fluorides	Na_2O, K_2O, lime dust, kish, iron oxide fume	Baghouse dusts with high lime corrosive slags
Steelmaking	Scrubber waters. Suspended solids. Zinc compounds	CO flare, CO_2, SiF_4, fluorides, iron oxides	Fine iron oxides, alloy fume, noise	Skimmer, EAF, BO & ladle slags; refractories, baghouse dusts
Casting	Oil, fluorides. Suspended solids, heat	Lead, So_x	Fume, fluorides	Slag from exothermic compounds, refractories filter cake
Rolling	Oils. Suspended solids. Chromates, acids, alkalies	SO_x, NO_x, CO_2, smoke	Scarfing fume	Mill scale, oily mill scale, filter cake, ferrous sulphate
Coating	Chromates, phosphates, alkalies, acids, oils, suspended solids		Chlorinated hydrocarbons, solvents, acid mist	Neutral sludges, filter cakes, carbon

Source: UNIDO

Figure 1

Flow Chart of principal operations and sources of pollutants in an integrated steel works

(Source:UNIDO)

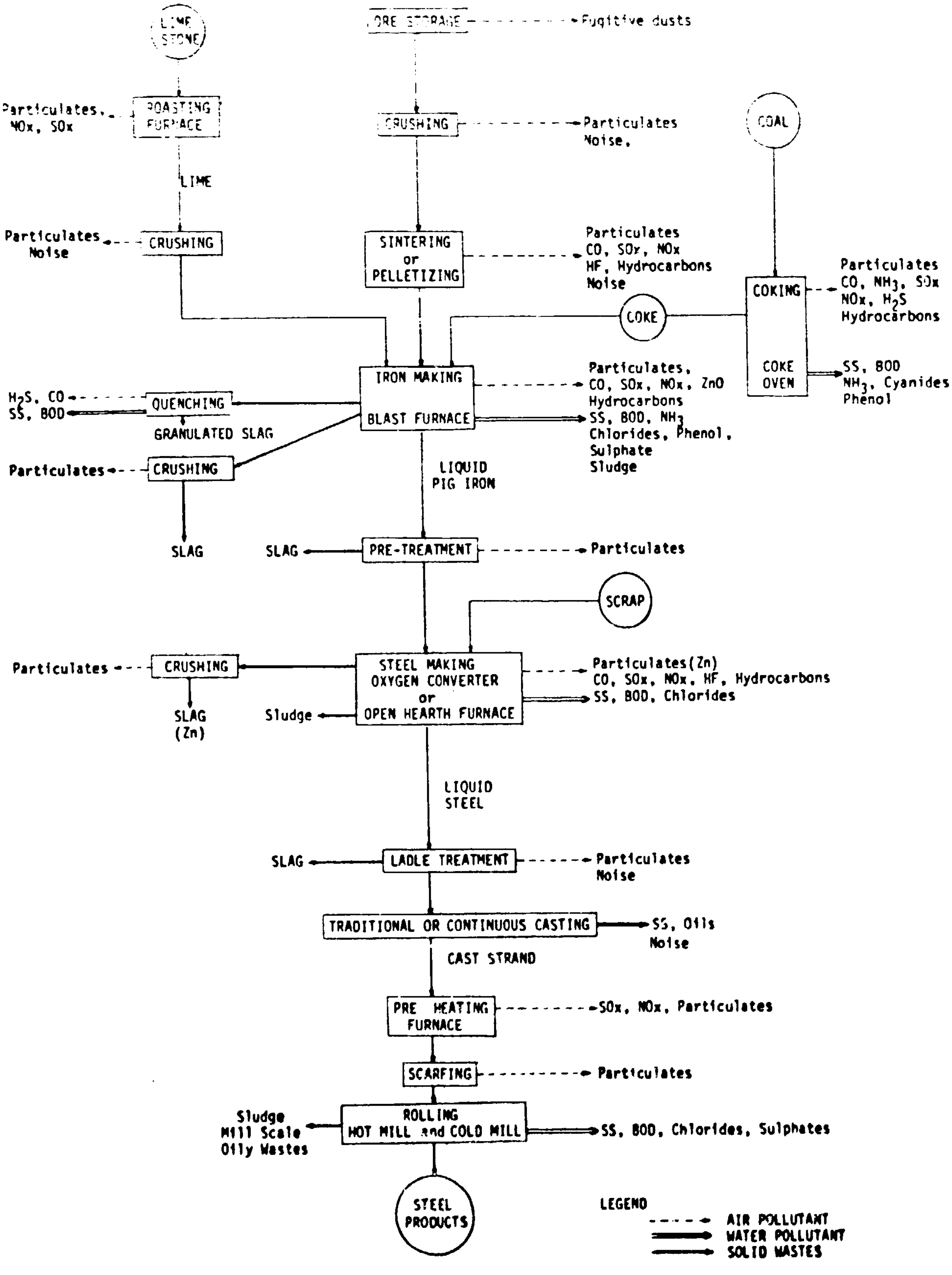


Table 2 Emissions from the main operations of an integrated steel plant, kg per one ton of rolled products[a/]

		Operation						
Source	Factor	Sintering	Coking	Ironmaking	Steelmaking	Casting and rolling	General	Approximate total
Fugitive	Dust, fume and grit	3	1	2	0.5	0.6	-	7
Stack gases	SO_x	4	0.3	0.2	0.2	2.0	-	7
	NO_x	1	0.2	0.2	0.1	0.5	-	2
	CO	40	0.3	8.5	15.0	0.33	-	60
	HF	0.04	trace	trace	0.4	variable	-	0.5
	Hydrocarbons	0.1	0.2	0.15	0.05	0.2	-	1
Waters	Suspended solids	0.28	0.06	0.24	0.07	0.20	-	1
	Oxygen demand	0.05	0.08	0.16	0.20	0.14	-	0.5
	Ammonia	-	0.03	0.08	-	-	-	0.1
	Phenol	-	0.005	0.006	-	-	-	0.01
	Cyanides	-	0.02	0.03	-	-	-	0.05
	Chlorides	...	-	0.05	0.05	0.20	-	0.50
	Sulphates	...	...	0.003	-	0.40	-	0.50
Solids	Dust	recycled	) 2	12	30		-	) 70
	Sludge		)	12	15	10	-	)
	Slag	-	-	300	100	10	-	400
	Millscale	-	-	-	-	30	-	30
	Oily wastes	-	-	-	-	10	-	10
General	Refractories	-	-	-	-	-	20	20
	Debris	-	-	-	-	-	40	40
	Human wastes	-	-	-	-	-	10	10
							Approximate total	660

a/ Levels are indicative only and are rounded from UNEP/WG.124/33/FINAL Individual plants vary widely depending on raw materials used and the anti-pollution equipment installed.

Notes: 1. These figures assume environmental controls.
2. Many slags are now recycled or sold.

The cost of pollution control equipment varies from country to country, based on legislation and other local conditions existing in the particular country.

Emmission Factors	(kg/t raw steel) Integrated works	Mini-mills
dusts	1 - 9	0.3 - 3
SO_2	2 - 11	2 - 7
NOx	0.4 - 3	0.1 - 1.2
CO	63	10

Control Costs

Investment	($ 1983/t installed annual capacity) Integrated works	Mini-mills
air pollution control	65 - 125	6 - 9
water pollution control	14 - 42	8 - 23
Total	79 - 167	14 - 32

Operating Costs	($ 1983/t raw steel) Integrated works	Mini-mills
	7 - 31	1 - 3

(Source: UNIDO)

Economic of scale:

Economic of scale have been analyized both for capital costs and production costs for three alternative plant capacities for DR - EF route including sensitivity analysis in respect of raw materials.

The data contained in the following tables 1 - 6 *) describe tentatively the order of magnitude of the respective costs.

---

*) Source: Arab Iron and Steel Union
Direct Reduction Symposium, 14-16 October 1984

Table 1 MAJOR PRODUCTION FACILITIES FOR DR-EF PLANTS

	A		B		C	
	Alt. 1		Alt. 2		Alt. 3	
	Billets	Slabs	Billets	Slabs	Billets	Slabs
Direct reduction:						
No. of modules	1	1	2	2	3	3
Modules capacity, '000 tons/yr	400	400	600	600	600	600
Electric arc furnace:						
No. of furnaces	2	2	6	6	6	6
Heat size, tons	85	85	85	85	130	130
Continuous casting machine:						
No. of machines	2	2	6	6	6	6
Strands for machine	4	1	4	1	6	1

Table 2 ESTIMATES OF CAPITAL COST FOR DR-EF PLANTS

(million US $)

	A		B		C	
	Alt. 1		Alt. 2		Alt. 3	
	Billets	Slabs	Billets	Slabs	Billets	Slabs
Direct reduction facilities	75	75	175	175	250	250
Steelmelt shop incl. EAF, CC etc	46	75	104	170	155	200
Auxiliary and yard facilities	40	40	85	85	120	200
Subtotal ..	161	190	364	430	525	570
Design, engg. and administr. expenses 10% of items 1-3	16	19	36	43	52	57
Contingencies 10% of items 1 to 4	18	21	40	47	58	63
TOTAL ..	195	230	440	520	635	690

Table 3

PRODUCTION COST ESTIMATES FOR DR-EF ROUTE
(US $ per ton)

		A			B			C		
		Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3	Alt.1	Alt.2	Alt.3
Production cost excluding fixed charges										
Sponge iron	..	97	93	92	104	100	99	87	83	83
Liquid steel	..	180	176	172	178	174	169	171	167	163
Billets	..	200	194	190	197	192	187	189	184	180
Slabs	..	201	195	189	199	193	187	191	185	180
Production cost including fixed charges at 20%(1)										
Billets	..	292	263	256	289	261	254	281	253	247
Slabs	..	310	277	262	307	274	259	299	267	252

NOTE

(1) To cover interest charges and depreciation

Table 4

RELATIVE COSTS OF DR/EF STEELMAKING CAPACITIES/ALTERNATIVES

	Alt. 1	Alt. 2	Alt. 3
DR/EF capacity, million tons	2.24	0.94	1.26
Capital cost, million US $			
DR/EF	830	330	510
Investment, US $/ton crude steel			
DR/EF	371	350	405
Annual works cost, million US $			
DR/EF	478	204	274
Fixed charges, million US $			
DR/EF	124	49	77
Annual production cost, million US $			
DR/EF	602	253	351
Production cost US $/ton crude steel (billets)			
DR/EF	269	269	279

Table 5

PRODUCTION COST ESTIMATE

DR-EF route	Unit price US $/ton	Alternative 1 Specific consumption kg/ton	Alternative 1 Works cost US $/ton	Alternative 2 Specific consumption kg/ton	Alternative 2 Works cost US $/ton	Alternative 3 Specific consumption kg/ton	Alternative 3 Works US $/ton
Sponge iron							
Raw materials							
Iron oxide pellets ..	55.00	750	41.25	750	41.25	750	41.25
Sized iron ore ..	36.00	750	27.00	750	27.00	750	27.00
Natural gas ..	2.6/gcal	2.8 gcal	7.28	2.8 gcal	7.28	2.8 gcal	7.28
Conversion costs ..			20.46		21.56		21.57
Works cost of sponge iron ..			95.99		97.09		97.10
Liquid steel							
Raw materials							
Sponge iron ..		756	72.57	770	77.09	889	86.32
Purchased scrap ..	120.00	354	42.48	333	39.96	222	26.64
Burnt lime ..	12.00	45	0.54	45	0.54	50	0.60
Ferro-manganese ..	605.00	11.5	6.96	11.5	6.96	12	7.26
Ferro-silicon ..	915.00	3.5	3.20	3.5	3.20	4	3.66
Aluminium ..	1 400.00	0.5	0.70	0.5	0.70	0.5	0.70
Fluorspar ..	60.50	2	0.12	2	0.12	2	0.12
Conversion costs ..			61.12		60.49		65.22
Works cost of liquid steel..			187.69		189.06		190.52
Billets							
Raw materials							
Liquid steel ..		1 064	199.70	1 064	201.16	1 064	202.71
Conversion costs ..			14.02		15.54		14.92
Works cost of billets ..			213.72		216.70		217.63
Fixed charges ..			55.36		52.13		61.11
PRODUCTION COST OF BILLETS (DR-EF ROUTE) ..			269.08		268.83		278.74
Say ..			269		269		279

Table 6

SENSITIVITY ANALYSIS - DR-EF ROUTE

Sensitive item	Variation over base case per cent	Alternative 1 US $/t	Alternative 2 US $/t	Alternative 3 US $/t
	Base case	213.47	217.31	217.48
Iron oxide pellets	5	215.13	219.06	219.44
	10	216.79	220.82	221.41
	15	218.44	222.58	223.37
	(-) 5	211.81	215.55	215.51
	(-) 10	210.15	213.80	213.55
	(-) 15	208.50	212.04	211.58
Iron ore	5	214.55	218.46	218.76
	10	215.64	219.61	220.05
	15	216.72	220.76	221.33
	(-) 5	212.38	216.16	216.19
	(-) 10	211.30	215.01	214.91
	(-) 15	210.21	213.86	213.62
Natural gas	5	213.76	217.62	217.83
	10	214.05	217.93	218.17
	15	214.35	218.23	218.52
	(-) 5	213.17	217.00	217.13
	(-) 10	212.88	216.69	216.79
	(-) 15	212.59	216.38	216.44
Purchased scrap	5	215.73	219.44	218.90
	10	217.98	221.56	220.32
	15	220.24	223.69	221.74
	(-) 5	211.21	215.18	216.06
	(-) 10	208.96	213.05	214.64
	(-) 15	206.70	210.93	213.21

Table 7

COMPARISON of DEPRECIATION and INTEREST CHARGES

in US dollars per metric ton of product

	Developed areas	Developing areas	
		1	2
depreciation in 15 years	$\frac{330}{15} = 22$ $+ 1$ 23 (for bars around 18)	$\frac{1\,000}{15} = 67$ $+ 3$ 70	
interest with 50 % debt	$165 \times \frac{15}{100} = 24{,}75$ (for bars 18,75)	$500 \times \frac{15}{100} = 75$	---
66 % debt	---	---	$666 \times \frac{15}{100} = 100$
total for one ton wire rod	47,75	145	170
total for one ton bar	36,75		

Source: UNIDO/ID/WG.458/2

1. A mini-mill and a brief equipment list

1. Plant capacity: 70 000 tpy

2. Product mix

	Reinforcing bars	Flat bars	Angles
size [mm]:	10 - 25	50 x 6 (max)	50 x 50 (max)
quantity [tpy]:	60 000	5000	5000
steel grade:	Plain carbon		

3. Type of plant: Mini-mill
   - Scrap based electric arc furnace
   - continuous casting machine
   - rolling mill

4. Main raw materials: Scrap, limestone, ferroalloys

5. List of main equipment

5.1 Steelmeltshop:

5.1.1 Electric arc furnace and accessoires

- 30 ton capacity, 4.5m shell dia, EAF, 18 MVA transformer, mechanicals, elelctricals and controls, refractories, electrodes, top charging etc.
- furnace tilting mechanism
- fume extraction system
- scrap charging buckets
- immersion pyrometer
- electrode make-up platform
- slag pots
- furnace bottom fettling machine
- operating tools and tackles

5.1.2 Storage and handling facilities

- Storage bunkers for limestone and ferroalloys
- Steel teeming 35-ton ladles, refractories
- Tundish transfer car
- Steel boxes for additions etc.

5.1.3 Ladle preparation facilities

- Horizontal ladle drier
- Ladle stand
- Slide gate nozzle assembly and preparation facilities
- Miscellaneous fabricated items

5.1.4 Continuous casting machine and accessories

- 3-strand continuous billet (120 mm sq) casting machine of low head design, steel structure, mechanical and electrical equipment, instruments and controls, billets cut-off equipment, discharge roller tables and cooling bed, tundishes and tundish preheaters, refractories etc., cooling water system, mould
- drummy bar, discharge roller tables
- lubrication system, mould tables with oscillation drives, withdrawal and straightening units, secondary cooling system, steam exhaust system etc.
- immersion pyrometer
- optical pyrometer
- tundish stands
- tundish tilting stand
- tundish drying station
- repair and assembly facilities
- operating tools and tackles
- pipes, fittings
- instrument for compressed air

5.1.5 EOT Cranes and Hoistes

- EOT magnet crane for scrap handling and charging
- EOT crane for liquid steel handling
- Electric hoistes, pulley blocks etc.

5.1.6 Miscellaneous equipment

- scale for scrap bucket weighing
- crawler crane with magnet for scrap handling
- shearing machine and cutting torcher for scrap preparation
- pneumatic rammers, chipping hammers, chains etc.
- repair and assembly facilities

5.1.7 Instrumentation and Control System

5.2 Rolling mill: 5.2.1 Billet Heating Furnace

- End-charge, end-discharge continuous pusher type furnace, with billet pusher blowers, recuperators, controls etc.
- Furnace charging and discharging equipment including billet charging grid, furnace roller table etc.

5.2.2 Mill mechanical equipment

- Semi-continuous roughing train consisting of three stands
- Six intermediate stands
- Three finishing stands
- off-line straightening machine
- mill shears
- scrap handling system
- scale handling and removal system etc.

5.2.3 Bar finishing facilities as

- Colling bed approach and run-in roller tables
- cooling bed
- shear
- weighing machine

5.2.4 Roll shop facilities as

- Roll changing device
- oil lubrication system
- Bearing section facilities etc.

5.2.5 Electrical equipment

It includes among others the

- main drive motors for mill stands
- protection, monitoring and regulation equipment
- motor ventilation system
- auxiliary
- Power distribution equipment, subdistribution board etc.

5.2.6 Cranes as

- Billet storage cranes
- mill crane
- finished product handling cranes

5.2.7 Transfer car and other miscellaneous handling equipment as

- Roll transfer car
- transfer equipment for finished products
- grab buckets, magnets etc.

5.3 Electric prower distribution and communication facilities

5.4 Water supply facilities

5.5 In-plant transport facilities as
cranes, trailers, trucks etc.

5.6 Auxiliary facilities as

- maintenance shop
- stores
- laboratory equipment

5.7 Manpower requirements (approximately)

- Administration	45	
- Works office	15	
- Steelmeltshop	130)	3 shifts/day and
- Rolling mill	140)	7 days/week
- Maintenance, Plant service	130	
	460	(about 5 % Engineering and University graduates)

6. Plant construction

6.1 Construction facilities and preliminary works

- Construction power system
- construction water system
- Soil investigation and site survey
- construction roads
- contractors' areas
- construction offices

6.2 Production units

- Steelmelt shop
- bar and rod mill

6.3 Auxiliary units

- Administrative building complex
- repair and maintenance shop and stores

6.4 Utilities

- Power system
- Water system
- Fuel oil storage and distribuation system
- compressed air plant
- piping, cabling, roads, sewerage and drainage

6.5 A tentative construction schedule is given in Figure 1

Figure 2 illustrates a general layout of the plant.

7. Capital cost

It includes:
- civil and structural
- mechanical and electrical equipment
- other costs as transport cost, erection cost etc.

The total capital cost has the following break down:

a) Steelmeltshop	35 %
b) Rolling mill	45 %
c) Other utilities as water system, electric power system, repair shop laboratory, store etc.	20 %

The establishment of a production plant is feasible if the market requirements are higher or at least the same as the break-even point of the production.

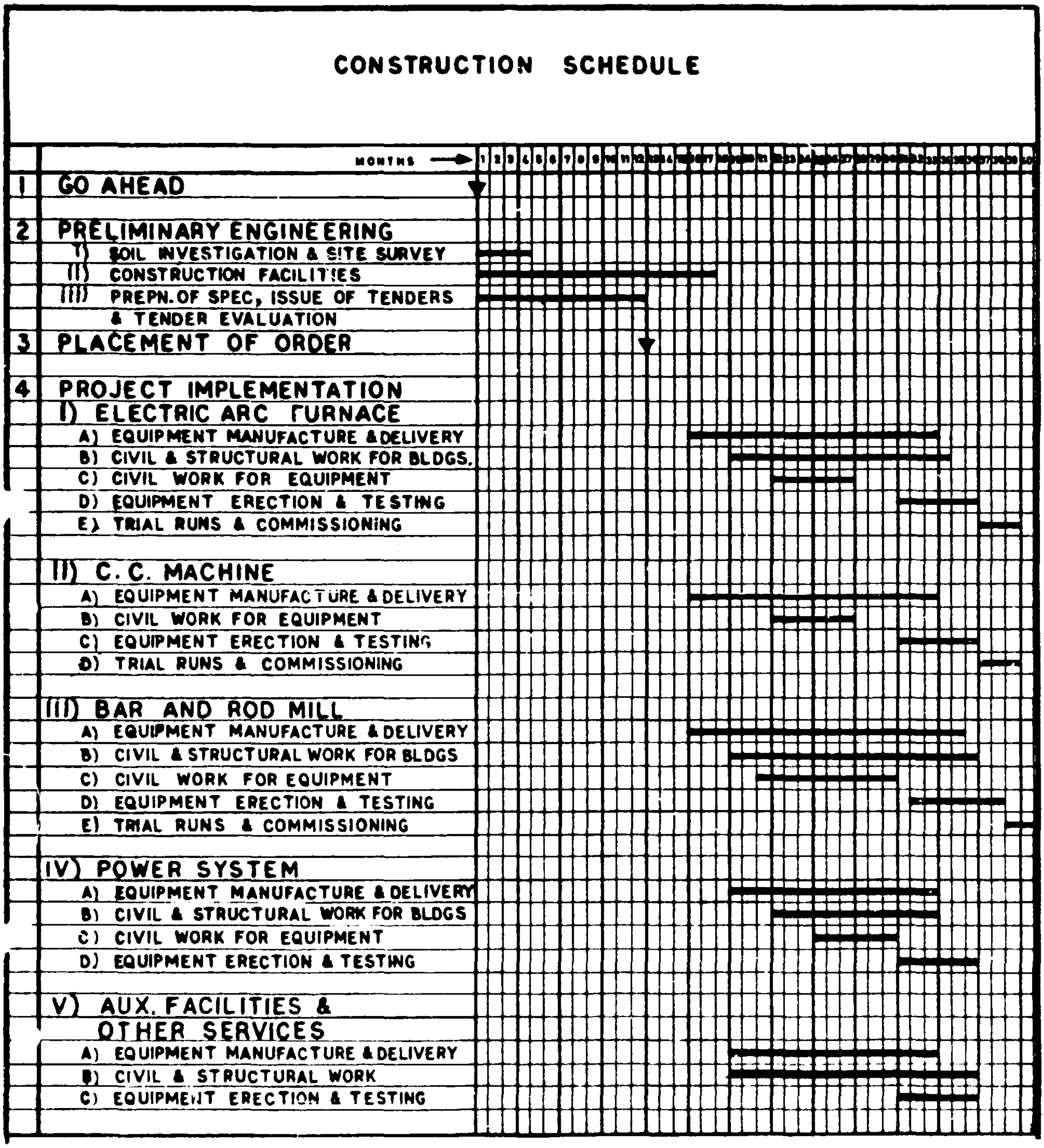
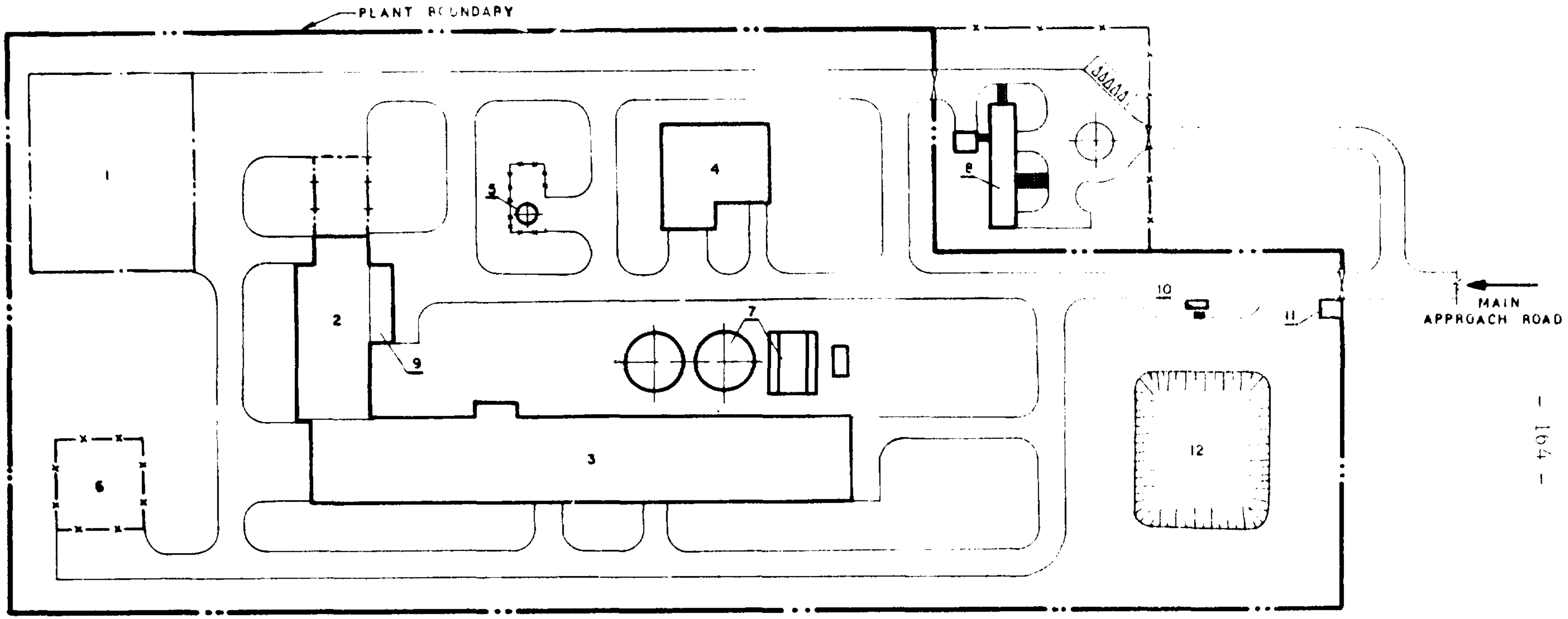


Figure 1

Source: UNIDO



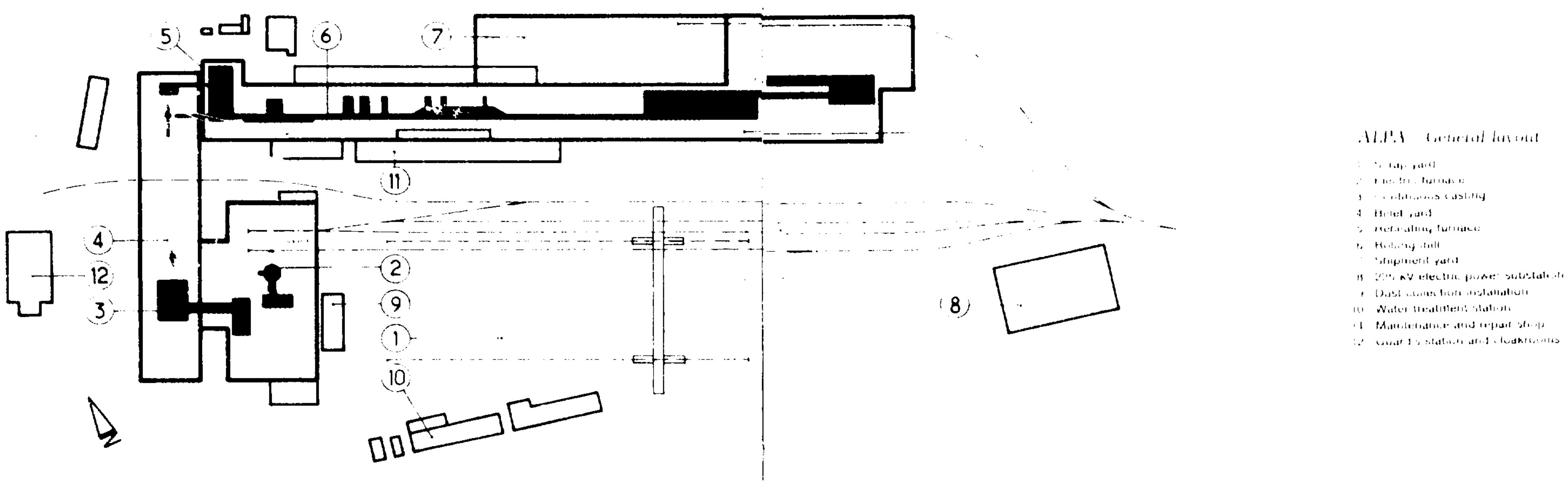
LEGEND

1 OPEN SCRAP YARD
2 STEELMELT SHOP
3 BAR AND ROD MILL
4 REPAIR SHOPS AND STORES
5 FUEL OIL STORAGE
6 ELECTRIC SUBSTATION
7 WATER SUPPLY FACILITIES
8 ADMINISTRATIVE BLDG., CANTEEN & FIRST AID
9 OFFICE AND LABORATORY
10 WEIGHBRIDGE
11 GATE HOUSE
12 SLUDGE POND

Figure 2
PLANT
GENERAL
LAYOUT

Source:UNIDO

2. Alpa mini-mill in
Farcheville (France)



Source: UNIDO

alpa mini-mill technical data

Site

Porcheville, near Mantes-la-Jolie (60 km from Paris)

Communications

Motorway and railway between Paris and Rouen.

Electric power

220-kV power supply from substation of the Porcheville power plant. Transformation to 20-kV by two 20- and 40-MVA transformers

Oxygen

Distribution through nearby factories after metering, this system relieving the operator of daily maintenance and accounting problems

Gas and water

Supplied from the networks of the industrial area.

Pollution control

Closed water circuits

Stack gas collection (furnace and casting bay) exhaust and collection in a bag filter before discharging to atmosphere

Production and capacity

- Steel shop

180,000 tpy, round the clock.

- Rolling mill:

160,000 tpy of reinforcing bars from 80 to 40 mm diameter, in two-shift operation.

Personnel

About 300 people.

Production facilities

- One 60-ton electric furnace of 5.2-m diameter with 500-mm electrodes, supplied by transformer with a power rating of 30 MVA.
- One 4-strand continuous casting machine producing billets of 120 × 120 mm with curved moulds
- One reheating furnace of the pusher type with lateral charging and discharging; maximum billet length of 10 m, reheating rate of 30 seconds per billet, production of 60 tph.
- One rolling mill including a roughing mill of 450 mm with three stands in which the billet passes twice and 14 intermediate and finishing stands.

Quality control

- Systematic testing of heats by spectrograph
- Mechanical tests before marketing of reinforcing bars.

Storage and handling

Scrap storage (packs, turnings, croppings, etc.) in stockyard (capacity: 25 000 t) reclaimed by gantry with 85-m span for loading into furnace buckets.

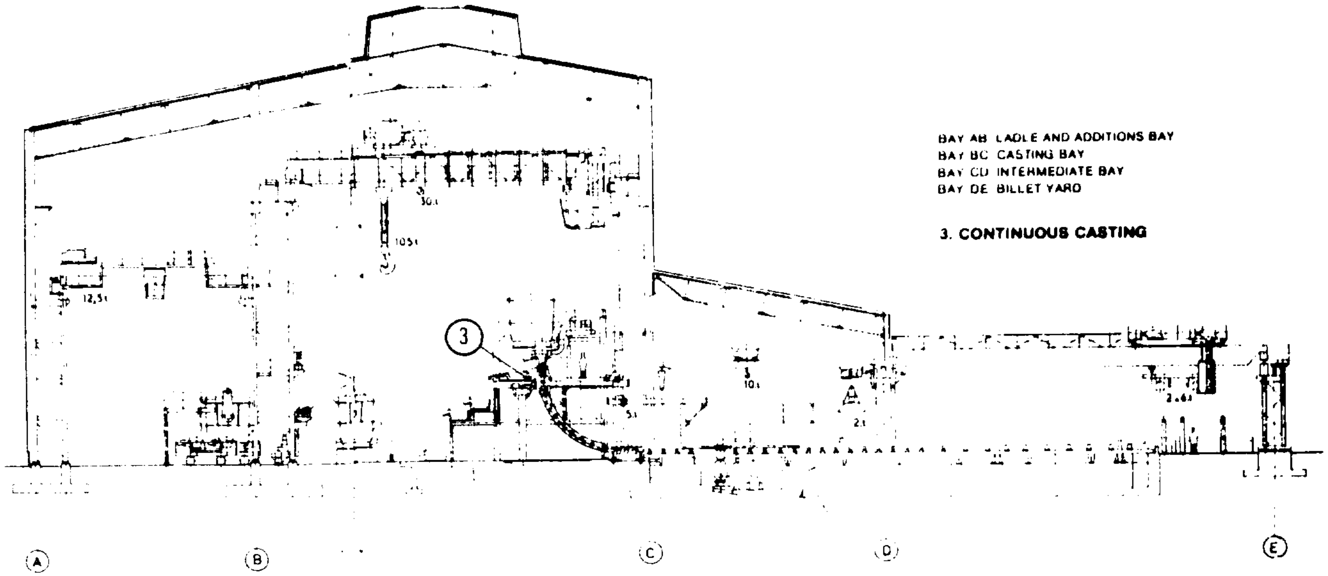
Handling in the steel shop bay by two 105-t travelling cranes, loading of wagons and lorries from the finished-product stockyard equipped with two cranes of 4-ton capacity each

Maintenance

Current maintenance in a shop equipped with conventional machines. Provision is made for maximum use of local resources for more complex or extensive jobs

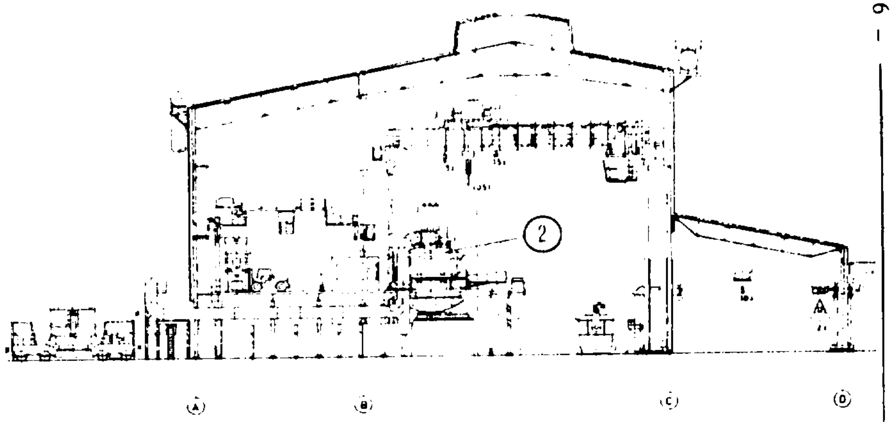
General services

Offices, cloakrooms, washrooms, dining halls and infirmary



BAY AB LADLE AND ADDITIONS BAY
BAY BC CASTING BAY
BAY CD INTERMEDIATE BAY
BAY DE BILLET YARD

3. CONTINUOUS CASTING



2. ELECTRIC FURNACE

3. Design of the USIBA integr. mini-mill(Braz)

Main features

- Availability of electrical power, water, natural gas, limestone and ferroalloys
- Location on the coast
- Choise of the direct reduction-electric furnace formula
- Selection of the HyL process (natural gas with a 6.2 km pipe-line) as the method of producing sponge iron
- Production of sponge iron with a high metal content (86-92 % Fe) and low gangue,phosphorus and sulphur contents
- Choise of the IRSID continuous sponge-iron charging system
- Melting and refining in a 20 ft. dia UHP electric furnace
- Continuous casting production of billets (semi-finished 80 x 80 mm to 160 x 160 mm from 3 to 10 meters in length, of carbon and low-alloy steels.
- Rolling and finishing production of round bars, wire rod and small shapes.
- The electrical power available in the area is supplied by means of a 220 kV line 6 km in length
- Process water is supplied through a 600 mm diameter pipeline 4.5 km in length.
- Proximity to an industrial center provided the required basic facilities
- Availability of skilled labor and technicians: The proximity of the city of Salvador, fully covered requirements in this field
- Production capacity: 300 000 tpy

Source: ID/WG.146/105

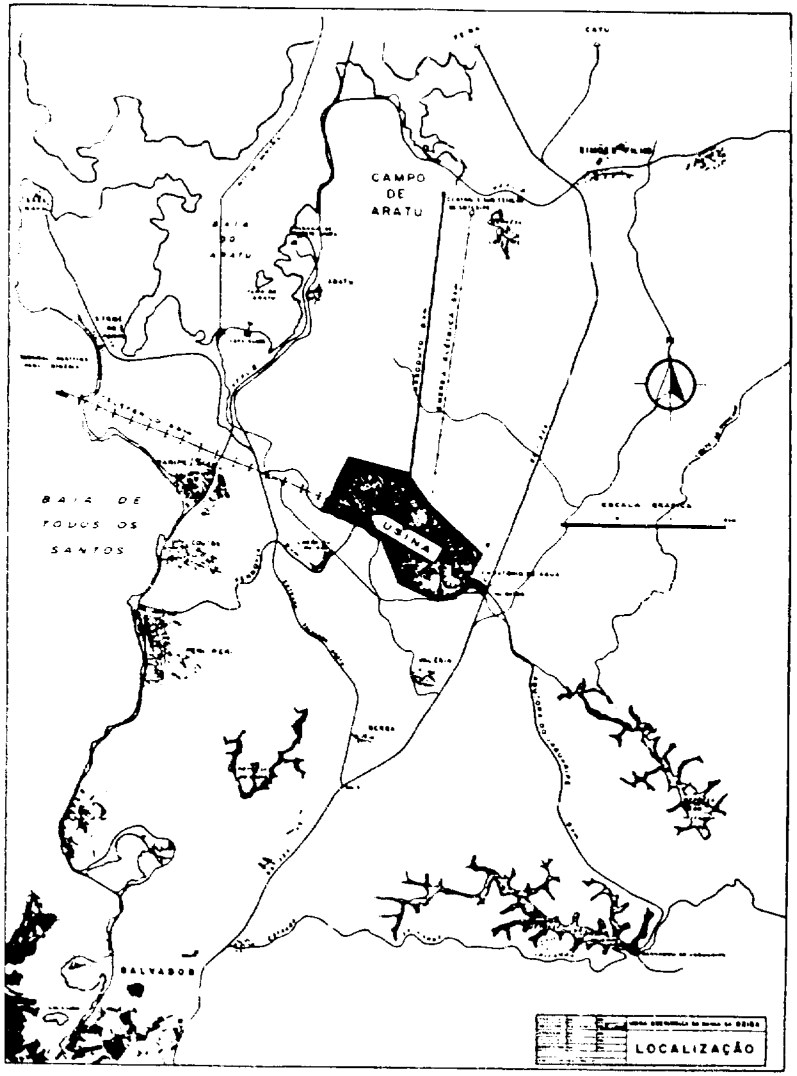


Fig. 1 – Location of USIBA plant

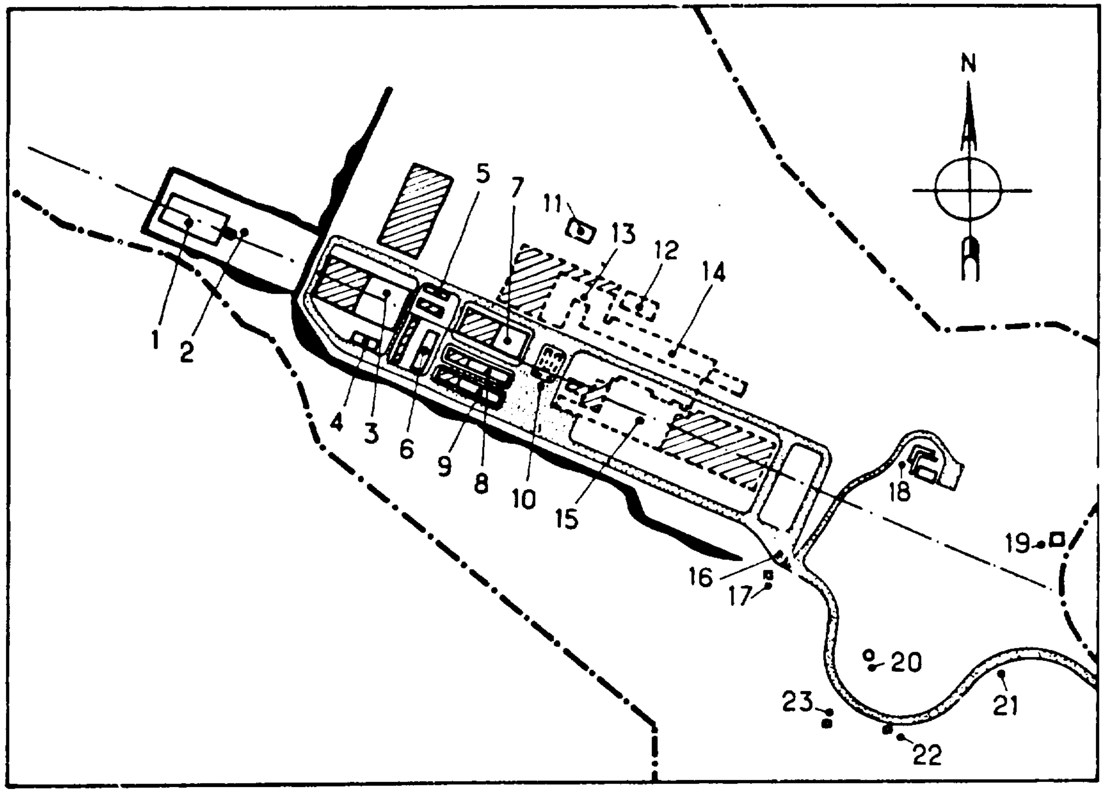


Fig. 2 - General layout of USIBA plant. 1. Ore stockyard, 2. Ropeway terminal, 3. HyL direct reduction unit, 4. Vehicle shop, 5. Offices and dressing rooms, 6. Storage, 7. Foundry, 8. Mechanical maintenance shop, 9. electrical maintenance shop; 10. Offices, laboratories, & dressing rooms 11. Water treatment, 12. Substation, 13. Continuous casting, 14. Hot rolling, 15. Cold rolling, 16. Main entrance 17. Restaurant, 18. Main offices, 19. Weather station, 20. Water tower

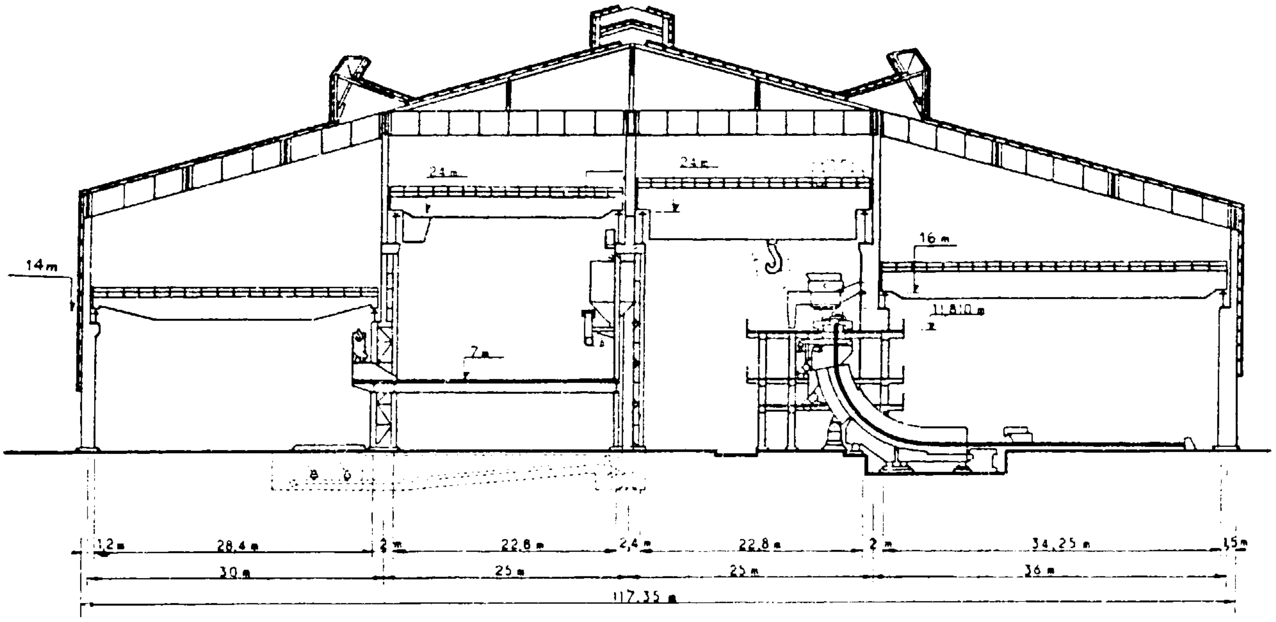


Fig.3a - Transverse section of steelmaking shop

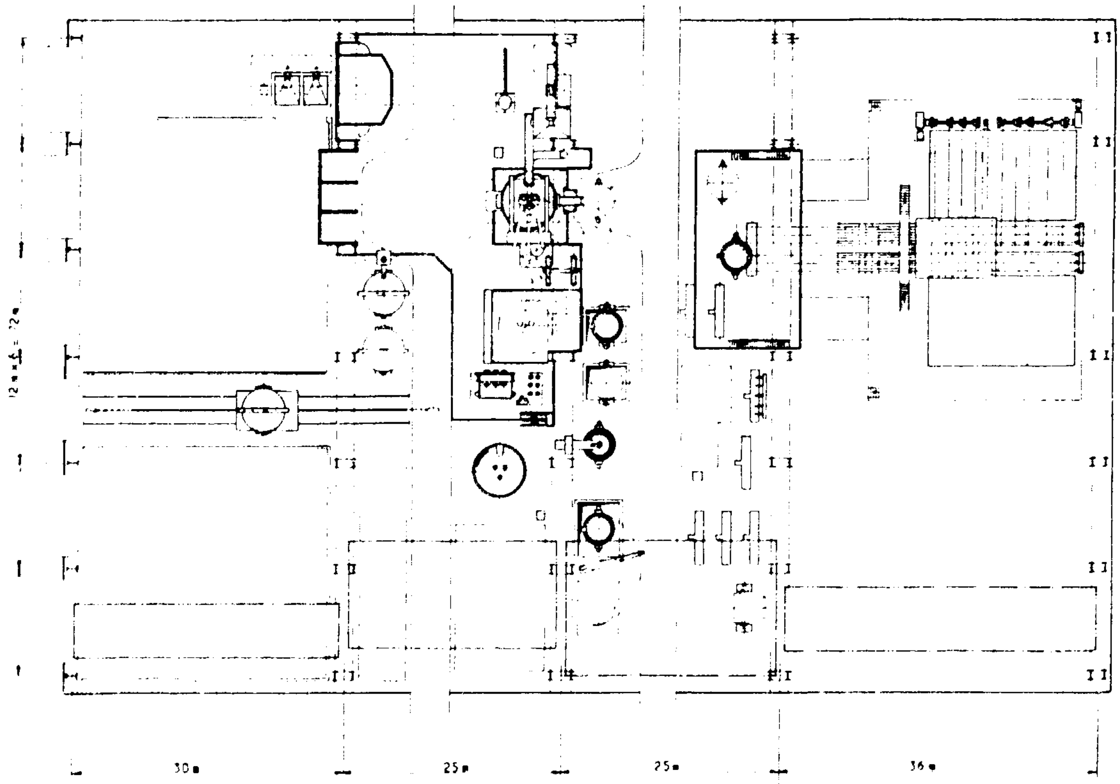


Fig.3b - General layout of steelmaking shop in initial phase

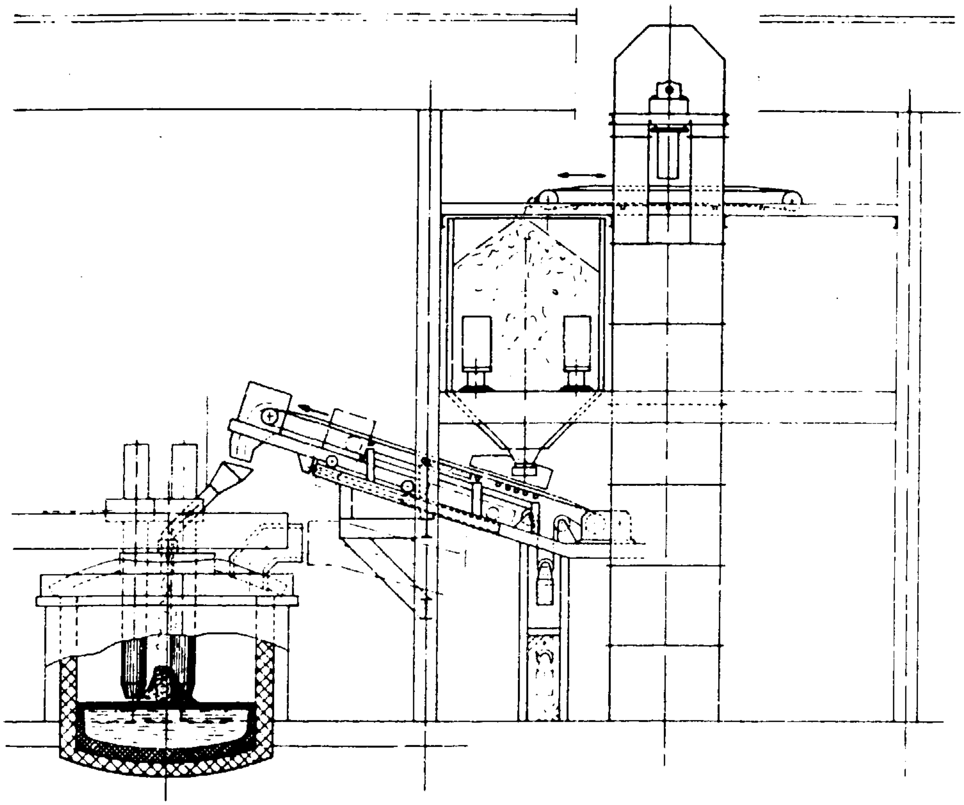
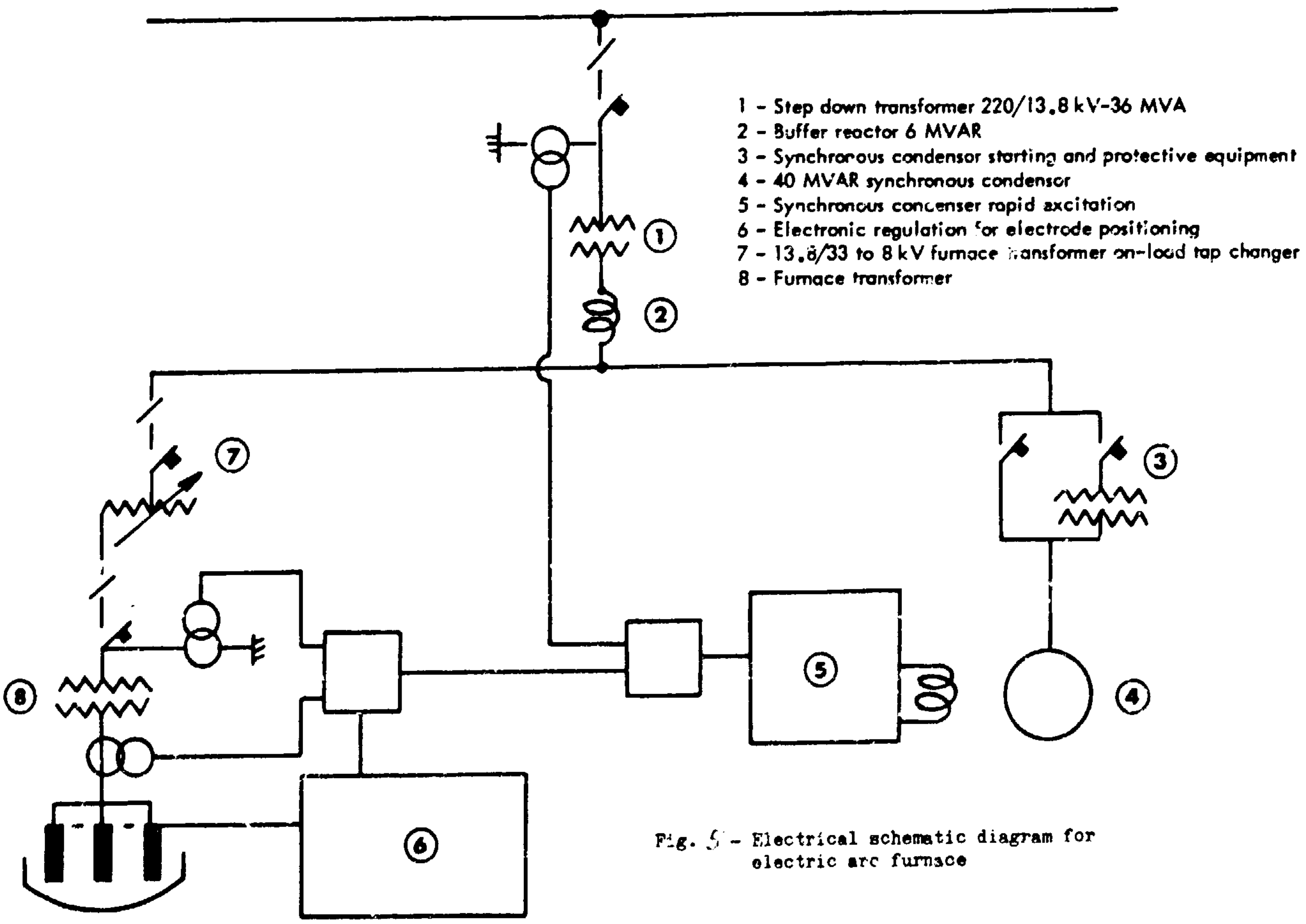


Fig. 4 - IRSID continuous sponge-iron charging system



1 - Step down transformer 220/13.8 kV-36 MVA
2 - Buffer reactor 6 MVAR
3 - Synchronous condensor starting and protective equipment
4 - 40 MVAR synchronous condensor
5 - Synchronous concenser rapid axcitation
6 - Electronic regulation for electrode positioning
7 - 13.8/33 to 8 kV furnace transformer on-load tap changer
8 - Furnace transformer

Fig. 5 - Electrical schematic diagram for electric arc furnace

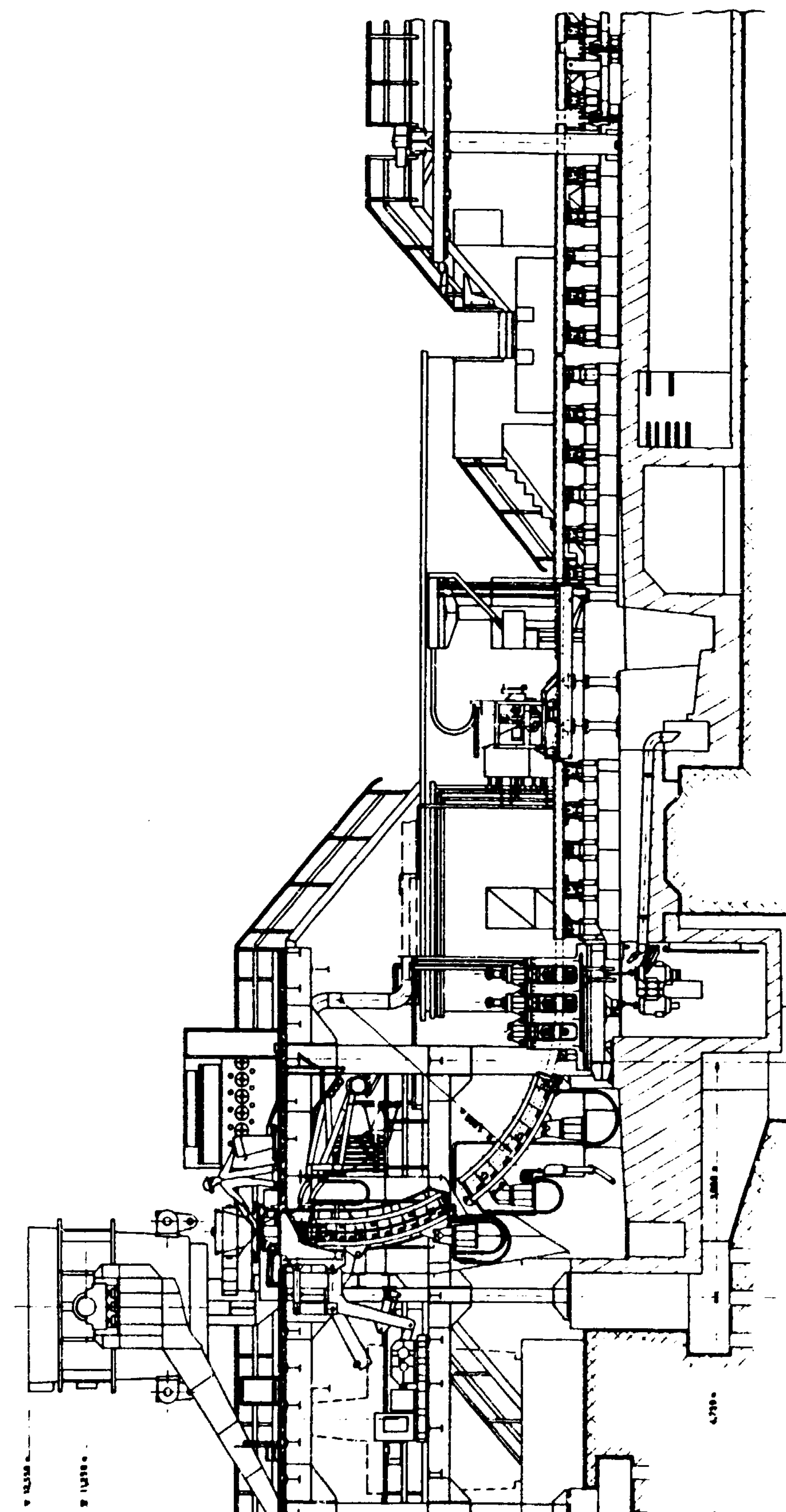


Fig. 6 – Cross-section of continuous-casting plant

4. Mini-mill (rolling-mill) in Nigeria

Quo Steel Products Ltd was incorporated on 29th November 1977 and was established as a private liability company, its purpose being the construction and operation of a steel rolling mill for the manufacture and trading of steel rods, bars, sections and allied products

The authorised share capital of the company is N 10 Million.

The major shareholder is the Government of Cross River State, while other participants to the equity capital are Manilla Insurance Co. Ltd and Investment Trust Co. Ltd.

Danieli & C. has an equity participation of 14%.

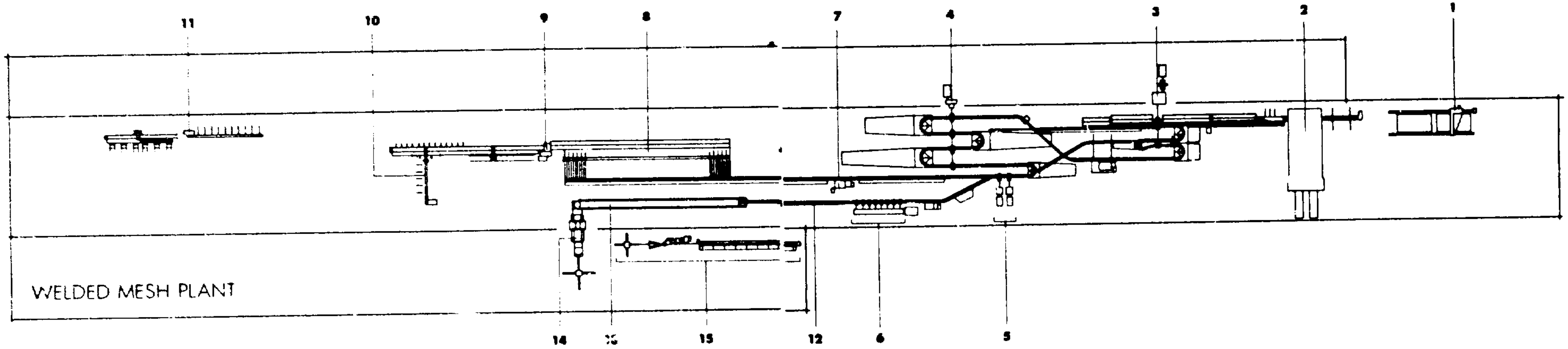
The plant consists mainly of:

- a rolling mill of the capacity of 100.000 t/y
- a welded mesh plant of the capacity of 5.000 t/y
- an electric power diesel generating plant of the capacity of 12.000 KVA

Danieli is presently carrying out the implementation of the project on a turn-key basis by virtue of a contract which was initiated in December 1981.

SOME OPERATING DATA

Starting material:	120 mm square billets 2 (4) m long 220 (440) Kgs
Steel quality:	low and medium carbon steel
Finished material:	Ø 5.5 to Ø 12 mm in coils Ø 12 to Ø 32 mm in straight bars 20 to 50 mm angles 20 to 50 mm flats equivalent small sections electrowelded mesh
Max. finishing speed:	30 m/sec with the small diameters
Output.	100.000 tons/year
Furnace capacity:	18/20 tons/hour



1) Billet cutting to furnace size
2) 18/20 tph reheat furnace
3) 450 mm dia. roughing mill train
4) 300 mm dia. intermediate mill train
5) 300 mm dia. intermediate-finishing mill train
6) 200 mm dia. finishing mill train
7) Bar cutting to cooling bed-length
8) 30x5 m walking beam type cooling bed
9) Bar cutting to length and collecting services
10) Bending services
11) Straightening services
12) Water-spray cooling line for wirerod
13) Loop cooling conveyor
14) Coil compacting and tying services
15) Decoiling-straightening and cut-to-length services

Appendix - 6

Epitome with: - selected steel producers*)
- selected equipment suppliers**)

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*) Source: 1984 Directory Iron and Steel Plants

**) Source: Metallurgical Plantmakers of the World

1. SELECTED STEEL PRODUCERS

ARGENTINA

Avellaneda
- Acindar Industria Argentina de Aceros S.A.

Buenos Aires
- Acindar Industria Argentina de Aceros S.A
- Dalmine Siderca S.A.I.C.
- SOMISA-Sociedad Mixta Siderurgia Argentina

Campana
- Dalmine Siderca S.A.I.C.

La Tablada
- Acindar Industria Argentina de Aceros S.A.

San Nicolas
- SOMISA-Sociedad Mixta Siderurgia Argentina
  - (General Savio Wks.)

Villa Constitucion
- Acindar Industria Argentina de Aceros S.A.

AUSTRALIA

New South Wales
- **Newcastle**
  - Broken Hill Pty. Co., Ltd., The
    - (Newcastle Steel Works)
- **Port Kembla**
  - Broken Hill Pty. Co., Ltd., The
    - (Subsidiary, Australian Iron & Steel Pty. Ltd.)
  - John Lysaght (Australia) Ltd.
- **Shortland**
  - Broken Hill Pty. Co., Ltd., The
    - (Central Research Laboratories)
- **Sydney**
  - Broken Hill Pty. Co., Ltd., The
  - John Lysaght (Australia) Ltd.
- **Waratah**
  - Commonwealth Steel Co. Ltd.

Queensland
- **Brisbane**
  - Broken Hill Pty. Co., Ltd., The

South Australia
- **Adelaide**
  - Broken Hill Pty. Co., Ltd., The
- **Whyalla**
  - Broken Hill Pty. Co., Ltd., The
    - (Whyalla Wks.)

Tasmania
- **Hobart**
  - Broken Hill Pty. Co., Ltd., The

Victoria
- **Hastings**
  - John Lysaght (Australia) Ltd.
- **Melbourne**
  - Broken Hill Pty. Co., Ltd., The
    - (Subsidiary, Australian Iron & Steel Pty. Ltd.)

Western Australia
- **Kwinana**
  - Broken Hill Pty Co., Ltd., The
    - (Subsidiary, Australian Iron & Steel Pty. Ltd.)
    - (BHP Minerals Ltd.)
- **Perth**
  - Broken Hill Pty. Co., Ltd., The

AUSTRIA

Linz
- Voest-Alpine AG

BANGLADESH

Chittagong
- Bangladesh Steel and Engineering Corp.
  - (Chittagong Steel Mills Ltd.)

Dacca
- Bangladesh Steel and Engineering Corp.

BELGIUM

Flemalle
- Tubemeuse S.A.
  - (Tube Mills)

Seraing
- Cockerill Sambre, S.A.
- Tubemeuse S.A.
  - (Steelworks)

BRAZIL

Belo Horizonte
- ACESITA-Cia. Acos Especiais Itabira
- USIMINAS-Usinas Siderurgicas de Minas Gerais S/A

Ipatinga
- USIMINAS-Usinas Siderurgicas de Minas Gerais S/A

Rio de Janeiro
- Nacional, Cia. Siderurgica

Timoteo
- ACESITA-Cia. Acos Especiais Itabira

Volta Redonda
- Nacional, Cia. Siderurgica

CHILE

Talcahuano
- Huachipato S.A., Compania Siderurgica

FRANCE

Dunkirk
- Francaise des Aciers Speciaux, Compagnie

Fos-sur-Mer
- SOLMER-Societe Lorraine et Meridionale de Laminage Continu
  - (Plant)

Mondeville
- Normandie, Societe Metallurgique de

Montataire
- Montataire, S.A. de Construction et de Galvanisation de

Paris
- Francaise des Aciers Speciaux, Compagnie
- Montataire, S.A. de Construction et de Galvanisation de
- Normandie, Societe Metallurgique de
- Sacilor
- SOLMER-Societe Lorraine et Meridionale de Laminage Continu
- Ugine Aciers
- Societe USINOR
- VALLOUREC S.A.

St. Etienne
- Francaise des Aciers Speciaux, Compagnie

Strasbourg
- Strasbourg S.A., Laminoirs de

Trith-Saint-Leger
- L'Escaut, S.A. Metallurgique de
- Francaise des Aciers Speciaux, Compagnie

WEST GERMANY

Bochum
- Krupp Stahl AG

Dortmund
- Hoesch Huettenwerk AG
- Hoesch Werke AG

Duisburg
- Thyssen Stahl Aktiengesellschaft

Dusseldorf
- Mannesmann AG

Hagen
- Hoesch Hohenlimburg AG

Hamm
- Hoesch Rohr AG

Hohenlimburg
- Krupp Stahl AG

Rheinhausen
- Krupp Stahl AG

Siegen
- Hoesch Siegerlandwerke AG

INDIA

Bhilai
- Steel Authority of India Ltd.

Bokaro
- Steel Authority of India Ltd.

Bombay
- Tata Iron & Steel Co., Ltd., The
- Zenith Steel Pipes and Industries Ltd.

Calcutta
- Tata Iron & Steel Co., Ltd., The

Durgapur
- Steel Authority of India Ltd.

Jamshedpur
- Tata Iron & Steel Co., Ltd., The
  - (Town Div.)

Jharia
- Tata Iron & Steel Co., Ltd., The

Kulti, West Bengal
- Indian Iron & Steel Co., Ltd., The
  - (Kulti Wks.)

New Delhi
- Steel Authority of India Ltd.

Noamundi
- Tata Iron & Steel Co., Ltd., The

Rourkela
- Steel Authority of India Ltd.

Ujjain
- IISCO Stanton Pipe & Foundry Co. Ltd.

West Bokaro
- Tata Iron & Steel Co., Ltd., The

ITALY

Bergamo
- Dalmine SpA
  - (Dalmine Plant)

Busano Canavese
- Teksid S.p.A.
  - (Sima S.p.A.)

Buttigliera Alta (Torino)
- Teksid S.p.A.
  - (Fasteners)
  - (Mechanical Prods.)

Livorno
- Dalmine SpA
  - (Piombino Plant)

Lovere (Bergamo)
- Terni
  - (Wks.)

Massa
- Dalmine SpA
  - (Massa Plant)

Milano
- Dalmine SpA
- NUOVA SIAS-Societa Italiana Acciai Speciali p.a.

Naples
- Dalmine SpA
  - (Torre Annunziata Plant)

Rome
- Terni

Sesto San Giovanni (Milano)
- Teksid S.p.A.
  - (Gilby S.p.A.)

Terni
- Terni

Torino
- Teksid S.p.A.
  - (Hot Forging and Cold Extrusion)

Trieste
- Terni
  - (Wks.)

JAPAN

Akashi
- Kobe Steel, Ltd.
  - (Akashi Plant)
  - (Construction Machinery Plant)

Amagasaki
- Kobe Steel, Ltd.
  - (Amagasaki Wks.)
- Sumitomo Metal Industries, Ltd.
  - (Central Res. Laboratories)
  - (Steel Tube Wks.)

Chiba
- Kawasaki Steel Corp.
  - (Chiba Wks.)
  - (Welding Rod and Iron Powder Plant)

Fujisawa
- Kobe Steel, Ltd.
  - (Fujisawa Plant)

Fukuchiyama
- Kobe Steel, Ltd.
  - (Fukuchiyama Plant)

Fukuoka
- Sumitomo Metal Industries, Ltd.
  - (Kokura Steel Wks.)

Fukuyama City
Nippon Kokan K.K.
(Fukuyama Wks.)
Handa
Kawasaki Steel Corp.
(Chita Wks.)
Hatano
Kobe Steel, Ltd.
(Hatano Plant)
Hidaka-cho
Kobe Steel, Ltd.
(Hidaka Plant)
Hikari City
Nippon Steel Corp.
(Hikari Wks.)
Himeji
Nippon Steel Corp.
(Hirohata Wks.)
Ibaraki
Kobe Steel, Ltd.
(Ibaraki Plant)
Kainan
Sumitomo Metal Industries, Ltd.
(Kainan Steel Tube Wks.)
Kakogawa
Kobe Steel, Ltd.
(Kakogawa Wks.)
Kamaishi
Nippon Steel Corp.
(Kamaishi Wks.)
Kashima
Sumitomo Metal Industries, Ltd.
(Kashima Steel Wks.)
Kawasaki
Nippon Kokan K.K.
(Kehin Wks.)
Kimitsu City
Nippon Steel Corp.
(Kimitsu Wks.)
Kobe
Kawasaki Steel Corp.
(Hanshin Wks.)
Kobe Steel, Ltd.
(Industrial Mach. Plant)
(Kobe Wks.)
Kochi
Kobe Steel, Ltd.
(Kochi Plant)
Kurashiki
Kawasaki Steel Corp.
(Mizushima Wks.)
Kure
Kobe Steel, Ltd.
(Marine Parts Plant)
Moji-ku
Kobe Steel, Ltd.
(Moji Plant)
Mooka
Kobe Steel, Ltd.
(Mooka Plant)
Muroran
Nippon Steel Corp.
(Muroran Wks.)
Nagoya
Kobe Steel, Ltd.
(Nagoya Plant)
Niigata
Nippon Kokan K.K.
(Niigata Wks.)
Niihama
Kobe Steel, Ltd.
(Chemical Equipment Plant)
(Heavy Machinery Plant)
(Rotating Machinery Plant)
(Steel Casting and Forging Plant)
Oita City
Nippon Steel Corp.
(Oita Wks.)
Osaka
Sumitomo Metal Industries, Ltd.
(Osaka Steel Wks.)
Saijo-cho
Kobe Steel, Ltd.
(Saijo Plant)
Sakai City
Nippon Steel Corp.
(Sakai Wks.)
Shimminato
Nippon Kokan K.K.
(Toyama Wks.)
Shimonoseki
Kobe Steel, Ltd.
(Chofu Plant)
(Chofu-kita Plant)
Tokai City
Nippon Steel Corp.
(Nagoya Wks.)
Tokyo
Kawasaki Steel Corp.
Kobe Steel, Ltd.
Nippon Kokan K.K.
Nippon Steel Corp.
(Tokyo Wks.)
Sumitomo Metal Industries, Ltd.
Wakayama
Sumitomo Metal Industries, Ltd.
(Wakayama Steel Wks.)
Yawata
Nippon Steel Corp.
(Yawata Wks.)

KOREA

Pohang
Pohang Iron & Steel Co.,
Ltd. (POSCO)

LUXEMBOURG

Luxembourg
Arbed S.A.

NETHERLANDS

Beverwijk
Hoogovens Groep BV

NEW ZEALAND

Auckland
Broken Hill Pty. Co., Ltd., The

NORWAY

Mo
AS Norsk Jernverk

PHILIPPINES

Iligan City
National Steel Corp.
Makati, Metro Manila
Broken Hill Pty. Co., Ltd., The
National Steel Corp.

SOUTH AFRICA

Newcastle, Natal
Iscor Limited
(Iscor Wks.)
Pretoria, Transvaal
Iscor Limited
(Iscor Wks.)
Vanderbijlpark, Transvaal
Iscor Limited
(Iscor Wks.)
Vereeniging, Transvaal
Union Steel Corp. (of
South Africa) Ltd., The

SPAIN

Aviles
ENSIDESA-Empresa Nacional
Siderurgica, S.A.
Baracaldo (Vizcaya)
AHV-Altos Hornos de Vizcaya, S.A.
Gijon
ENSIDESA-Empresa Nacional
Siderurgica, S.A.
Madrid
Altos Hornos Del Mediterraneo,
S.A.
ENSIDESA-Empresa Nacional
Siderurgica, S.A.
Sagunto
Altos Hornos Del Mediterraneo,
S.A.

SWEDEN

Avesta
Avesta Jernverks Aktiebolag
Borlange
SSAB Svenskt Stal Aktiebolag (Swedish
Steel Corp.)
(Dobel AB)
(Domnarvet Div.)
(Special Products Div.)
Danderyd
AB SKF
(SKF Steel)
Fagersta
Fagersta AB
Goteborg
AB SKF
Grangesberg
SSAB Svenskt Stal Aktiebolag (Swedish
Steel Corp.)
(Iron-ore Mines Div.)
Hagfors
Uddeholms Aktiebolag
Kolsva
Kohlswa Jernverks Aktiebolag
Lesjofors
Lesjofors AB
Lulea
SSAB Svenskt Stal Aktiebolag (Swedish
Steel Corp.)
(Coke Plant Div.)
(Metallurgy Div.)
(Plannja AB)
(Profile Div.)
Oxelosund
SSAB Svenskt Stal Aktiebolag (Swedish
Steel Corp.)
(Heavy Plate Div.)
Sandviken
Sandvik AB
Stockholm
SSAB Svenskt Stal Aktiebolag (Swedish
Steel Corp.)
Surahammar
Surahammars Bruks AB

TAIWAN

Kaohsiung
China Steel Corp.

TRINIDAD and TOBAGO

Couva
Iron & Steel Co. of
Trinidad and Tobago Ltd.

TURKEY

Eregli
Eregli Iron and Steel Co.

UNITED KINGDOM

London
British Steel Corp.
(British Steel Corp. (Int'l.) Ltd.)
Broken Hill Pty. Co., Ltd., The
Sheffield
Sheffield Forgemasters Ltd.

VENEZUELA

Bolivar
SIDOR-C.V.G. Siderurgica
del Orinoco, C.A.
(Plant)
Caracas
SIDOR-C.V.G. Siderurgica
del Orinoco, C.A.

U. S. A.

ALABAMA

Birmingham
- Republic Steel Corp.
  - (Southern District, Thomas Works, Flat Rolled Products Group)

Fairfield
- United States Steel Corp.
  - (Fairfield Works)

Gadsden
- Republic Steel Corp.
  - (Southern District, Gulfsteel Works, Flat Rolled Products Group)

Selma
- Interlake, Inc.
  - (Alabama Metallurgical Corp.)

CALIFORNIA

Lodi
- Interlake, Inc.
  - (Lodi Fab Industries, Inc.)

Los Angeles
- Cyclops Corp.
  - (Elwin G. Smith Div., Los Angeles Plant)
- Republic Steel Corp.
  - (Union Drawn Steel Div., Los Angeles Plant)

Pittsburg
- Interlake, Inc.
  - (Pittsburg Plant)
- United States Steel Corp.
  - (Pittsburg Works)

Torrance
- Armco Inc.
  - (National Supply Co., Div. Armco)

COLORADO

Pueblo
- CF&I Steel Corp.
  - (Mining Dept.)
  - (Pueblo Plant)
  - (Subsidiary, The Colorado & Wyoming Railway Co.)

CONNECTICUT

East Hartford
- Republic Steel Corp.
  - (Union Drawn Steel Div., Hartford Plant)

Hamden (New Haven)
- Cyclops Corp.
  - (Eastern Plant)

Willimantic
- Jones & Laughlin Steel Corp.
  - (Willimantic Cold Finish Bar Plant)

GEORGIA

Cedar Springs
- Republic Steel Corp.
  - (Georgia Tubing Corp.)

ILLINOIS

Burr Ridge
- Interlake, Inc.
  - (Acme Packaging and Matl. Hdlg. and Storage Prods. Divs.)
  - (Matl. Hdlg. and Storage Prods. Div.)

Chicago
- Inland Steel Co.
- Interlake, Inc.
  - (Chicago Plant)
  - (Iron and Steel Div.)
  - (Manufacturing and Processing Plant)
  - (Riverdale Plant)
- Republic Steel Corp.
  - (Chicago District, Bar Products Group)
  - (Chicago Plant, Tubular Products Group)
- United States Steel Corp.
  - (South Works)

Granite City
- National Steel Corp.
  - (Granite City Steel Div.)

Hennepin
- Jones & Laughlin Steel Corp.
  - (Hennepin Works)

Oak Brook
- Interlake, Inc.

Oak Forest
- Interlake, Inc.
  - (Acme Packaging Div.)

Pontiac
- Interlake, Inc.
  - (Pontiac Plant)

INDIANA

Chesterton
- Bethlehem Steel Corp.
  - (Burns Harbor Plant)

East Chicago
- Inland Steel Co.
  - (Indiana Harbor Works)
- Jones & Laughlin Steel Corp.
  - (Indiana Harbor Works)

Gary
- Republic Steel Corp.
  - (Union Drawn Steel Div., Gary Plant)
- United States Steel Corp.
  - (Gary Works)
  - (USS Tubing Specialties)

Hammond
- Jones & Laughlin Steel Corp.
  - (Hammond Cold Finish Bar Plant)

Portage
- National Steel Corp.
  - (Midwest Steel Div.)

IOWA

Wilton
- Jones & Laughlin Steel Corp.
  - (Subsidiary, Midwest Precision Steel Co.)

KANSAS

Wichita
- Jones & Laughlin Steel Corp.
  - (Subsidiary, Central States Precision Steel Co.)

KENTUCKY

Ashland
- Armco Inc.
  - (Ashland Works)

Shepherdsville
- Interlake, Inc.
  - (A. J. Bayer Co.)

MARYLAND

Baltimore
- Armco Inc.
  - (Stainless Steel Div., Baltimore Works)

Sparrows Point
- Bethlehem Steel Corp.
  - (Sparrows Point Plant)

MICHIGAN

Dearborn
- Rouge Steel Co.
- Sharon Steel Corp.
  - (Dearborn Div.)

Detroit
- Cyclops Corp.
  - (Detroit Plant)
  - (Detroit Strip Div.)
- Jones & Laughlin Steel Corp.
  - (Detroit Plant)
- McLouth Steel Products Corp.
- National Steel Corp.
  - (Great Lakes Steel Div.)

Ferndale
- Republic Steel Corp.
  - (Detroit Plant, Tubular Products Group)

Gibraltar
- McLouth Steel Products Corp.
  - (Gibraltar Mill)

Trenton
- McLouth Steel Products Corp.
  - (Trenton Mill)

MINNESOTA

Minneapolis
- Cyclops Corp.
  - (Sawmill Tubular Div., Twin City Plant)

MISSISSIPPI

Gulfport
- Jones & Laughlin Steel Corp.
  - (Subsidiary, Southern Precision Steel Co.)

MISSOURI

Kansas City
- Armco Inc.
  - (Midwestern Steel Div., Kansas City Works)

St. Louis
- National Inter-Tech, Inc., a National Intergroup, Inc. Co.

NEW JERSEY

Alco
- Jones & Laughlin Steel Corp.
  - (Subsidiary, Mid-Atlantic Precision Steel Co.)

Riverton
- Interlake, Inc.
  - (Hoeganaes Corp.)

Rockleigh
- Interlake, Inc.
  - (Subsidiary, Arwood Corp.)

Union
- Sharon Steel Corp.
  - (Subsidiary, Union Steel Corp.)

NEW YORK

Brooklyn
- Republic Steel Corp.
  - (Brooklyn Plant, Tubular Products Group)

Buffalo
- Republic Steel Corp.
  - (Buffalo District)

Lackawanna
- Bethlehem Steel Corp.

New York
- CF&I Steel Corp.

Owego
- Republic Steel Corp.
  - (Owego Plant, Drainage Products Div.)

NORTH CAROLINA

Charlotte
- Republic Steel Corp.
  - (Charlotte Plant, Drainage Products Div.)

OHIO

Beverly
- Interlake, Inc.
  - (Beverly Plant)
  - (Globe Metallurgical Div.)

Cambridge
- Cyclops Corp.
  - (Elwin G. Smith Div., Cambridge Plant)

Campbell
- Jones & Laughlin Steel Corp.
  - (Campbell Works)

Canton
- Republic Steel Corp.
  - (Canton & Fairhope Plants, Drainage Products Div.)
  - (Canton Plant, Automated Storage Systems Div.)
  - (Canton Plant, Storage Systems Div.)
  - (Central Alloy District, Bar Products Group)

Cleveland
- Jones & Laughlin Steel Corp.
  - (Cleveland Works)
- Republic Steel Corp.
  - (Bar Products Group)
  - (Cleveland District, Flat Rolled Products Group)
  - (Cleveland Plant, Tubular Products Group)

Coshocton
- Cyclops Corp.
  - (Universal-Cyclops Specialty Steel Div., Coshocton Plant)

Dover
- Cyclops Corp.
  - (Empire-Detroit Steel Div., Dover Plant)

Elyria
Republic Steel Corp.
(Elyria Plant, Tubular Products Group) . . . .
Lorain
United States Steel Corp.
(Lorain-Cuyahoga Works) . . . .
Louisville
Jones & Laughlin Steel Corp.
(Louisville Plant) . . . .
Mansfield
Cyclops Corp.
(Empire-Detroit Steel Div., Mansfield Plant) . . . .
Martins Ferry
Wheeling-Pittsburgh Steel Corp.
(Martins Ferry Plant) . . . .
Massillon
Republic Steel Corp.
(Central Alloy District, Bar Products Group) . . . .
(Enduro Products Group) . . . .
(Union Drawn Steel Div.) . . . .
(Union Drawn Steel Div., Massillon Plant) . . . .
Middletown
Armco Inc. . . . .
(Middletown Works) . . . .
Niles
Republic Steel Corp.
(Mahoning Valley District, Flat Rolled Products Group) . . . .
Pepper Pike
Republic Steel Corp.
(Manufacturing Group) . . . .
Steubenville
Wheeling-Pittsburgh Steel Corp.
(Steubenville Plant) . . . .
Van Wert
Republic Steel Corp.
(Republic Buildings Corp.) . . . .
Warren
Republic Steel Corp.
(Mahoning Valley District, Flat Rolled Products Group) . . . .
Sharon Steel Corp.
(Brainard Strapping Div.) . . . .
Yorkville
Wheeling-Pittsburgh Steel Corp.
(Yorkville Plant) . . . .
Youngstown
Jones & Laughlin Steel Corp.
(Mahoning Cold Finished Bar Plant) . . . .
Republic Steel Corp.
(Youngstown Plant, Tubular Products Group) . . . .
Zanesville
Armco Inc.
(Zanesville Plant) . . . .

OREGON

Portland
Oregon Steel Mills . . . .

PENNSYLVANIA

Aliquippa
Jones & Laughlin Steel Corp.
(Aliquippa Works) . . . .
Allenport
Wheeling-Pittsburgh Steel Corp.
(Allenport Plant) . . . .
Ambridge
Armco Inc.
(Armco Tubular Div.) . . . .
Beaver Falls
Republic Steel Corp.
(Union Drawn Steel Div., Beaver Falls Plant) . . . .
Bethlehem
Bethlehem Steel Corp. . . . .
(Bethlehem Plant) . . . .
Bridgeville
Cyclops Corp.
(Universal-Cyclops Specialty Steel Div., Bridgeville Plant) . . . .
Butler
Armco Inc.
(Electrical Steel Div., Butler/Zanesville Works) . . . . . .
Fairless Hills
United States Steel Corp.
(Fairless Works) . . . .
Farrell
Sharon Steel Corp.
(Steel Div.) . . . .
Greenville
Sharon Steel Corp.
(Damascus Tube Div.) . . . .
Harrisburg
Republic Steel Corp.
(Harrisburg Plant, Drainage Products Div.) . . . .
Heidelberg
Cyclops Corp.
(Elwin G. Smith Div., Heidelberg Plant) . . . .
Homestead
United States Steel Corp.
(Mon Valley Works) . . . .
Johnstown
Bethlehem Steel Corp.
(Bar, Rod and Wire Div.) . . . .
Lebanon
Bethlehem Steel Corp.
(Industrial Fastener Div.) . . . .
Midland
Jones & Laughlin Steel Corp.
(Midland Specialty Steels Plant) . .
Monessen
Wheeling-Pittsburgh Steel Corp.
(Monessen Plant) . . . .
Pittsburgh
Cyclops Corp. . . . .
(Elwin G. Smith Div., Pgh. Plant) .
(Universal-Cyclops Specialty Steel Div., Pgh. Plant) . . . .
Jones & Laughlin Steel Corp. . . . . .
(Pittsburgh Works) . . . .
National Steel Corp., Subsidiary of National Intergroup, Inc. . . . .
United States Steel Corp. . . . .
Wheeling-Pittsburgh Steel Corp. . . .
Sharon
Cyclops Corp.
(Sawhill Tubular Div.) . . . .
Sharon Steel Corp. . . . .
Steelton
Bethlehem Steel Corp.
(Steelton Plant) . . . .
Templeton
Sharon Steel Corp.
(Subsidiary, Carpentertown Coal & Coke Co.) . . . .
Titusville
Cyclops Corp.
(Universal-Cyclops Specialty Steel Div., Titusville Plant) . . . .
Williamsport
Bethlehem Steel Corp.
(Bethlehem Wire Rope Div.) . . . . .

SOUTH CAROLINA

Fountain Inn
Interlake, Inc.
(Intape, Inc.) . . . .
Seneca
Republic Steel Corp.
(Seneca Plant, Drainage Products Div.) . . . .
Sumter
Interlake, Inc.
(Acme Strapping Corp.) . . . .

TENNESSEE

Bristol
Republic Steel Corp.
(Bristol Plant, Drainage Products Div.) . . . .
Counce
Republic Steel Corp.
(Counce Plant, Tubular Products Group) . . . .
Gallatin
Interlake, Inc.
(Hoeganaes Corp.) . . . .
Jackson
Republic Steel Corp.
(Republic Builders Products Group) . .

TEXAS

Baytown
United States Steel Corp.
(Texas Works) . . . .
Dallas
Lone Star Steel Co. . . . .
Houston
Cyclops Corp.
(Tex-Tube Div.) . . . .
Lone Star
Lone Star Steel Co. . . . .

UTAH

Provo
United States Steel Corp.
(Geneva Works) . . . .

WASHINGTON

Seattle
Bethlehem Steel Corp.
(Seattle Steel Div.) . . . .

WEST VIRGINIA

Beech Bottom
Wheeling-Pittsburgh Steel Corp.
(Wheeling Corrugating Co.-Div., Beech Bottom Plant) . . . .
Benwood
Wheeling-Pittsburgh Steel Corp.
(Benwood Plant) . . . .
Nitro
Republic Steel Corp.
(Nitro Plant, Container Div.) . . . . . .
Weirton
Weirton Steel Corp. . . . .
Wheeling
Wheeling-Pittsburgh Steel Corp.
(Wheeling Corrugating Co.-Div., LaBelle Works) . . . .

WISCONSIN

Racine
Interlake, Inc.
(Racine Plant) . . . .

CANADA

ALBERTA

Camrose
Stelco Inc.
(Camrose Works) . . . .
Edmonton
Stelco Inc.
(Edmonton Steel Works and Finishing Works) . . . .

NOVA SCOTIA

Sydney
Sydney Steel Corp. . . . .

ONTARIO

Brantford
Stelco Inc.
(Brantford Works) . . . .
Burlington
Stelco Inc.
(Burlington Works) . . . .
(Research Centre) . . . .
Gananoque
Stelco Inc.
(Gananoque Works) . . . .
Hamilton
Dofasco Inc. . . . .
Republic Steel Corp.
(Union Drawn Steel Co. Ltd., Hamilton Plant) . . . .
Stelco Inc.
(Canada Works) . . . .
(Canadian Drawn Works) . . . . .
(Frost Works) . . . .
(Hilton Works) . . . .
(Parkdale Works) . . . .
Nanticoke
Stelco Inc.
(Lake Erie Works) . . . .
Rexdale
Sidbec-Dosco Inc.
(Etobicoke Works) . . . .
Sault Ste. Marie
Algoma Steel Corp., Ltd., The . . . . . .
(Steelworks Div.) . . . .
(Tube Div.) . . . .
Toronto
Stelco Inc. . . . .
(Swansea Works) . . . .
Welland
Stelco Inc.
(Page-Hersey Works) . . . .
(Welland Tube Works) . . . .

QUEBEC

Contrecoeur
Sidbec-Dosco Inc.
(Contrecoeur Works) . . . .

Stelco Inc.
(McMaster Works) ....

Lachine
Stelco Inc.
(Dominion Works) ....

LaSalle
Sidbec-Dosco Inc.
(Truscon Works) ....

Longueuil
Sidbec-Dosco Inc.
(Longueuil Works) ....

Montreal
Sidbec-Dosco Inc. ....
(Montreal Works) ....
Stelco Inc.
(Notre Dame Works) ....
(St. Henry Works) ....

SASKATCHEWAN

Regina
Stelco Fabricators Ltd. ....

MEXICO

Cardenas, Michoacan
SICARTSA-Siderurgica Lazaro
Cardenas-Las Truchas, S.A. (Sidermex,
S.A.C.V.)
(Plant) ....

Mexico City
Altos Hornos de Mexico, S.A. ....
SICARTSA-Siderurgica Lazaro
Cardenas-Las Truchas, S.A. (Sidermex,
S.A.C.V.) ....

Monclova, Coahuila
Altos Hornos de Mexico, S.A. ....

2. SELECTED EQUIPMENT SUPPLIERS

1. ORE PREPARATION (stackers/reclaimers, pelletizing plants, etc.)

- Industrias Villares SA, Brazil
- Bethlehem Internat. Engineering Corp., USA
- Daelim Engineering Co Ltd., South Korea
- Simplex Engineering & Foundry Works, India
- Sumitomo Heavy Industries Ltd., Japan
- Krupp Industrie- und Stahlbau, Germany FR
- Italimpianti - Stá Italiana Impianti pA, Italy
- Lurgi Chemie und Hüttentechnik GmbH, Germany FR
- Davy Mc Kee (Minerals & Metals) Ltd., UK
- Skodaexport Foreign Trade Corp., Czechoslovakia
- Vöest-Alpine AG, Austria

2. RAW MATERIALS PROCESSING (scrap shears, scrap balling presses, scrap shredders, scrap granulators/separators, scrap preheaters etc.)

- Engineering Equipment inc., Philippines
- Danieli & C SpA, Italy
- Huta Zygmunt, Poland
- Usimec - Usiminas Mecânica SA, Brazil
- Bethlehem International Engineering Corp, U.S.A.
- SA Ateliers du Thirian, Belgium
- Nikko Industry Co Ltd., Japan
- Sumitomo Heavy Industries Ltd., Japan
- Thyssen AG Henschel, Germany FR
- Westerworks Engineers Ltd., India
- AB Svenska Fläktfabriken, Sweden

3. DIRECT REDUCTION PLANTS

- ACEC - Ateliers de Constuctions Electriques de Charleroi SA, Belgium
- Bechtel Inc, U.S.A.
- Danieli & C SpA, Italy
- Korf Engineering GmbH, Germany FR
- Midrex Corp., U.S.A.
- HYL, Mexico
- Kawasaki Steel Corp., Japan
- Sofresid, France
- Krupp Polysius AG, Germany FR
- Davy Mc Kee Corp., USA
- Lurgi Chemie und Hüttentechnik GmbH, Germany FR

4. MELTING AND REFINING FURNACES (Electric arc furnaces, electro-slag refining plants, ladle refining units etc.)

- Asea AB, Sweden
- Brown Boveri, Switzerland
- Clemex SA, Mexico
- Bethlehem International Engineering Crop., U.S.A.
- Kobe Steel, Japan
- Clesid, Creusot Loire Equipments Siderurgiques, France
- Voest Alpine AG, Austria
- Chang Ching Iron Works Co Ltd., Taiwan
- Ferrco Engineering, Canada
- BSC Associated Products Group, Machynis Works, U.K.
- Davy Mc Kee (Minerals & Metals) Ltd., U.K.
- Kawasaki Steel Crop., Japan
- Usimec - Usiminas Mecânica SA, Brazil
- Steel Plant Pvt Ltd., India
- Nikex Hungarian Trading Co., Hungary

5. CONTINUOUS CASTING MACHINES (Billets, blooms, slabs, rounds, wire rod, bars, horizontal)

- Mecan Arbed Sarl, Luxenbourg
- Kawasaki Steel Corp., Japan
- Bethlehem International Engineering Corp., U.S.A.
- Skodaexport Foreign Trade Corp., Czechoslovakia
- Concast AG, Switzerland
- Huta Zygmunt, Poland
- Mitshubishi Heavy Industries Ltd., Japan
- Rokop Davy Ltd., U.S.A.
- Hazelett Strip - Casting Corp., U.S.A.
- Danieli & C SpA., Italy
- VOest-Alpine AG, Austria
- Samsung Heavy Industries Co., Ltd., South Korea
- Korf Engineering GmbH., Germany F.R.
- Technica - Guss GmbH., Germany F.R.
- NKK - Nippon Kokan KK, Japan
- INNSE - Innocenti Santeustacchio SpA., Italy
- Erhardt Proyectos y Obras SA, Spain
- Machinoexport, V/O U.S.S.R.

6. REHEATING FURNACES (Walking beam furnaces, pusher furnaces etc.)

- Alarko Sanayi ve Ticarret AS, Turkey
- Iprolam, Romania
- Nikko Industry Co Ltd., Japan
- Clemex SA, Mexico
- Engineering Projects Ltd (EPI), India
- VIO Energomachexport, U.S.S.R.
- Estel Technical Services BV, Netherlands
- Dr. Schmitz & Apelt Argentina SA, Argentina
- Wistra Ofenbau GmbH, Germany F.R.
- Daido Steel Co. Ltd., Japan
- BWG - Bergwerk und Walzwerk Maschinenbau GmbH, Germany F.R.
- Fofumi SA, France
- Loftus Furnace Co., U.S.A.
- Mechatherm Engineering Ltd., U.K.
- Salem Furance Co., U.S.A.
- Hotwork Inc., U.S.A.
- Didier Engineering, Germany F.R.
- Birlec Division, U.K.

7. ROLLING MILLS (billets, sections, rods, bars, tubes, angles, wire, plates, strip, etc.)

- Mannesmann Demag Metallverformung, Germany F.R.
- Pullman Swindell, U.S.A.
- Davy-Loewy Ltd., U.S.A.
- Krupp Industrie- und Stahlbau, Germany F.R.
- SMS - Schloemann-Siemag AG, Germany F.R.
- Bethlehem International Engineering Corp., U.S.A.
- BSC Associated Products Group, Machynis Works, U.K.
- Danieli & C SpA, Italy
- Kawasaki Steel Corp., Japan
- Kobe Steel Ltd., Japan
- Mitshubishi Heavy Industries Ltd., Japan
- NKK - Nippon Kokan KK, Japan
- T. Sendzimir Inc., U.S.A.
- Vöest-Alpine AG, Austria
- Clemex, Mexico
- Iprolam, Romania
- Huta Zygmunt, Poland
- Friul Engineering SpA, Italy
- Sofresid, France
- Dominian Engineering Works, Canada
- Chang Shing Iron Works Co Ltd., Taiwan
- Josef Fröhling GmbH Walzwerkmaschinenbau,Germany F.R.

8. AUXILIARY ROLLING & FINISHING (shears, saws, scarfing equipment, grinding and surface conditioning equipment, straighteners, slitting equipment, cold drawing plant etc.)

- Davy-Loewy Ltd., U.K.
- Danieli & CSpA, Italy
- Korf Engineering GmbH, Germany F.R.
- NKK - Nippon Kokan KK, Japan
- Innobra - Innocenti Industria Mecânica SA, Brazil
- American Electric Fusion Co Inc., U.S.A.
- Iowa Precision Industries, U.S.A.
- Zdas - Zdarskè Strojirny Slèvàrny, Czechoslovakia
- Kawasaki Steel Corp. Japan
- Cockerill SA, Belgium
- Machinefabrik Bewo BV, Netherlands
- Colly SA, France
- Pusan Steel Pipe Industrial Co Ltd., South Korea
- Salem Engineering Co Ltd., U.K.
- Steel Rolling Mills of Hindustran Pvt Ltd, India
- Sack GmbH, Germany F.R.
- COM SpA, Italy
- Omnitrade Machinery, Canada
- IHI - Ishikawajima-Harima Heavy Indutries Co. Ltd., Japan
- Sencor - SendzimirEngineering Corp. U.S.A.
- Huta Zygmunt, Poland
- Lämneå Bruck AB, Sweden

9, POLLUTION CONTROL (wet electrostatic precipitators, dry electrostatic precipitators, fabric filters, Venturi scrubbers, spray towers, cyclones, water pollution control equipment, acid recovery equipment etc.)

- AAF - American Air Filter Co Inc., U.S.A.
- Deutsche Babcock AG,Germany F.R.
- Ipsco Sales & Manufacturing Ltd, New Zealand
- KHD Humboldt Wedag AG, Germany F.R.
- Nakashima Manufacturing Co Ltd., Japan
- Usimec - Usiminas Mecânica SA, Brazil
- Dust Control Equipment Ltd., U.K.
- Kawasaki Steel Corp., Japan
- Nikex Hungarian Trading Co., Hungary
- AB Svenska Fläktfabriken, Sweden
- Techint - Cia Tecnica Internazionale SpA, Italy
- Envirotech Corp., U.S.A.
- Elkem A/S, Norway
- VAW - Vereinigte Aluminium-Werke AG, Germany F.R.
- Lufttechnik Bayreuth RUskamp GmbH, Germany F.R.
- Babcock Woodall-Duckham Ltd., U.K.
- Maquiras de Proceso SA de CV, Mexico
- Italba SpA, Italy
- Ciba - Geigy AG, Switzerland
- Bethlehem International Engineering Corp, U.S.A.
- Keramchemie, Germany F.R.
- Holyhead Engineering Co Ltd., U.K.

10. REFRACTORIES (Magnesia base, dolomite-base, silica-base, alumino-silicate-base, high alumina-base, silicon carbide, zircon-base, bricks, fibre products, etc.)

- CEC Refractories, France
- Didier-Werke AG, Germany F.R.
- Dolomit Werke GmbH, Germany F.R.
- Kerametal Foreign Trade Co Ltd., Czechoslovakia
- Magnesital-Feuerfest GmbH, Germany F.R.
- Refractories Mexicanos SA, Mexico
- Refractorios Peruanos SA, Peru
- Kawasaki Steel Corp., Japan
- British Smelter Construction Ltd., U.K.
- Key Metals & Minerals Engineering Corp., U.S.A.
- Nippon Crusible Co Ltd., Japan
- Ozköseoglu Isi Sanayii ve Ticaret AS, Turkey
- SEPR - Sté Européen des Produits Réfractaires, France
- Chamotte Gibbons continenetal BV, Netherlands
- Davy Mc Kee Corp, U.S.A.
- Rami Refractory Specialties Ltd., Israel
- Sž Zelegarna Store, Yugoslavia
- Refractory Furnace Linings Ltd., U.K.
- Didier Taylor Belgium S.A., Belgium
- Bethlehem International Enfineering Corp., U.S.A.
- Borgestad Fabrikker A/S, Norway

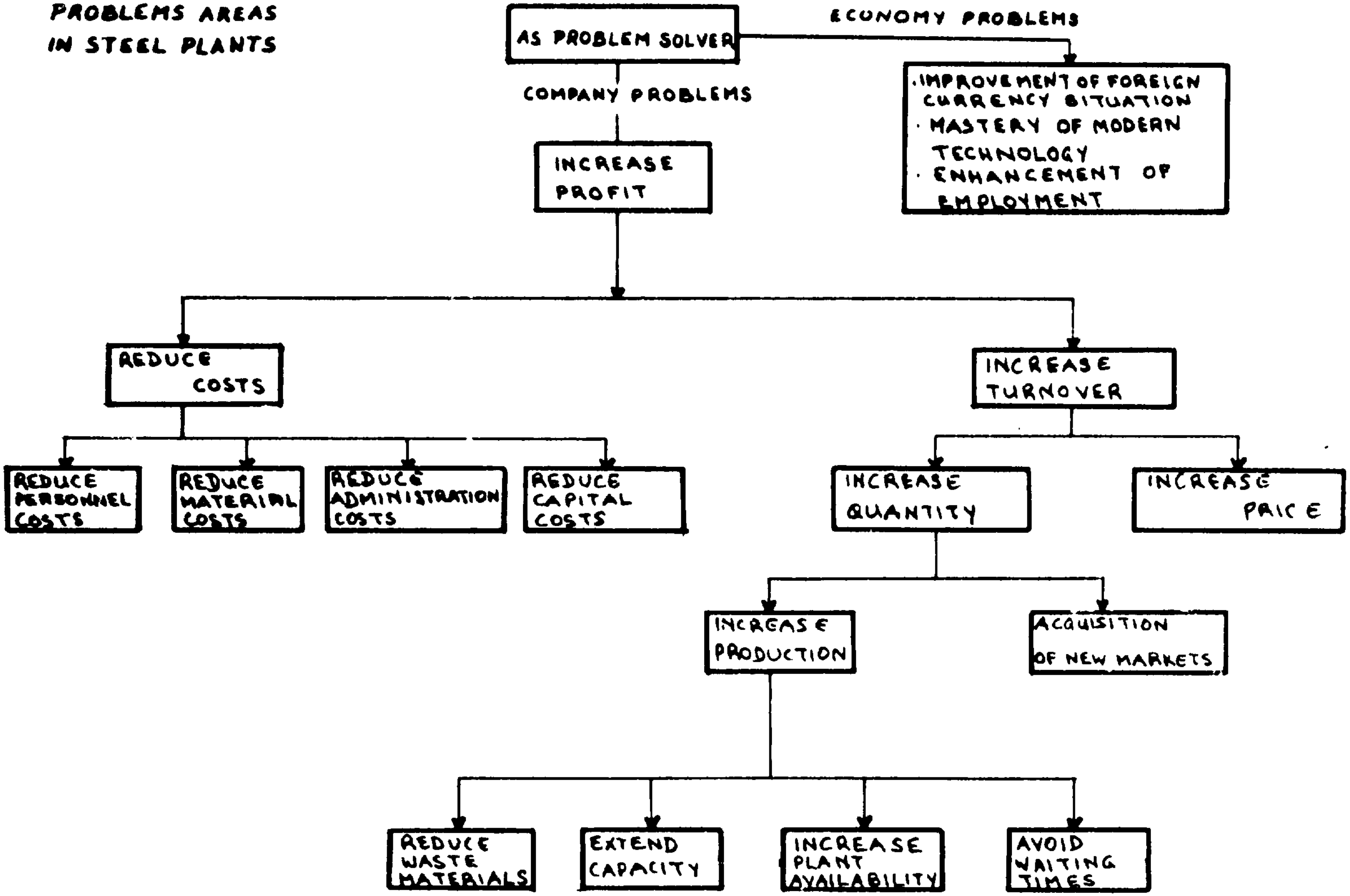
11. GENERAL (EOT Cranes, slag granulators, water-cooled panels for EAFs, hot metal transfer cars, graphite elctrodes, moulds for continuous casting machines, ladles, etc.)

- Cleveland Crane & Engineering Co., U.S.A.
- NKK - Nippon Kokan KK, Japan
- Krupp Indutrie & Stahlbau, Germany F.R.
- Ely Crane & Hoist Co., U.S.A.
- Jessop & Co Ltd., India
- Danieli & C SpA, Italy
- Pioneer Equipment Co Pvt Ltd., India
- Vöest-Alpine AG, Austria
- Mecan Arbed Sarl, Luxenbourg
- Delatte-Levivier SA, France
- Cosim SA, Spain
- Andco Inc, U.S.A.
- BSC Cumbria Engineering, U.K.
- Leybold - Heraeus GmbH, Germany F.R.
- MAN Maschinenfabrik Augsburg - Nürnberg AG, Germany F.R.
- Uniteers Vickers Pte Ltd., Singapore
- Dominion Engineering Works, Canada
- Cleveland Crane & Engineering Co, U.S.A.
- Skodaexport Foreign Trade Corp., Czechoslavakia
- Siegerländer Kupferwerke GmbH, Germany F.R.
- Saar-Metallwerke GmbH, Germany F.R.
- Sumitomo Heavy Industries Ltd, Japan
- Union Carbide Corp. U.S.A.
- Airco Carbon Division, U,S.A.
- Southern Eelctrodes Ltd., India

Appendix - 7

Problems areas in mini steel plants

Fig. 1:
PROBLEMS AREAS
IN STEEL PLANTS



(Source: Steel Times International)

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