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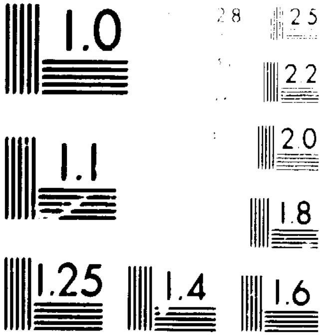
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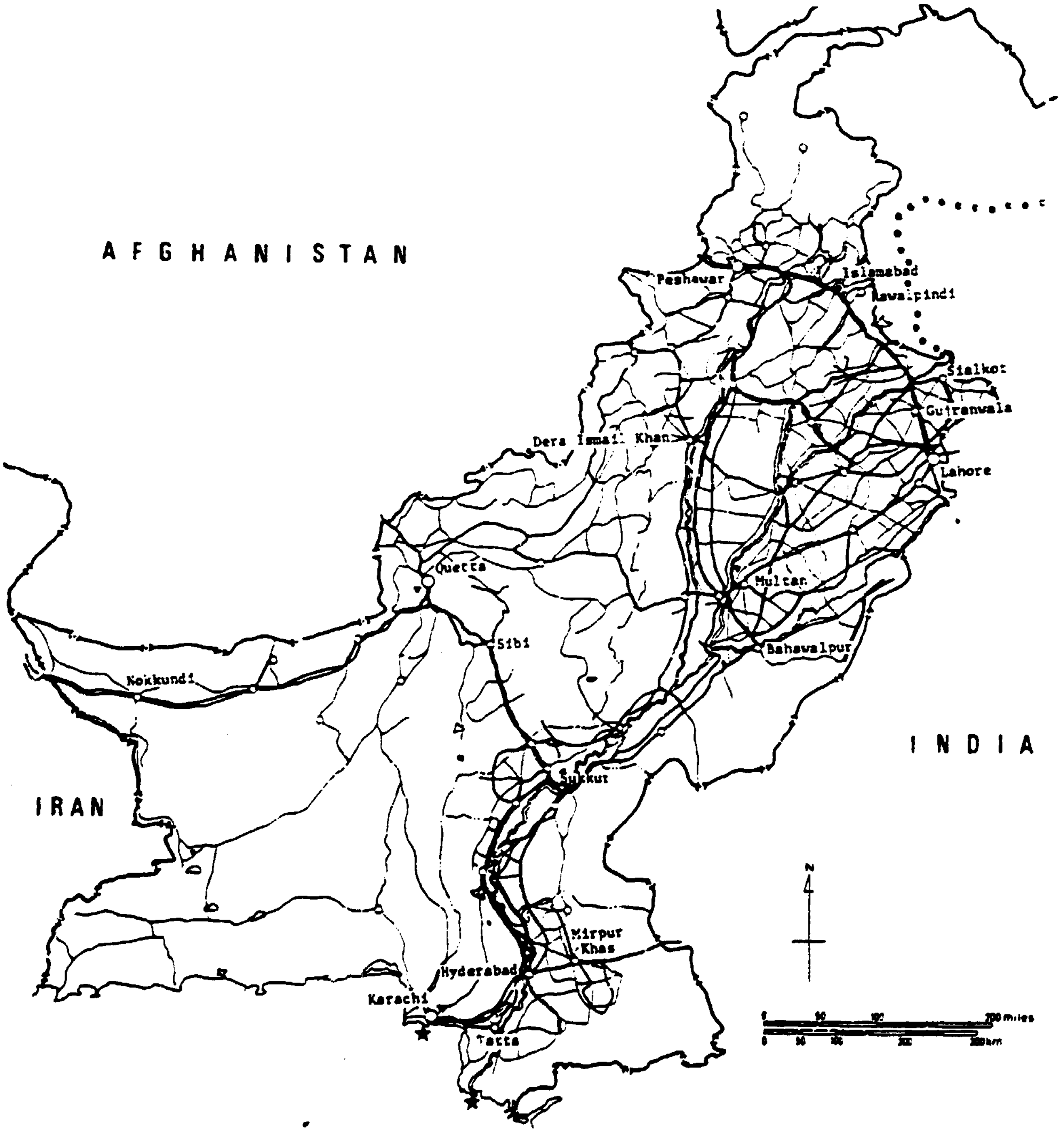
THE MASTER PLAN
FOR
THE IRON AND STEEL INDUSTRY
IN
PAKISTAN

(VOLUME I)

NOV. 1981

KOBE STEEL, LTD.

MAP OF PAKISTAN



FOREWORD

Preparation of the Master Plan for the iron and Steel Industry in Pakistan has been made by the Experts of Kobe Steel Limited based on Contract No. T81/02 between the United Nations Industrial Development Organization (the UNIDO) and Kobe Steel Limited (the Contractor) dated 2 Feb., 1981.

The aims of the Master Plan are:

a) to study the present situation in Pakistan as regards iron and steel production and requirements, and to evaluate relevant projections for the coming 20 - 30 (2000 - 2010);

b) to recommend measures to be taken for the full and proper utilization of installed melting capacities;

c) to recommend processes and technologies for future production units providing, inter alia, suggestions - cum - justifications for the most suitable sites for such production units;

d) to survey and evaluate possible capital goods industries which might be established in Pakistan on the basis of the local production of these basic metals and their alloys.

e) to prepare a detailed report including a programme for the subsequent implementation of the Project and specify, inter alia, financial, staff training and management requirements and possibilities.

In order to attain all such aims, the fact-finding surveys by the Experts were made twice in Pakistan over a period of time amounting to 6 man-months from February to June in 1981.

With cooperation of the counterparts, i.e. the Government officials of Ministry of Production and the Representatives of the UNDP in Pakistan, a large amount of the information and data relevant to the aims had been obtained from various fields during the surveys. Afterwards, such information and data were appraised and evaluated by the Experts' home study, and as a result the Draft Final Report of the Master Plan was prepared and forwarded to the UNIDO in August 1981.

The Contractor was informed that the UNIDO had reviewed the Draft Final Report, which was found acceptable in November 1981. At the same time, the Experts received the substantive comments on the Draft Final Report from the UNIDO and was requested to give due consideration to the said comments on the preparation of the Final Report of the Master Plan.

Under these circumstances, the Final Report of the Master Plan has been elaborately prepared to achieve the aim and end.

The Contractor has the pleasure of fullfilling the implementation of the Final Report of the Master Plan for the Iron and Steel Industry in Pakistan.

27 November, 1981,

Kobe Steel, Limited.

First Study Team Itinerary in Pakistan

DATE		LOCATION	PLACE VISITED
Feb. 15	Sun.	Islamabad	UNIDO
Feb. 16	Mon.	Islamabad	Ministry of Production
Feb. 17	Tue.	Islamabad	Ministry of Production
Feb. 18	Wed.	Islamabad	Planning Commission (Transport)
			Ministry of Petroleum & Natural Resources
			Ministry of Industries
Feb. 19	Thu.	Islamabad	Chief Controller of Import & Export
			Economic Affairs Division
			Planning Commission (Physical Planning and Housing)
			Munistry of Communications
Feb. 21	Sat.	Islamabad	Planning Commission (Industry and Commerce)
		Taxila	Heavy Mechanical Complex Ltd.
			Heavy Foundry & Forge Ltd.

DATE		LOCATION	PLACE VISITED
Feb. 22	Sun.	Peshawar	Directorate of Industries & Mineral Development, NWFP
			Frontier Industries & Corporative
		Nowshera	Nowshera Engineering Co., Ltd.
Feb. 24	Tue.	Karachi	Pakistan Steel
Feb. 25	Wed.	Karachi	Pakistan Steel
Feb. 26	Thu.	Karachi	Pakistan Steel Port Bin Qasim Authority
Feb. 28	Sat.	Karachi	Hardware Manufacturing Co., Ltd.
			Ahmed Enterprise Ltd.
			Ahmed Investment Ltd.
			Statistics Division, Planning and Development
			Pakistan Industrial Development Corporation
			Pakistan Automobile Corp., Ltd.
			Japan External Trade Research Organization, Karachi Office

DATE			LOCATION	PLACE VISITED
Mar.	1	Sun.	Karachi	Controller of Import & Export
				Pakistan Mineral Development Corporation
				Karachi Shipyard & Engineering Works Ltd.
				Trading Corporation of Pakistan Ltd.
				Hashimi Can Co., Ltd.
				Pakistan Machine Tool Factory Ltd.
Mar.	2	Mon.	Karachi	Metropolitan Steel Corp., Ltd.
				Amie Investment Ltd.
				National Construction Ltd.
				Pakistan Shipbreakers Association
				State Engineering Corp. Ltd.
Mar.	3	Tue.	Karachi	Karachi Pipe Mills Ltd.
				Pakistan Steel (City Office)
				Indus Steel Pipes Ltd.
				Asian General Agencies Ltd.
				Sind Engineering Ltd.
				Awami Autos Ltd.
Mar.	4	Wed.	Karachi	Razaque Steel Ltd.
				Quality Steel Works Ltd.
			Quetta	Geological Survey of Pakistan

DATE			LOCATION	PLACE VISITED
Mar.	5	Thu.	Karachi	Special Steels of Pakistan Ltd.
			Quetta	Baluchistan Development Authority
				Dept. of Industries, Commerce, Mineral Resources and Labour, Govt. of Baluchistan
Mar.	7	Sat.	Lahore	Pakistan Steel Melters Association
				Javed Pervez Co., Ltd.
				Nawaz Shehbaz Ltd.
				Pakistan Steel Re-rolling Mills' Association
				Kamran Steel Re-rolling Mills Ltd.
Mar.	8	Sun.	Lahore	Pakistan Railways (Head Office)
				Ghee Corporation of Pakistan Ltd.
				Pakistan Oil Expellers & Steel Rolling Mills Ltd.
			Kalabagh	Kalabagh (Chichali) Iron Ore Deposit
Mar.	9	Mon.	Lahore	Pakistan Engineering Co., Ltd. (Head Office)
				Pakistan Engineering Co., Ltd. (Badami Bagh Works)
				Pakistan Engineering Co., Ltd. (Kot Lakhpat Works)

DATE		LOCATION	PLACE VISITED
Mar. 10	Tue.	Lahore	Public Works Department
			Water & Power Development Authority
			Metal Advisory Services
			Pakistan Re-rolling Mills' Association
Mar. 11	Wed.	Lahore	Directorate of Industries & Mineral Development, Punjab
			Sui Northern Gas Pipelines Ltd.
			Ittefaq Foundries Ltd.
		Gujranwala	National Pipe Industries Ltd.
			General Ceramic Industry
			Steel Casting Ltd.
			Babar Stainless Steel
			Punjab Small Industry
Mar. 12	Thu.	Lahore	Pakistan Council of Scientific Industrial Research Laboratories
			Punjab Steel Ltd.
			Ittefaq Foundries Ltd.
Mar. 15	Sun.	Islamabad	Ministry of Production
Mar. 16	Mon.	Karachi	Pakistan Steel
			Statistics Division
			Central Publication Branch

Second Study Team Itinerary in Pakistan

DATE		LOCATION	PLACE VISITED
Jun. 8	Mon.	Islamabad	UNIDO Ministry of Production
Jun. 9	Tue.	Islamabad	Planning Commission (Industries & Commerce)
Jun. 10	Wed.	Lahore	Lahore Municipal Corporation Water and Sanitation Agency Aryan Steel Industries Ltd. Laldin & Sons Ltd. Musllin Steel Re-rolling Mills Yonus Brothers Steel Re-rolling Mills Mughal Mechanical Works and Steel Rolling Mills Pakistan Steel Re-rolling Mills' Association
Jun. 11	Thu.	Lahore	Pakistan Engineering Corporation Ltd.
		Gujranwala	Climax Engineering Co., Ltd.
Jun. 14	Sun.	Karachi	Pakistan Steel Mac Donald Layton Co., Ltd. Landhi, Karangi Area - Site Survey -

DATE		LOCATION	PLACE VISITED
Jun. 15	Mon.	Karachi	Karachi Development Authority
			Karachi Electoric Supply Co., Ltd.
			Pakistan Shipbreakers Association
Jun. 16	Tue.	Karachi	Statistics Division
			Pakistan Steel
			Resource Development Corp.
			A.R. Hasami & Co., Ltd.

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Currency Equivalents

Rs	-	Pakistan Rupee
US$	-	A United States Dollar, Rs9.9

Fiscal Year

July to June 30 (beginning from the 1st of July of each calendar year to and ending on the 30th of June in the next calendar year)

1979-80	-	July 1, 1979 to June 30, 1980

Numerical Abbreviations and Conversions

mm	-	millimetre
cm	-	centimetre
m	-	metre
km	-	kilometre
in	-	inch (1 in = 2.54 cm)
ft	-	foot (pl. feet) (1 ft = 0.305 m)
cm^2	-	square centimetre
m^2	-	square metre
km^2	-	square kilometre
m^3	-	cubic metre
Nm^3	-	normal cubic metre
MMm^3	-	million cubic metres
ft^3, cu ft	-	cubic foot (1 ft^3 = 0.0283 m^3)
MMSCF	-	million standard cubic feet

Numerical Abbreviations and Conversions (Cont'd)

g	-	gramme
kg	-	kilogramme
t, tonne	-	metric ton (1 tonne = 1,000 kg)
lb (s)	-	pound (1 lb = 0.454 kg)
sec	-	second
min	-	minute
h	-	hour
d	-	day
mon	-	month
y	-	year
l	-	litre
gal	-	gallon (1 British gallon = 4.546 litre, 1 US gallon = 3.785 litres)
A	-	ampere
V	-	volt
W	-	watt
Hz	-	herz
MW	-	mega watt
kVA	-	kilo volt ampere
MVA	-	mega volt ampere
kWh	-	kilo watt hour
MWh	-	mega watt hour
HP, HP	-	horse power
A.C., A/C	-	alternating current
D.C., D/C	-	direct current
°C	-	degree centigrade

Numerical Abbreviations and Conversions (Cont'd)

kcal	-	kilo calorie
Gcal	-	giga calorie
BTU	-	British thermal unit (1 BTU = 0.252k cal)
%	-	per cent
tr	-	trace
ppm	-	parts per million
kg/m^3	-	kilogramme per cubic metre
kg/t	-	kilogramme per tonne
mmAq	-	mm aquar (= water)
m/sec	-	metre per second
t/day	-	tonne per day
tpy, t/y	-	tonne per year

Abbreviations of Public Organizations

HFF	-	Heavy Foundry and Forge
HMC	-	Heavy Mechanical Complex
KESC	-	Karachi Electric Supply Corporation
KGSC	-	Karachi Gas Supply Company
KSEW	-	Karachi Shipyard & Engineering Works
NWFP	-	North West Frontier Province
OGDC	-	Oil and Gas Development Corporation
PECO	-	Pakistan Enginering Company Limited
PCSIR	-	Pakistan Council of Scientific and Industrial Research Laboratories

Abbreviations of Public Organizations (Cont'd)

PIDC	-	Pakistan Industrial Development Corporation Limited
PMDC	-	Pakistan Mineral Development Corporation Limited
PMTF	-	Pakistan Machine & Tool Factory
SSP	-	Special Steels of Pakistan Limited
TCP	-	Trading Corporation of Pakistan
WAPDA	-	Water & Power Development Authority

Abbreviations of Other Organizations

AISI	-	American Iron and Steel Institute
DAC	-	Development Assistance Committee
IISI	-	International Iron and Steel Institute
IMF	-	International Monetary Fund
ISIJ	-	Iron and Steel Institute of Japan
JICA	-	Japan International Cooperation Agency
JISF	-	Japan Iron and Steel Federation
JIS	-	Japanese Industrial Standard
OECD	-	Organization for Economic Cooperation and Development
UNIDO	-	United Nations Industrial Development Organization

Other Abbreviations

DWT	-	dead weight tonnage
LDT	-	light displacement tonnage
C&F	-	cost and freight
CIF	-	cost, insurance and freight
ASC	-	apparent steel consumption
CSE	-	crude steel equivalent
GDP	-	gross domestic product
GNP	-	gross national product
SI	-	steel intensity
DCF	-	discounted cash flow
ROI	-	internal rate of return
BF	-	blast furnace
BOF	-	basic oxygen furnace
CC	-	continuous casting
DR	-	direct reduction
EAF	-	electric arc furnace
EF	-	electric furance
IF	-	induction furnace
HP	-	high power
UHP	-	ultra high power
DRI	-	direct reduced iron (called often sponge iron)
GI	-	galvanized iron sheet
HIB	-	high briquetted iron
LCS	-	low carbon steel
HCS	-	high carbon steel

Other Abbreviation (Cont'd)

COM	-	coal oil mixture
PCI	-	pulverized coal injection
RDI	-	reduction degradation index

EXECUTIVE SUMMARY

In the Master Plan Study for the Iron and Steel Industry in Pakistan:-

The study has been forecast on the demand for iron and steel in Pakistan for coming two to three decades and how the iron and steel industry in Pakistan should be by the year 2000. The investigation has been carried out on the steel-consuming industries in Pakistan to predict the demand for steel products by categories in the domestic market, and also made on the present state of equipment and production of iron- and steel-making to evaluate the existing equipment and technical standards, and as a result some problems have been pointed out.

From the forecast of supply and demand for iron and steel in Pakistan, some projects for the future iron and steel industry in Pakistan were taken up. Each iron- and steel-making process of the projects was evaluated, and then the feasibility in individual cases as independent project and the effectiveness from the national economic point of view were appraised respectively.

As a result, the following scenario has been recommended to the future iron and steel industry in Pakistan.

A DR plant, with an annual capacity of 400,000 tonnes, will be installed at the earliest possible date to provide DRI to the existing steelmakers (melters and semi-integrated mills) suffering from the shortage of scrap and the unstableness of their price.

Next, the construction of a DR integrated mills, with an annual capacity of 380,000 tonnes for bars and sections, will start around 1986-87 so that the production may start around 1991-92 when there will be their demand on the market.

Pakistan Steel probably will have mastered the required operational technologies when the BF integrated with an annual 1.1 million tonne capacity will be smoothly operated. And in order that the existing hot strip mill with an annual 1.8 million tonne capacity will be fully utilized, a project for doubling the production in Pakistan Steel will be carried out mainly for the iron- and steelmaking area to be accomplished around 1994-95 when the demand for flat products will be anticipated to be sufficiently grown on the market.

Furthermore, a project for doubling the capacity of the afore-mentioned DR integrated will start around 1995-96 in order to increase the production of non-flat products, which will be in short supply on the market in the latter half of 1990's.

As for the location for these projects, all of them will be sited in Karachi area conveniently close to the seaport since they will have to depend almost on overseas sources for their raw amterials for the time being due to behind in the development of indigenous raw materials from the problems of their quality, quantity, accessibility, etc. Just as this industry is a sort of transport industry for heavy bulky material, so the iron and steel industry is definitely raw material oriented.

The process through which above recommendation has been reached is described hereinafter.

SUMMARY

1. CURRENT ECONOMIC CONDITIONS IN PAKISTAN

Pakistan has a population of 80,230,000 in 1979-80, and had GNP per capita of US$230 as of 1978 according to the World Bank.

The real GNP annual growth rate of Pakistan after the separation of Bangladesh was about 6% up to this time. Agriculture's share of GNP decreased below 30% at last in 1978-1979 (36% in 1972-1973), but the manufacturing industry's share did not increase or rather declined (15% in 1979-1980).

Owing to the rapid increase in the amount of money sent back home by those who are working in the Middle East countries, the net overseas income's share made a rapid increase from 0% to 6%. The shares of construction and service industries increased very slightly. In this way the Pakistani economy has been far from making a vigorous growth.

Speaking about the manufacturing industry, priority was given to large-scale engineering industry and chemical (fertilizer) industry on the basis of the nationalization policy during the days of the preceding government but the cotton industry which has tradionally been privately owned and operated rather tended to shrink for fear of nationalization. The present government has taken the policy of shifting back to private ownership of enterprises but no drastic changeover has not yet been accomplished. The engineering industry which has been given emphasis has been levelling on such a low rate of operation as somewhere around 30% because the engineering products are so expensive that the domestic market does not expand.

Pakistan produces natural gas but she is still far from self-sufficiency in energy and the rise in imported oil price has resulted in the expansion of the country's total payments for imports. Pakistan's exports consist mainly of agricultural products such as rice, sugar and cotton. There are labour-intensive light industries (carpets, medical instruments, etc.) which mainly comprize very small-scale traditional enterprises but their share of the country's GNP is very small and their growth rate is low. As a result Pakistan's imports were nearly twice the exports in 1979-1980, thus bringing heavy pressure to bear on the country's balance of international payments.

2. EXISTING IRON AND STEEL INDUSTRY IN PAKISTAN

In Pakistan today crude steel is all produced by small electric furnaces of 0.5 to 15 tonnes/heat. There is no converter in use except at Pakistan Steel which is now under construction, and there is no open-hearth furnace.

The crude steel production by the electric furnaces numbering about 80 at the present time amounts to about 388,000 tonnes/year, of which 75% is produced by electric arc furnaces. The latent productive capacity of the electric furnaces is estimated at 606,000 tonnes/year.

The crude steel is made in the form of steel ingot of mild steel of cross section 160 mm by 200 mm and 65 to 250 kg in weight. The continuous casting of billets omitting the ingot-making process has just begun to be used only by a few major semi-integrated mills.

On the other hand, the rolling of steel materials has been undertaken by small mills numbering as many as 700 companies.

Most of them are obsolete uniaxially arranged three-high stands and the rolling operations are performed by a primitive method in which the hot steel is handled by men using tongs. Relatively modern types of mechanized mills are in use at some major companies.

The production of steel products by these rolling mills amounts to 574,000 tonnes/year and their latent productive capacity is estimated at around 820,000 tonnes/year. The steel products consist mainly of round bars which accound for 60% of the total production, small- and medium-size sections, and deformed and twisted ribbed bars for concrete reinforcement.

Pakistan produces almost no steel sheets and plates at the present time and depends nearly upon imports. Pakistan Steel in Pipri is the first integrated iron- and steelworks which will have a crude steel productive capacity of 1.1 million tonnes per year and produce mainly steel sheets when completed.

Pakistan Steel devoted to the production of sheets can be regarded as an epoch-making project but, it is, on the other hand, considered as a premature one in view of the present stage of development of the Pakistani economy, the present steel demand structure and precedents for iron and steel industry in other developing countries. Therefore the expansion of the flat-product market for Pakistan Steel is considered the most important task which must be accomplished first of all. Iron- and steelmaking facilities are found to become equal in their specifications to the similar facilities of the same scale in advanced steelmaking countries and they do not seem to pose any problems about their capacity of 1.1 million tonnes per year as far as the equipment balance is concerned.

"Personal and technology" are essential to making the integrated iron-and steelworks well-balanced operated.

If adequate technical assistance is provided by advanced steelmaking countries, Pakistan Steel will probably exceed 90% of its nominal capacity in about five years after commencement of plant operations in the best possible case.

Raw materials for use by EAF and the BF/BOF routes are mainly iron ore, coal, limestone, dolomite, fluorite, scrap, and ferroalloys.

Of these materials, limestone, dolomite, fluorite, and part of scrap are presently procured in Pakistan and other materials have to be imported.

The reserves of indigenous raw materials such as iron ore and coal are known to some extent by the surveys conducted in the past but they are little developed because of the problems of their quality, quantity, and accessibility. With regard to the indigenous materials, only approx. 80,000 tonnes of coking coal are produced a year at Sharigh, Balchistan. Surveys are now under way to estimate the iron ore reserves in the Pachinko/Chigendik area but the stage of a feasibility study for the development has not yet been reached. As for the iron ore deposits at Kalabagh, their economical development will have many problems regarding of their mining and beneficiation because thick overburdens cover the deposits and their quality is poor and complexed. Accordingly, there is no hope for their practical use for the time being.

Thus, Pakistan Steel will basically depend on imports for the principal raw materials for the production of steel and this pattern is expected to continue in the future. The sources of scrap can be divided into three - locally generated scrap, imported scrap and scrap from ship-breaking, and their ratios at the present time are 40:36:24. Imported scrap is very unstable in price because it is easily influenced by the world market situation and for this reason there are strong needs for replacing scrap with such sources of iron as DRI.

The Pakistani ship-breaking business is so active in recent years that it is said to rank the third in the world and handle 300,000 to 400,000 LDT/year. About 85% of scrap is recovered from demolished ships and thus obtained scrap assumes considerable importance as the material for melting (20%) and for re-rolling (80%).

The majority of rolling mills in Pakistan use the re-rollable scrap from ship-breaking as their main stockfeed. Their products are mainly plain round bars and they know from experience that the products made from re-rollable scrap from ship-breaking can well meet the needs of the users even without inspection and guarantee. Since ship-breaking is done mainly by human muscle power, the maximum possible size of ships which can be demolished in this matter would be 20,000 LDT. In view of the world's registered ships, it will be possible for Pakistan's ship-breaker to maintain on the existing level of 300,000 to 400,000 LDT, or 260,000 to 340,000 tonnes of scrap.

As for utilities in iron and steel industry, the total electricity demand of Pakistan is generated by hydraulic power (80%) and thermal power (20%) and the supply of electric power is a little short on whole. WAPDA and KESC respectively have their production increase programme, but their development efforts fail to catch up with the rapidly increasing demands under the present circumstances.

Natural gas has been considerably developed mainly in the Sui area and it is almost consumed as a fuel at the present time. Natural gas should be consumed more as feedstock for chemicals and fertilizers, and agent for reduction of iron ore rather than as a fuel. From the worldwide energy resource point of view, the energy pattern will convert from oil- and gas-oriented to coal which still remain unutilized in Pakistan.

In the Karachi area, the industrial water supply from the intake piping network from the Indus River is not enough to meet the demand,and the water supply and demand situation is rather tight. Underground water is used for industry in Punjab.

3. MARKET STUDY FOR IRON AND STEEL IN PAKISTAN

In consideration of the production by EAF and rolling mills, the total production of steel in Pakistan in 1979-80 is estimated at 701,000 tonnes in terms of crude steel equivalent. Steel imports are estimated to be 543,000 tonnes in terms of finished steel products. Since there are no steel exports from Pakistan, from the above statistics, the apparent steel consumption in this country is estimated at 1,334,000 tonnes in terms of crude steel equivalent.

Pakistan's dependence on overseas sources of iron including scrap is about 72% and it is estimated to be about 80% if ship-breaking scrap indirectly imported through the ship-breakers are included.

As for the present structure of demand for steel products, non-flat products, mainly bars and sections, account for 58% of the total and flat products, mainly sheets, are so low as 42% like in other developing countries. This is due to the fact that most of the demand for steel is from the construction industry and there are few steel fabricated frame structures and also that there are some flat steel products-consuming industries such as electrical appliances and various cans but they are still very small in scale. That is to say that the durable goods industry and capital goods industry have not sufficiently grown in Pakistan.

Pakistan's steel consumption at the present time can be regarded as being very low compared with the international level. Pakistan's per capita steel consumption in 1979 was 17 kg and lower than this level was 2 kg in Bangladesh, 14 kg in Indonesia, and 14 kg in Nigeria. Per capita steel consumption in Latin American countries, the Republic of Korea, and Taiwan exceeded 100 kg. Coming between these groups of nations are the Philippines 32 kg, Egypt 34 kg, Morocco 36 kg and Thailand 41 kg.

According to the IISI (International Iron and Steel Institute), if a developing country is to achieve its take-off, it is required to fulfill the conditions listed below in addition to GNP per capital of US$200 (at 1963 prices).

- Ratio of investment (to GDP) is at least 20%.
- The manufacturing industry takes more than 20% share of GDP.
- Capital goods industry takes more than 10% share of the entire manufacturing industry.
- Domestic steel consumption per gross capital formation of US$ one million (at 1963 prices) exceeds 700 tonnes.

At the present time Pakistan fails to fulfill all of these requirements. Some of the above-mentioned developing countries with their per capita steel consumption ranging from 30 kg to 40 kg do not meet two or three of these requirements for take-off but the respective figures they have achieved are still higher than those of Pakistan. Most of the countries with their per capita steel consumption exceeding 100 kg meet almost all of those requirements.

As seen what has so far been discussed, Pakistan is still a country before reaching the stage of take-off and its steel consumption has been hovering on such a low level because available indigenous raw-material resources are very few and the prices of steel products are so high.

For making forecasts of the demand for steel in Pakistan over the next 20 to 30 years, such forecasting methods as the macroscopic GDP correlation analysis, the Steel-Intensity analysis developed by the IISI, and the time-trend method have been employed.
In making the forecasts, Pakistan's GNP was assumed to make an annual growth of 5% and the population increase was assumed as was predicted by the United Nations in 1978.

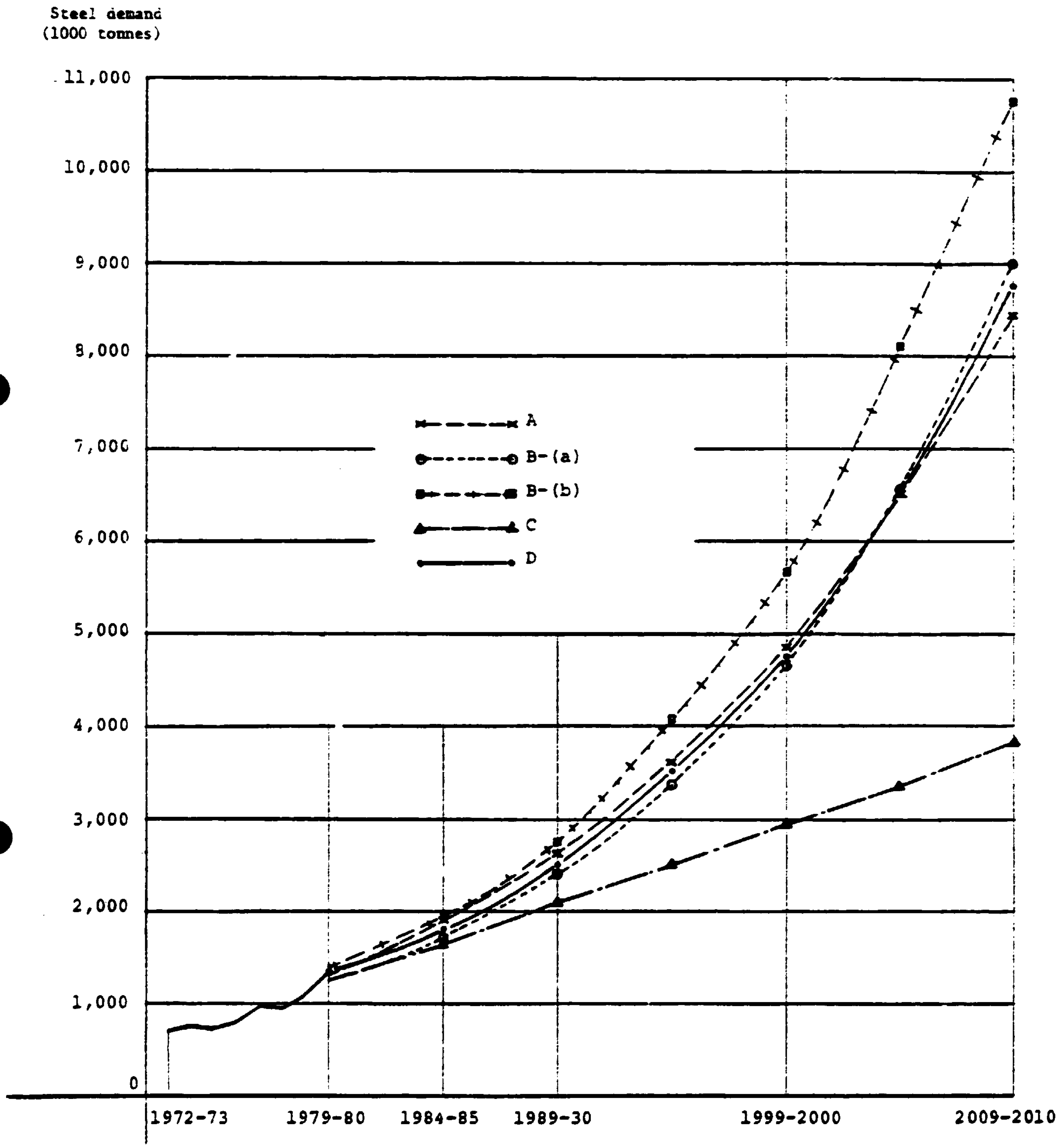

Fig. S-1 Forecast of Steel Demand in Pakistan

Thus produced data are shown in Fig. S-1, from which it is seen that the GDP correlation analysis (Case A) and Steel-Intensity analysis (Pakistan data, Case B-(a)) results show an estimated yearly increase of 6 to 7%.

The Steel-Intensity analysis (IISI-prepared data for nine developing countries, Case B-(b)) showed an annual growth rate of about 7% and the time-trend (Case C) showed so low an annual growth rate as 3 to 5%. The combination of Case A and Case B-(a) is showed as Case D.

Case C represents a pessimistic case, an annual growth rate gradually decreasing. Case A and B-(a) demonstrate a similar trend to show an annual growth rate of 6 to 7%. Case B-(b) represents the most optimistic case, showing an annual growth rate of more than 7% during the entire period. It is desirable to eventually adopt Case D which is a combination of Case A and B-(a). The appropriateness of Case D is evaluated through the analysis of the 1970-1978 data for developing countries and Case D is finally adopted. Figures of Case D are showed in Table S-1.

Talbe S-1 Forecast of Steel Demand in Pakistan

	1979-80	1984-85	1989-90	1999-2000	2009-2010
Steel consumption (1,000 tonnes)	1,340	1,786	2,510	4,765	8,749
Steel consumption per capita (kg/person)	17	19	23	34	49
GNP per capita (US$ at 1963 prices)	149	163	179	227	291

These are the forecast on the basis of crude steel. Table S-2 shows them on the basis of steel products by categories.

In general, steel demand for construction applications has accounted for a higher proportion in developing countries, and in order to meet such demand, a large number of ingot-makers by open hearth and electric furnace and re-rollers have existed in those countries.

As developing countries progress towards a take-off stage, the proportion of non-flat products increases for the construction of houses and buildings and for the improvement of infrastructure. After then, as income increases and as durable goods spread, demand for flat products increases. In the case of Pakistan, non-flat products currently account for a large share and it is estimated to account for 58%. Future shares of flat and non-flat products could be estimated on the basis of actual changes seen in many developing countries. Generally, the data for many developing countries indicate an increase in the share of flat products and a decrease in the share of non-flat products as develping stages.

Pakistan is expected to trace the same trend, but as her current per capita steel consumption and GNP are low and are not expected to show a rapid increase, their shares are not expected to change as rapid as witnessed in other more developed countries.

In Pakistan the production of ghee oil cans, home appliances, motorcycles, light vehicles and various machines will certainly increase gradually, but their increase rate is expected to be relatively small.

In view of the above-mentioned consideration, flat and non-flat products in Pakistan are expected to show same share in 2009-2010.

Table S-2 Demand Forecast of Steel Products by Categori

	1979-80	(%)	1984-85	(%)	1989-90	(%)	1999-2
Rolled Products total	1,151.5	(100.0)	1,593	(100.0)	2,264	(100.0)	4,3
Non-flat Products	666.8	(57.9)	892	(56.0)	1,223	(54.0)	2,2
Bars, Wires, Wireless	420.0		558		761		1,4
Bars	381.4		505		688		1,2
Wire Rods	18.5		26		36		[illegible]
Wires	20.1		27		37		[illegible]
Sections	245.0		331		455		8
Angles, I beams	206.0		280		387		7
Rails	39.0		51		68		1
Seamless Pipes	1.8		3		7		[illegible]
Flat Products	484.7	(42.1)	701	(44.0)	1,041	(46.0)	2,0
Plates	21.3		32		56		1
Sheets	463.4		669		985		1,95
Uncoated	283.7		402		580		1,1
Coated	128.7		194		299		6
GI	51.6		76		116		2
Tinned	77.1		116		181		3
Others	-		2		2		
Welded pipes	51.0		73		106		2

Note: ( ) shows share percentage

SECTION 1

emand Forecast of Steel Products by Categories (Unite: 1000 tonnes/year)

1984-85	(%)	1989-90	(%)	1999-2000	(%)	2009-2010	(%)
1,593	(100.0)	2,264	(100.0)	4,346	(100.0)	8,064	(100.0)
892	(56.0)	1,223	(54.0)	2,260	(52.0)	4,032	(50.0)
558		761		1,404		2,484	
505		688		1,265		2,226	
26		36		69		129	
27		37		70		129	
331		455		839		1,516	
280		387		717		1,315	
51		68		122		201	
3		7		17		32	
701	(44.0)	1,041	(46.0)	2,086	(48.0)	4,032	(50.0)
32		56		130		282	
669		985		1,956		3,750	
402		580		1,130		2,137	
194		299		609		1,186	
76		116		230		444	
116		181		370		718	
2		2		9		24	
73		106		217		427	

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SECTION 2

4. RECENT PROGRESS AND FUTURE PROSPECTS OF IRON AND STEEL INDUSTRY

In order to envision the Pakistani iron and steel industry in the future, a brief study of the latest advances was made in the iron and steel industry of the world, mainly in advanced iron and steel countries.

Until the first half of the 1970's, the iron and steel industry, particularly that of Japan, had rapidly increased its production by the increased capacity with active installation for larger scale of equipment. But it has made a slight change in its direction in response to the shift to a low-growth economy after the "oil crisis" of 1973. The main points of such a changeover are energy savings and cost reduction. Plant equipment still tend to the increases in size, speed and integrated mill operations. It must not be overlooked the fact that such tendencies of equipment are integrated in the energy-saving and cost-reducing programmes from an overall point of view.

Speaking about ironmaking technology, there have appeared blast furnaces so large as 5,000 m^3 to further accelerate the high-efficiency (low-cost) ironmaking operations by the use of large blast furnaces. On the other hand, vigorous efforts are being made to reduce the fuel and auxiliary material requirement per unit of product to a maximum possible limit and to extend oil-less blast furnace operations by such a method as the injection of pulverized coal.

In the field of steelmaking technology, a progress is being made in the high-efficiency (low-cost) steel production by large converters. The top-blown converter technology may be said to have been brought very nearly to perfection by the introduction of dynamic control techniques. From now on, further efforts will be devoted to energy and labour savings. On the other hand, rapid progress will be made in the development of the top-and bottom-blown converter comprising the top-blown one with the advantageous features of the bottom-blown one, and also in the development of various ladle metallurgy, mainly the degassing process.

It is now becoming possible to make high-grade steel by continuous casting process owing to the advances made in degassing techniques and electro-magnetic stirring techniques.

In the field of rolling, progress is being made in the increases in size and speed, automation and integration of rolling mills from the viewpoint of energy savings. The use of hot charge and direct rolling techniques will be further increased in the future.

The tasks which must be accomplished by the iron and steel industry in the future will be the development and practical application of the production process techniques to overcome the industry's vulnerabilities in respect of raw material and energy resources and also to increase the efficiency of investment.

What is conceivable as an iron- and steelmaking process in the future is the integration of the processes, that is, the accomplishment of a total system in which the entire iron and steel production operations are considered as a single system so that the individual processes may be combined in a continuous line.

The technical feasibility . such a total system has not yet been proved at the present time and much more efforts will be needed for the accomplishment of such a goal.

The integration of iron- and steelmaking processes will have many outstanding advantageous feaures in respect of raw material and energy savings through the omission of such intermediate stages as heating and cooling and the ease of computer control and therefore it is anticipated to become the mainstream of iron and steel production technology in the future.

Riding on the tide flowing towards the integration of production processes, practically feasible techniques will be introduced one after another into the processes, trending to one-heat process, integrated continuous process, etc. in the future. For the immediate future before and during the 1990's, "the direct coupling of continuous casting and hot rolling operations" and "continuous cold rolling process" are expected to be realized.

As for the techniques required to enable the direct coupling of continuous casting and hot rolling operations, it will be necessary to establish the defect-free billets making techniques such as high-purity steel melting technique, defect-free slab making technique, and the technique for removing defects from hot billets and the electro-magnetic stirring technique, the establishment of a continuous casting system which will be able to properly cope with diversification such as the technique of multiple casting of different types of steel in continuous casting, slab sizing technique, and slab size changing technique, and also the establishment of the techniques for high-precision rolling of low-temperature hot billets and high-speed continuous casting such as direct rolling, warm rolling and improvements in rolling dimensional accuracy. It is expected that efforts will be made for the realization of the one-heat process.

With regard to the continuous cold rolling technology, there is a hope for the completion of fully continuous cold rolling process incorporating the integration of acid pickling and cold rolling processes and continuous annealing process. Here is expected the development a compact-sized mechanical descaling equipment, an automatic test system for the surface flaws of cold-rolled steel, and full line automatic control system.

5. CONDITIONS AND POSSIBILITY CONCERNING INTRODUCTION OF MODERN IRON- AND STEELMAKING TECHNOLOGY INTO PAKISTAN

Most developing countries are regarding the iron and steel industry as a symbol of the indutsrialization of the country, and planning to develop it as a national policy. However if modern iron and steel industry is to be conducted, various technical and economic conditions and limitations must be considered, and Pakistan does not always meet these conditions.

There are various process routes for manufacturing iron and steel, and they are all incessantly improving and progressing. The three basic process routes are available as follows:-

- Blast furnace – basic oxygen furnace operation, i.e. integrated iron- and steelmaking using iron ores and coke (BF/BOF process route).

- Direct reduction furnace – electric furnace and subsequent metallurgical operation (DR/EF process route).

- All scrap melting in an electric furance and subsequent operation (Scrap/EF process route).

Each of them has the characteristics as mentioned below. The BF/BOF process is suitable for mass production. Most of the iron- and steelworks constructed in the advanced iron- and steelmaking countries are based on this process.

Therefore they have a crude steel production capacity of 3-10 million tonnes/year and enjoy high productivity and economic efficiency.

But a large amount of fund and the advanced control techniques for the continuous oepration of iron- and steelmaking are required for the construction and operation of this process.

DR/EAF process is smaller in the scale of production facilities and mroe flexible in production than BF/BOF. This process has often been constructed in the countries with abundant energy resources.

The scrap/EAF process is characterized by smaller energy consumption, capital cost and scale of production facilities. But the problem is how to secure a sufficient quantity of good scrap at all times.

Although the technological research and development and improvement will be made on these processes over coming 20 years, no drastic change will occur fundamentally to them.

All these manufacturing processes depend much on the raw material and energy conditions, and the countries, which have to rely mainly on the imported raw materials and energy sources, construct usually iron- and steelworks at seashore.

As mentioned above, what process is selected in the production facilities depends mostly on the conditions of raw materials. Demand is a large factor for determining the scale of iron- and steelworks. There is a measure, not absolute but comparative, of the techno-economical capacity limits. If the demand is not higher than a certain techno-economical limit, it is not worthy of the production equipment with this limit. The iron and steel industry in advanced countries which had enjoyed the scale merits due to enlarged production capacity had to turn their direction since the 1st oil crisis in 1973. They have been concentrating on the target to save the energy sources in the production process, and have improved and developed their facilities and techniques mostly in relation with this target.

The iron and steel industry in Pakistan took the first step toward modern iron and steel industry at last and is going to enjoy the scale merits due to their enlarged production facilities, although they are not so large-sized as those of the advanced countries. They must develop their industry by further adopting the energy and resources saving techniques which the advanced countries have so far introduced.

When the Pakistani iron and steel industry is examined from these standpoints, the level of production facilities and their operation technique in the existing melters and rolling mills is equal to that in advanced steel-producing countries about 30 years ago. As for the various equipment and techniques these advanced countries acquired these 30 years, Pakistan is in a position to obtain them if it wants. It will, therefore, be proper to think that Pakistan will reach the present level of production facilities and techniques of the advanced countries after about 20 years from now, i.e. by the year 2000.

Pakistan Steel is the first integrated iron- and steelworks in Pakistan and mainly producing flat products. It is usual for the first BF integrated works to start from producing mainly non-flat steel products. It may be possible for the first integrated iron- and steelworks producing flat products to master individual processes in about 10 years. But it will take additional years before it is regarded as a total system. Further the technical cooperation with the advanced iron- and steelmaking countries should be required.

DRI is lower in metallic iron content but less variable in quality than scrap. DRI has, therefore, the merit that the so-called quality steel with warrantable quality can be made from it. Further scrap tends to fluctuate in price by the speculative factors, but iron ore which is the stockfeed for DRI has no speculative factor, and thus DRI makes possible to plan and conduct the production in a long range view. DRI is strongly demanded in Pakistan and will be realized earlier, if the stable supply of raw materials and energy can be secured.

A DR integrated iron and steel plant is generally suitable for the smaller scale production compared with the BF/BOF process, and in most cases for producing non-flat products because of its scale. As Pakistan has already had the ground for producing non-flat products, this process will smoothly be received. But the technical cooperation with advanced countries is nevertheless necessary in this field during an early stage, because the iron- and steelworks must be considered as the total system, not as individual processes of DR, EAF, etc.

6. PROSPECTIVE PROJECT STUDY

First of all, the pelletizing facility is taken up as the project for raw materials for ironmaking, but it is omitted here as its demand is too small compared with its production capacity limit, and also the production of indigenous iron ores suitable for pelletizing cannot be expected for the time being.

Secondly, the possibility of installation of DR plant in place of the scrap-based process is examined. The existing ingot/billet makers will maintain a yearly output of 350,000-360,000 tonnes both at present and in future as shown in Table S-3, even if the participation of Pakistan Steel in the market and a certain role of the shipbreaking industry are taken into account. It is, therefore, necessary to produce DRI in an annual production of about 400,000 tonnes to ensure the stable operation of these makers.

Table S-3 Supply and Demand of Ingot/Billet for Non-flat Products

(Unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	642	734	980	988
Supply capacity				
Pakistan Steel	-	380	380	380
EAF	512	555	584	642
Re-rollable Scrap (including ship-breaking)	250	250	250	250
Total	762	1,185	1,214	1,272
Supply				
Pakistan Steel	-	240	380	380
EAF	362	344	350	358
Re-rollable Scrap (including ship-breaking)	175	150	250	250
Total	537	734	980	988

The supply and demand of non-flat products will be a balance short of 200,000 tonnes/year during 1989-90 and of 500,000 tonnes/year during 1993-94 as shown in Table S-4 even if Pakistan Steel enters the market with formed sections and such conditions are prepared that the existing mills can fully utilize their own capacities. Therefore, it will be necessary to install a bar-section plant at least with a production scale of 400,000 tonnes/year around that years.

As for the DR module it is generally considered more profi table from the techno-economical viewpoint to employ larger module for instance, 600,000 t/y in consideration of the above-mentioned DR plant for DRI which substitues for scrap.

However as mentioned in detail in Appendix to 6-2 , when 600,000 t/y module is adopted for the DR plant, its opera tion rate will have to be kept low for several years from its start-up for the reason of demand. In this case, the scale merit can not fully be utilized and the demerit of increasing fixed costs will grow.

Accordingly we recommend to install 400,000 t/y module respectively for DRI production and for the integrated steel works at their each required periods.

Table S-4 Non-flat Supply and Demand Projection

(Unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	667	892	1,223	2,260
Production Capacity				
Pakistan Steel	-	120	120	120
Rolling Mill	820	861	902	919
Total	820	981	1,022	1,039
Supply				
Pakistan Steel	-	100	120	120
Rolling Mill	574	668	902	919
Total	574	768	1,022	1,039
Balance	93	124	201	1,221

To meet the supply and demand for these non-flat products, various possibilities such as rolling mill, semi-integrated plant, DR integrated plant, the downstream of Pakistan Steel can be conceived. Among them, it is decided to take up here a rolling mill with a 400,000 tonnes/year capacity and a DR integrated plant with the same capacity, because it is considered that Pakistan Steel should concentrate on flat-products and that any semi-integrated plants cannot solve the present problems of scrap.

Lastly, the flat product market is examined. Some products are oversupplied and some are short at the time when Pakistan Steel will enter the market. It will be necessary to adjust them. (This is mentioned in detail in Appendix to 6-1.)

It is expected that the demand will be almost doubled after the first half of 1990's as shown in Table S.5, provided that more than 90 % of utilization can be realized in several years from now using every possible measure and all-out efforts, though Pakistan Steel will have various difficulties at the start-up period.

Table S-5 Supply and Demand Projection of Flat Products

(Unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	485	701	1,041	2,086
Supply	-	470	623	623
Balance	485	231	418	1,463

The maximum utilization of hot strip mill (capacity: 1.8 million tonnes/year) shall be most carefully considered for doubling the production capacity of Pakistan Steel. In planning a future iron and steel industry from viewpoint of national economy, such a basic concept should be employed that Pakistan Steel concentrates on flat products, and non-flat is manufactured by another plant.

Flat products have taken up as the main to double the production capacity of Pakistan Steel. An alternative has been planned that the supply of billets to the above-mentioned new rolling mill is also added to the product mix to advance the time to double the capacity. Thus, two plans for doubling Pakistan Steel have been prepared.

As a result, five Projects, which are called the valuable plans to be taken up, have survived.

Project A: (DR plant with a 1.1 million tonnes/year capacity)

The existing ingot makers are so much troubled with unstable supply of raw materials that they hope strongly scrap to be supplied to them steadily both in quality and price. On the other hand, Pakistan has natural gas which is mainly used as fuel. However, it has not so much reserves that it should be transferred to the use of chemical and steel industries from the viewpoint of effective use of precious resources.

From this viewpoint, a DR plant with a 4˜0,000 tonnes/year capacity proposed to supply the materials to the existing ingot makers having total production capacity of nearly 400,000 tonnes/year.

Project B: (DR integrated steel works with a 400,000 tonnes/year capacity)

Almost all bars and sections for construction materials are presently self-supplied in Pakistan, in which the quality steel with secured quality is very limited. Modern integrated plant will become necessary to cope with the increase of demand for such products in future.

DR integrated steel works with a 400,000 tonnes/year capacity have been proposed judging from the extent of demand increase more than 400,000 tonnes in 1994-95.

Project C: (A rolling mill with a 400,000 tonnes/year capacity)

The plan of a bar section rolling mill is taken up corresponding to the production of billets by Pakistan Steel in Project D-2 and further for using surplus ingot and billet from the present ingot supply capacity.

Project D-1: Doubling the capacity of Pakistan Steel only for flat products)

Firstly, it is the most important to fully utilize the hot strip mill for doubling the production capacity of Pakistan Steel.

Next, it is undesirable for the Pakistani iron and steel industry that a giant supplier like Pakistan Steel undertakes the production also of non-flat products and makes a complete monopoly of the rather narrow market of Pakistan.

Therefore, the doubling capacity only for flat products is proposed.

Project D-2: (Doubling the capacity of Pakistan Steel for flat products and billets)

Then an alternative to Project D-1 is proposed, the billet supply to a rolling mill (Project C), to the product mix of Pakistan Steel doubling the capacity, in order to realize doubling the capacity as early as possible and alleviate the burden of the existing part.

The outline of product mix and production facilities of the above five Projects is shown in Table S-6.

Table S-6 Summary of Projects

Projects	Name	Basic Concept	Main Facilities (Additional only)	Product Mix (Additional only) 1,000 tonnes/year	
A	400,000 t.p.a. DR Plant	DRI supply as an alternative of scrap to existing ingot makers	. DR	. DRI	400
B	400,000 t.p.a. DR integrated	Effective dealing with new demand of non-flat products. Utilization of natural resources (Natural gas).	. DR . EAF . Billet CC . Bar-section mill	. Bar/Section	380
C	400,000 t.p.a. Rolling mill	Effective dealing with new demand of non-flat products. Utilization of existing supply capacity of ingot/billet.	. Bar-seccion mill	. Bar/Section	400
D-1	Pakistan Steel doubling for flat products	Effective dealing with new demands for flat products. Utilization of existing hot rolling mill.	. Sinter plant . Coke oven . BF . BOF . Slab CC . Cold rolling mill . Galvanizing line . Tinning Line	. Hot rolled sheets . HRS for welded pipes . Cold rolled sheets . Galvanized sheets . Tinned plates and sheets	190 140 300 80 250
D-2	Pakistan Steel doubling for flat and non-flat products	Effective dealing with new demands for flat procucts and billet for non-flat products.	. Sinter plant . Coke oven . BF . BOF . Slab CC . Billet CC . Cold rolling mill . Tinning line Galvanizing line	. Billets 150 mm sq. . Hot rolled sheets . HRS for welded pipes . Cold rolled sheets . Tinned plates and sheets	200 120 140 270 250

The location of iron and steel industry is generally determined by raw material conditions and consuming places. Also utilities, supporting industries, man-power, etc. must be considered. It can be concluded that Karachi, one of demand and supply centre of iron and steel, is the only site for future Projects. Because new iron and steel Projects rely almost 100% on the imported raw materials and that the location of iron and steel industry should preferably be decided according to the raw material conditions unless it has huge scale and very much intensive consuming places, namely steel industry is also transportation industry of heavy bulky materials. From this viewpoint, Karachi is most preferable for the site, because it is neighbouring the sea and equipped modern ports. On the other hand, Lahore, another demand and supply center of steel products, is located at a distance of about 1,300 km from the port and disadvantageous on the imported raw material basis. As Karachi has some problems in utilities, the government is required to consider the policies to construct the infrastructure for utilities.

7. FINANCIAL AND ECONOMIC EVALUATION FOR PROJECTS

In the financial and economic analysis for the Projects, all the prices are calculated in US dollars on a constant price basis that the prices in the first half of 1981 are assumed to remain unchanged throughout 20 years of the project life.

Table S-7 shows the construction cost which is calculated on the turn-key basis limited to the facilities inside the battery area.

Table S-7 Construction Cost

(Unit: US$ million)

Project	A	B	C	D-1	D-2
Direct Construction Cost					
Iron Making	67	57	-	315	315
Steel Making	-	59	-	171	190
Rolling Mill	-	62	78	269	234
Others	-	34	-	104	104
Installation, Civil and Construction	25	195	72	521	487
Total	92	407	150	1,380	1,330
Pre-operational Expenses	9	48	12	176	171
Total Construction Cost	101	455	162	1,556	1,501
Construction Cost per annual tonne of crude steel (US$/tonne)	-	1,081	-	1,396	1,346
Construction Cost per annual tonne of products (US$/tonne)	253	1,197	405	1,621	1,532

Of the above construction cost, it is assumed that 30% is the capital share and 70% is long-term loans under relatively soft terms and conditions. The amount equivalent to net working capital and the fund requirement after start-up shall be supplied from short-term loans.

The present Pakistani domestic prices were used for calculating the costs of domestically supplied raw materials, and the current international market prices were used for the imported materials, to estimate the production costs. The results are shown in Table S-8.

Table S-8 Production Cost (5th year from start-up)

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Production Quantity (1,000 tonnes)	(400)	(380)	(400)	(960)	(980)
Variable Cost (unit cost US$/t)	(103.9)	(197.5)	(538.9)	(259.1)	(251.2)
	41.6	75.1	215.6	248.7	246.2
Fixed Cost					
Labour Cost	0.2	1.2	0.2	2.2	2.2
Maint. and Repair	1.8	9.0	2.7	30.4	29.3
Depreciation & Amo.	10.0	44.0	14.0	160.0	155.0
Total	12.0	54.2	16.9	192.6	186.5
Total Production Cost	53.6	129.3	232.5	441.3	432.7
Production Cost/ Product·t (US$/t)	134.0	340.3	581.3	459.7	441.5

The profit and loss were calculated based on the present Pakistani market prices which were assumed on each product.

Table S-9 shows the profit and loss in the 5th year when the operation will be placed on its way and become stable.

Table S-9 Profit & Loss Forecast
(5th year from start-up)

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Sales Revenue (quantity: 1,000 tonnes)	(400)	(380)	(400)	(960)	(980)
	82.4	236.0	248.4	801.0	745.4
Production Cost					
Variable Cost	41.6	75.1	215.6	248.7	246.2
Fixed Cost	12.0	54.2	16.9	192.6	186.5
Total	53.6	129.3	232.5	441.3	432.7
Operating Income	38.8	106.7	15.9	359.7	312.7
Non-Operating Expenses					
General Adm.	0.4	0.8	-	2.4	2.4
Financial Expenses	3.3	14.9	5.4	50.7	48.9
Total	3.7	15.7	5.4	53.1	51.3
Net Income before Tax	25.1	91.0	10.5	306.6	261.4
Tax	13.8	50.1	5.8	168.6	143.8
Net Income after Tax	11.3	40.9	4.7	138.0	117.6
Accumulated Net Income after Tax in 20th year from start-up	277.4	1,047.5	182.6	3,619.9	3,183.1
Marginal Profit Ratio (%)	49.5	68.2	13.2	69.0	67.0
Ratio of Net Income to Net Sales (%)	30.5	38.6	4.2	38.3	35.1

On the basis of these financial projections, the break-even point analysis and internal rate of return on investment are taken as indices, in order to examine the financial feasibility of these Projects as an enterprise. The results are shown in Table S-10.

Table S-10 Financial Indices

		Project A	Project B	Project C	Project D-1	Project D-2
Break-even Point	(Quantity 1,000 tonnes /year)	(117.6)	(128.0)	(206.1)	(334.8)	(366.1)
	(%)	29.4	33.7	51.5	34.9	37.4
ROI	(%)	16.12	14.62	7.58	14.27	13.49

These indices show that all these projects have more or less the feasibility as an business concern. All Projects except C show a remarkable profitability Even Project C isn't low.

Following this, these projects were evaluated from the standpoint of national economy.

As for the tax revenue of the government, in all Projects the revenue will be decreased because the government cannot get import duties now getting.

Next, the saving of foreign currencies which is one of the most important factors for Pakistan is examined. Every project will contribute much to saving foreign currencies. Among them, Project B is the best in respect to efficiency.

As for the added value, Projects D-1 and D-2 show excellent results in terms of absolute value. In respect of efficiency, Project A shows the best result.

Lastly, ROI on national economy basis was found the highest in Project A.

These indices are shown in Table S-11.

Table S-11 Economic Analysis

	Projects				
	A	B	C	D-1	D-2
Tax Revenue of Government (US$ million)	- 408	- 521	- 1,713	- 473	- 786
Foreign Currency Saving (Efficiency)	(33%)	(102%)	(43%)	(41%)	(38%)
(US$ million)	266	1,291	824	2,500	2,280
Added Value (Efficiency)	(7.4)	(6.4)	(4.0)	(6.4)	(6.0)
(US$ million)	746	2,918	594	10,032	9,027
ROI (%) on National Economy basis	6.64	5.65	0.41	6.03	5.40

From the above calculation, two SCENARIOs can be taken out.

SCENARIO I:

Project A should be immediately set about to construct a DR plant to supply DRI to the existing ingot makers which are suffering from insufficient supply of raw materials, i.e. scrap.

Then, starting preparation around 1986-87 and a construction of DR integrated works (Project B (i) should be started in 1987-88.
It will be completed in 1991-92 and supply bars and sections as construction materials.

Meanwhile, starting preparation around 1987-88 when Pakistan Steel has already reached a stable operation, and start in 1989-90 to construct additional facilities for doubling Pakistan Steel toward full operation by 1996-97. (Project D-I)

In order to meet increased demand for bars and sections, the DR integrated steel works should be expanded to 800,000 tonnes/year level in 1995-96. (Project B (ii))

As Projects B and D-1 will be carried out during the same time from 1989-90 to 1991-92, some difficulties are expected in securing necessary funds and in carrying them out, but it is not impossible to implement them concurrently as they reach their peak at different times.

SCENAPIO II:

Project A should be immediately carried out to construct a DR plant to supply DRI to the existing ingot makers which are suffering from insufficient supply of raw materials, i.e. scrap.

Then, construction of doubling Pakistan Steel should be started around 1987-88. (Project D-2) To do so, it is necessary to start preparatory works and studies around 1985-86.

In order to complete D-2 at the same time (1992-93), construction works should be started for a rolling mill (Project C) in 1989-90.

In addition, it will be necessary to install a DR integrated steel works (Project C) as there will be a short supply of bars and sections coming to 400,000 tonnes in around 1991-92.

These SCENARIOs' time schedule is shown in Table S-12.

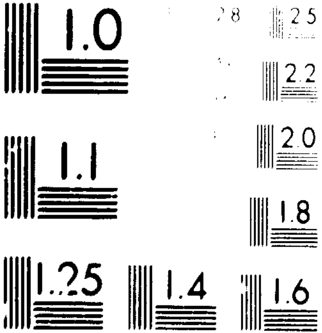
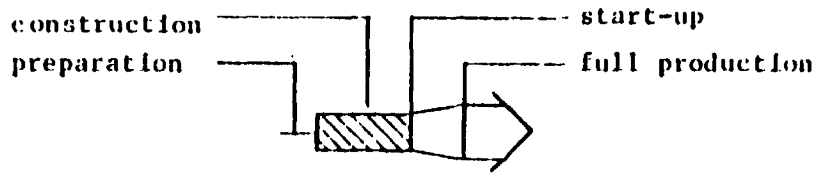

1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

Table S-12 Time Schedule of Projects and SCENARIO

Products	Project	1981 -82	1984 -85	1989 -90	1994 -95	1999 -2000	SCENARIO I	SCENARIO II
D R I	A						○	○
Bars and Sections	B				(i)	(ii)	○ (i)&(ii)	○ (ii)only
	C						—	○
Flat Products	D-1						○	—
	D-2						—	○



Comparing these two SCENARIOS, it is recommended to adopt SCENARIO I, as various indices shows clearly its superiority.

Some mention should be made about the probability of forecast. The balance of supply and demand was reviewed on the assumption to utilize the existing facilities (ingot makers, rolling mills, Pakistan Steel, etc.) to their full capacities in order to supplement the deficiency of those existing facilities, we have proposed the Projects.

For the maximum utilization of the existing facilities, it is necessary to get some assistances from the government, to have careful planning and training and to introduce technologies from advanced steel producing countries.

It is fear that Pakistan may be unable to satisfy the assumptions listed earlier and thus may be unable to fully utilize the existing facilities. Then, production costs will be further raised and the Projects proposed will have to be set about much earlier than the SCENARIO.

Therefore, the Government officials and persons concerned should not consider this Master Plan as a statis time table, but the plan should be used in a dynamic manner, watching the production trend at Pakistan Steel and the utilization of the existing facilities including ingot makers, rolling mills, etc.

In addition, they are required to fully recognize that, as one of the basic things, the thoroughness of statistics for the Pakistani industries concerned are indispensable for the development of Pakistani economy and its iron and steel industry.

1. CURRENT ECONOMIC CONDITIONS IN PAKISTAN

1.1 Evolution of Economic Development Programmes

The history of economic development programmes in Pakistan dates from 1955 when First Five-Year Plan (1955-60) started. At present, Fifth Five-Year Plan is under way.

The First Five-Year Plan preceded by Six-Year Development Plan starting from 1951 (1951-57), but this programme was abandoned with two years left over in consequence of the change in international circumstances brought about by the outbreak of the Korean War. The first systematic programme in Pakistan is therefore considered to have started from First Five-Year Plan. In ten years covered by First Five-Year Plan (1955-60) and the second one (1960-65), the economic development system was somewhat consolidated, and the agricultural infrastructure was developed. At the same time, the cotton industry was developed as a key industry. Third Five-Year Plan (1965-70) aimed at diversification and sophistication of industries. This third programme was "oriented to the economic growth" as the preceding two programmes. In Fourth Five-Year Plan (1970-75), importance was attached to the impartial and equitable distribution of the fruit of the economic development with a view to correcting the "distortion of growth" so far brought about the preceding programmes.

However, in the course of execution of this fourth programme, the change of government and the secession of Bangladesh occurred, and its execution was stopped. Then, the international monetary crisis, the oil crisis and other fluctuations occurred on the international level, while the formation of the Buddh government and the independence of Bangladesh took place on the national level. Pakistan was thus very busily occupied in coping with both national and international political and economic problems. As a result, any new economic development programme was not worked out till 1978, that is, till after the formation of the present government.

In 1978, the present government announced Fifth Five-Year Plan. This current programme includes the following five basic strategic points:

1) Recovery of the balance of production growth and economic functions between industrial sector and agricultural one.

2) Increase in allocation of funds to regions and sectors so far ignored.

3) Mobilization of national funds and reduction in dependency on foreign funds.

4) Promotion of the contribution of private sectors to the industrial development.

5) Repletion of social welfare.

Total investment for this programme amounts to Rs 210,200 million, of which 70.4% or Rs 148,200 million is invested in the public sectors and 29.6% or Rs 62,000 million in the private sectors. In financing, importance is attached to domestic savings. The funds raised from this source accounts for 75% of the total investment. The dependency on the financial help abroad represents 25%. The target annual growth rates aimed by this programme throughout its period are 7% for GDP (at factor cost), 7.2% for GNP and 4.2% for national income per capita. To this end, target production figures for agricultural and industrial products are set by supposing the annual growth rates of 6% for agricultural production, 10% for industrial production (15% for large-scale industries), 11% for export volume and 6.3% for import volume.

Table 1.1.1 Sectoral Allocation in First, Second, Third, Fourth, Fifth Year Plans

(Unit: Rs 1,000 million, %)

Sector	First Plan (1955-60)	Second Plan (1960-65)	Third Plan (1965-70)	Fourth Plan (1970-75)	Fifth Plan (1978-83)
Agriculture	1.21 (11.2)	3.42 (14.9)	8.12 (15.6)	10.01 (13.3)	26.00 (12.4)
Water, Power & Fuel	2.16 (20.0)	4.39 (19.1)	8.70 (16.7)	17.47 (23.3)	50.60 (24.1)
Industry & Mining	3.05 (28.2)	6.12 (26.6)	13.16 (25.3)	15.99 (21.3)	42.50 (20.2)
Transport & Communication	1.79 (16.6)	4.05 (17.6)	10.61 (20.4)	11.40 (15.2)	38.60 (18.4)
Physical Planning & Housing	1.49 (13.8)	3.41 (14.8)	6.48 (12.5)	7.80 (10.4)	23.00 (10.9)
Social & Other Sectors	1.10 (10.2)	1.61 (7.0)	4.93 (9.5)	12.33 (16.5)	29.50 (14.0)
Total	10.80 (100.0)	23.00 (100.0)	52.00 (100.0)	75.00 (100.0)	210.20 (100.0)

Source: [25 Years of Pakistan in Statistics 1947-1972] Table 16.01

[Economic Survey 1979-80] Table 18.1

Table 1.1.2 Development of Gross National Product at Constant Factor

Cost of 1959-60 (Unit: Rs million, %)

	1954-55 A	1959-60 B	1964-65 C	1969-70 D	1974-75 E	1977-78 F	Average Annual Growth Rate(%) B/A	C/B	D/C	E/D	F/E
Agriculture	6,948	7,711	9,276	12,574	13,074	14,348	2.1	3.8	6.3	0.8	3.1
Mining & Quarrying	45	70	122	157	181	210	9.2	11.8	5.2	2.9	5.1
Manufacturing	1,569	2,018	3,514	5,186	6,136	6,833	5.2	11.7	8.1	3.4	3.7
Large Scale	802	1,159	2,523	4,042	4,509	4,823	7.6	16.8	9.9	2.2	2.3
Small Scale	767	859	991	1,144	1,627	2,010	2.3	2.9	2.9	7.3	7.3
Construction	289	427	1,029	1,357	1,754	2,248	8.1	19.2	5.7	5.3	8.6
Electricity & Gas Distribution Service	37	87	172	639	949	1,245	18.6	14.6	30.0	8.2	9.5
Transport Storage & Communication	823	952	1,588	2,026	2,575	3,003	3.0	10.8	5.0	4.9	5.3
Others	4,757	5,561	7,659	10,397	14,724	16,743	3.2	6.6	6.3	7.2	4.4
Gross Domestic Product	14,468	16,826	23,360	32,336	39,393	44,630	3.1	6.8	6.7	4.0	4.2
Net Factor Income from/to Rest of the World	(-)4	(-)23	(-)61	(+)2	(+)258	(+)2,675	-	-	-	-	-
Gross National Product	14,464	16,803	23,299	32,338	39,651	47,305	3.0	6.8	6.8	4.2	6.1

Source: Statistics Division

1.2 Economic Trend in the 1970's

In this Section, the macroscopic economic and industrial trends in Pakistan from 1972-73 after East Pakistan was seceded up to now are described centring around GDP, GNP, investment, international trade and labour force.

1.2.1 Structural Change in Gross Domestic Product and Gross National Product

The actual figures of Gross Domestic Product (GDP) and Gross National Product (GNP) are given at constant factor cost of 1959-60 and at current factor cost in Table 2.1.1 and Table 2.1.4, respectively. In 1979-80, Pakistan recorded GNP of Rs 227.6 thousand million and GDP of Rs 210.6 thousand million. The change in GDP growth rate from 1972-73 onward is shown at constant 1959-60 prices in Table 2.1.2. This table shows that the actual annual growth rate of GDP from 1972-73 to 1979-80 is 5.5% on the average. The GDP shows a comparatively high growth rate of about 6% for the last three years after 1977-78, though its growth rate was low for three years after the oil crisis.

This is partly because, owing to favourable weather conditions, the agriculture accounting for some 30% of the GDP registered a growth of 4.2% in 1978-79 and 5.0% in 1979-80, growth much more rapid than that recorded in the preceding years, and partly because the large-scale manufacturing industries having registered a negative annual growth since 1974-75 have remarkably increased their production since 1977-78 as a result of improvement in utilization ratio of equipment, technology and management, and expansion of equipment in some industries.

Table 1.2.4 gives the GNP share of main sectors. As is clear from this table, the share of the agriculture decreased from 36.3% in 1972-73 to 29.8% in 1979-80 and that of the manufacturing sector also decreased in the same period from 16.1% to 14.6% as a result of decline in the large-scale manufacturing industries. On the other hand, the share of the service sector, including construction service, increased from 46.7% to 50.0% in the same period.

Table 1.2.1 Gross National Product at

Sectors	1972-73	1973-74	1974-75
1. Agriculture	12,821	13,357	13,074
Major Crops	7,473	7,844	7,455
Minor Crops	1,478	1,585	1,679
Livestock	3,651	3,724	3,799
Fishing	128	115	82
Forestry	91	89	59
2. Mining & Quarrying	161	180	181
3. Manufacturing	5,678	5,101	6,136
Large Scale	4,265	4,585	4,509
Small Scale	1,413	1,516	1,627
4. Construction	1,346	1,490	1,754
5. Electricity & Gas Distribution Services	903	1,068	949
6. Transport, Storage and Communication	2,355	2,466	2,575
7. Wholesale and Retail Trade	4,743	5,449	5,622
8. Banking and Insurance	826	879	1,006
9. Ownership of Dwellings	1,231	1,275	1,321
10. Public Administration & Defence	2,599	2,983	3,972
11. Services	2,516	2,653	2,803
12. Gross Domestic Product	35,179	37,901	39,393
13. Net Factor Income from/ to Rest of the World	(+)181	(+)184	(+)258
14. Gross National Product	35,360	38,085	39,651
15. Population (in million)	65.24	67.20	69.21
16. Per Capita Gross Income (in rupees)	542	567	573

Constant Factor Cost of 1959-60

(Unit: Million RS)

1975-76	1976-77	1977-78 (Revised)	1978-79 (Provisional)	1979-80 (Provisional)
13,659	13,998	14,348	14,948	15,851
7,833	7,944	8,110	8,532	9,177
1,839	920	1,966	2,013	2,123
3,875	3,993	4,114	4,239	4,368
86	96	100	104	121
26	45	58	60	62
175	205	210	217	239
6,231	6,258	6,833	7,160	7,741
4,486	4,385	4,823	5,003	5,426
1,745	1,873	2,010	2,157	2,315
2,094	2,076	2,248	2,452	2,707
985	1,143	1,245	1,346	1,531
2,605	2,649	3,003	3,265	3,401
5,724	5,660	6,121	6,516	6,876
1,039	1,124	1,241	1,390	1,450
1,369	1,418	1,469	1,522	1,577
3,854	4,135	4,593	4,934	5,105
2,964	3,060	3,319	3,510	3,711
40,699	41,727	44,630	47,262	50,189
(+)711	(+)1,255	(+)2,675	(+)3,042	(+)3,004
41,410	43,022	47,305	50,304	53,193
71.29	73.43	75.63	77.90	80.23
581	586	625	646	663

Source - Statistics Division

Table 1.2.2 Gross National

Sectors	1972-73	1973-74	1974-75
1. Agriculture	21,907	28,084	33,533
Major Crops	12,346	15,331	18,268
Minor Crops	2,833	3,777	5,003
Livestock	6,169	8,247	9,629
Fishing	379	476	383
Forestry	180	253	250
2. Mining and Quarrying	386	560	793
3. Manufacturing	9,695	12,751	17,479
Large Scale	7,282	9,583	12,844
Small Scale	2,413	3,168	4,635
4. Construction	2,298	3,114	4,996
5. Electricity and Gas Distribution Services	955	1,217	1,264
6. Transport, Storage and Communication	4,261	5,587	7,404
7. Wholesale and Retail Trade	8,582	12,346	16,166
8. Banking and Insurance	1,408	1,801	2,612
9. Ownership of Dwellings	2,237	2,868	3,766
10. Public Administration and Defence	4,430	5,750	8,113
11. Services	4,636	6,363	8,514
12. Gross Domestic Product	60,795	80,441	104,640
13. Net Factor Income from/to rest of the World	(+)463	(+)617	(+)1,147
14. Gross National Product	61,258	81,058	105,[illegible]37
15. Population (in million)	65.24	67.20	69.21
16. Per Capita Gross Income (in rupees)	939	1,206	1,528

Product at Current Factor Cost

(Unit: Rs million)

1975-76	1976-77	1977-78 (Revised)	1978-79 (Provisional)	1979-80 (Provisional)
38,338	43,686	49,370	56,370	66,272
20,572	22,484	26,827	30,958	35,509
6,030	6,963	7,689	8,218	9,457
11,130	13,395	13,741	15,970	19,786
447	552	702	779	1,034
159	292	411	445	486
968	1,196	1,222	1,459	1,887
20,054	22,234	25,278	27,870	33,782
14,438	15,579	17,842	19,474	23,679
5,616	6,655	7,436	8,396	10,103
6,739	7,376	8,316	9,544	11,813
1,713	1,916	2,151	2,806	4,789
9,338	9,252	11,182	13,114	15,050
18,321	19,769	22,796	26,179	30,429
3,021	3,573	4,222	5,112	5,909
4,356	4,931	5,460	6,082	7,000
9,490	10,371	13,044	14,012	15,964
10,085	11,382	13,221	15,114	17,709
121,423	135,686	156,562	177,662	210,604
(+)2,992	(+)5,480	+12,139	+13,922	+17,013
124,415	141,166	168,701	191,58[illegible]	227,617
71.29	73.43	75.63	77.90	80.23
1,745	1,922	2,231	2,459	2,837

Source - Statistics Division

Table 1.2.3 Annual Growth Rate of Gross Domestic Product & Gross National Product

(Unit: %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	1972-73 -1979-80 Average
Agriculture	1.7	4.2	-2.1	4.5	2.5	2.5	4.2	6.0	2.9
Mining & Quarrying	1.3	11.8	0.6	-3.3	17.7	1.9	3.3	10.1	5.2
Manufacturing	10.7	7.5	0.6	1.6	0.4	9.2	4.8	8.1	5.3
Large Scale	11.9	7.5	-1.7	-0.5	-2.3	10.0	3.7	8.5	4.5
Small Scale	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3
Construction	15.7	10.7	17.7	19.4	-0.9	8.3	9.1	10.4	11.1
Others	10.4	10.5	8.8	1.6	3.5	9.4	7.1	5.2	7.0
Gross Domestic Product	7.2	7.7	3.9	3.3	2.5	6.9	5.9	6.2	5.5
Gross National Product	7.5	7.7	4.1	4.4	3.9	10.0	6.3	5.7	6.2
Per Capita Gross Income	4.4	4.6	1.1	1.4	0.9	6.7	3.4	2.6	3.1

Source: Table 1.2.1

Table 1.2.4 Change in Structure of GNP (at

Sectors	1972-73	1973-74	1974-75
A. Production of Goods	52.77	51.56	48.91
1. Agriculture	36.26	35.07	32.97
(1) Major Crops	21.13	20.60	18.80
(2) Minor Crops	4.18	4.16	4.23
(3) Others	10.94	10.31	9.94
2. Mining & Quarrying	0.45	0.47	0.46
3. Manufacturing	16.06	16.02	15.48
(1) Large Scale	12.06	12.04	11.37
(2) Small Scale	4.00	3.98	4.11
B. Service	46.72	47.96	50.44
1. Construction Service	3.81	3.92	4.42
2. Other Services	42.91	44.04	46.02
C. Gross Domestic Product (GDP)	99.49	99.52	99.35
1. Net factor income from/to the rest of the world	+0.51	+0.48	+0.65
D. Gross National Product (GNP)	100.00	100.00	100.00

constant factor cost of 1959-60)

(Unit : %)

1975-76	1976-77	1977-78	1978-79	1979-80
48.45	47.56	45.23	44.38	44.80
32.98	32.54	30.33	29.72	29.80
18.92	18.47	17.14	16.96	17.25
4.44	4.46	4.16	4.00	3.99
9.64	9.61	9.03	8.76	8.56
0.42	0.48	0.45	0.43	0.45
15.05	14.54	14.45	14.23	14.55
10.83	10.19	10.20	9.94	10.20
4.21	4.35	4.25	4.29	4.35
49.83	49.43	49.12	49.57	49.55
5.06	4.83	4.75	4.87	5.09
44.77	44.60	44.37	44.70	44.46
98.28	96.99	94.35	93.95	94.35
+1.72	+3.01	+5.65	+6.05	+5.65
100.00	100.00	100.00	100.00	100.00

Source: Table 1.2.1

The expenditure structure of the GNP is given in Table 1.2.5 and the percentage share of each expenditure, in Table 1.2.6. These tables show that:

1) the share of "Private Consumption Expenditure" and that of "General Government Current Consumption Expenditure" have been kept virtually unchanged, while the share of "Gross Domestic Fixed Capital Formation", which remained low till 1974-75, has increased since then;

2) while the amount of "Exports of Goods and Services" has constantly increased, its growth rate is less than that of the amount of "Imports of Goods and Services": towards 1972-73, the former amount was substantially equal to the latter amount, but since 1974-75, the latter has been kept nearly twice as large as the former;

3) the "Net Factor Income from/to Rest of the World" has increased since 1974-75 mainly because of remittance to home from Pakistanis working in the Middle East.

The rate of the gross domestic fixed capital formation to the GDP has exceeded its ratio to the GNP since 1977-78 as a result of increase in net factor income from/to the rest of the world and this is because the investment in large-scale manufacturing industries in the public sector perked up as shown in Table 1.2.7.

Table 1.2.5 Expenditure on

Flows	1972-73	1973-74
Private Consumption Expenditure	50,139	69,942
General Government Current Consumption Expenditure	7,724	8,539
Gross Domestic Fixed Capital Formation	7,647	10,614
Change in Stocks	1,000	1,000
Exports of Goods and Services	9,961	11,960
Imports of Goods and Services	(-)9,598	(-)15,202
Expenditure on Gross Domestic Product at Market Prices	66,873	86,853
Net Factor Income from/to rest of the World	(+)463	(+)617
Expenditure on Gross National Product at Market Prices	67,336	87,470
Indirect Taxes	(-)6,600	)9,486
Subsidies	(+)522	(+)3,074
Gross National Product at Factor Cost	61,258	81,058

Note: R = Revised

P = Provisional

Gross National Product at Current Prices

(Unit: Rs million)

1974-75	1975-76	1976-77	1977-78	(R) 1978-79	(P) 1979-80
92,120	104,911	118,965	141,074	160,088	191,330
11,950	14,343	15,816	17,977	19,726	22,150
16,218	22,770	26,421	28,976	32,471	39,187
2,000	-	1,000	1,000	1,750	2,000
12,994	13,881	13,991	16,629	21,519	30,222
(-)23,016	(-)23,858	(-)26,741	(-)32,600	(-)42,510	(-)54,952
112,266	132,051	149,452	173,056	193,054	229,947
(+)1,147	(+)2,992	(+)5,480	(+)12,139	(+)13,922	(+)17,013
113,413	135,043	154,932	185,195	206,976	246,950
(-)11,560	(-)13,642	(-)15,650	(-)19,604	(-)22,292	(-)27,087
(+)3,934	(+)3,014	(+)1,884	(+)3,110	(+)6,900	(+)7,754
105,787	124,415	141,166	168,701	191,584	227,617

Source: Statistics Division

Table 1.2.6 Percentage Share of Expenditure on Gross National Product at Current Prices

(Unit: %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Private Consumption Expenditure	74.5	80.0	81.2	77.7	76.8	76.2	77.4	77.5
General Government Current Consumption Expenditure	11.5	9.8	10.5	10.6	10.2	9.7	9.5	9.0
Gross Domestic Fixed Capital Formation	11.3	12.1	14.3	16.9	17.1	15.6	15.7	15.9
Change in Stocks	1.5	1.1	1.8	-	0.7	0.5	0.8	0.8
Exports of Goods and Services	14.8	13.7	11.5	10.3	9.0	[illegible].0	10.4	12.2
Import of Goods and Services	-14.3	-17.4	-20.3	-17.7	-17.3	-17.6	-20.5	-22.3
Expenditure on GDP at Market Prices	99.3	99.3	99.0	97.8	96.5	93.4	93.3	93.1
Net Factor Income from/to rest of the World	0.7	0.7	1.0	2.2	3.5	6.6	6.7	6.9
Expenditure on GNP at Market Prices	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Table 2.1.5

Table 1.2.7 Percentage Share of Gross Fixed Capital Formation by Economic Activity

(Unit: %)

	1969-70	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79 (R)	1979-80 (P)
Private	51.1	50.1	51.9	48.7	36.2	32.1	28.5	29.4	30.2	29.6	30.8
Agriculture	7.0	6.6	7.8	8.0	7.0	5.2	5.9	6.1	6.7	6.4	6.3
Manufacturing Large Scale	17.7	17.4	14.9	10.0	6.6	6.1	5.7	5.8	5.3	5.0	4.7
Manufacturing Small Scale	2.8	2.9	3.2	3.3	3.1	2.8	2.2	2.2	2.2	2.1	2.0
Transport & Communication	7.5	7.4	8.9	12.7	9.4	6.3	4.7	4.4	4.2	4.3	5.3
Ownership of Dwellings	7.3	7.9	8.8	6.5	2.8	7.0	5.9	6.5	7.0	7.0	7.7
Others	8.8	7.9	8.3	8.2	7.3	4.7	4.1	4.4	4.8	4.8	4.8
Public	48.9	49.9	48.1	51.3	63.8	67.9	71.5	70.6	69.8	70.4	69.2
Manufacturing Large Scale	2.6	1.0	1.4	1.4	3.5	6.5	13.9	17.0	21.2	20.4	16.1
Electricity & Gas	2.3	8.2	6.0	5.0	6.6	14.9	14.0	9.5	9.6	9.3	8.3
General Government	15.6	13.4	13.4	20.7	25.3	23.3	21.6	22.7	19.5	21.6	19.8
Others	28.4	27.3	27.3	24.2	28.4	23.2	22.0	21.4	19.5	19.1	41.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Pakistan Economic Survey 1979-80, Table 2.4

Note: R = Revice, P = Provisional

As for the change in investment structure, the investment in housing construction etc. has been relatively favourable, but that in the private sector as a whole showed a relative decline in 1972-73 and has been dull since then. The possible causes of such dull investment in the private sector are the policy of nationalization adopted by the former government, the inflation after occurrence of the oil crisis and the subsequent decline of demand, the depression of agricultural production, etc. On the other hand, the investment in the public sector has constantly been increased, centring on the Federal Government, with funds raised through an increasing foreign assistance, in addition to the tax revenues.

The development of the Pakistani foreign trade is shown in Table 1.2.8. As is clear from this table, since 1973-74, the trade deficit has constantly increased, amounting in 1979-80 to Rs 23,519 million. This amount is almost equal to the total volume of exports in the same year. The exports are shown in Table 1.2.9 by categories of goods. This table shows that the share of the exports of manufactures goods in the total volume of exports has increased up to over 40% though the pace of increase is slow, while the export of primary commodities including mainly agricultural products presents a considerable variation in its evolution though its percentage share in the total volume of exports tends to show some decline: in 1979-80 when the crop of agricultural products, especially rice and raw cotton, was abundant, the percentage share of the export of primary commodities increased. The imports by categories are shown in Table 1.2.10. However, any definite tendency can not be seen from this table.

Table 1.2.8 Foreign Trade

(Unit: Rs million)

Year	Imports	Exports	Balance
1972-73	8,398.3	8,551.2	+152.9
1973-74	13,479.2	10,161.2	-3,318.0
1974-75	20,925.0	10,286.3	-10,638.7
1975-76	20,465.3	11,252.9	-9,212.4
1976-77	23,012.2	11,293.9	-11,718.3
1977-78	27,814.7	12,980.4	-14,834.3
1978-79	36,388.1	16,925.0	-19,463.1
1979-80	46,929.1	23,410.1	-23,519.0

Source: Statistics Division

Note: Re-imports and re-exports are not included.

Table 1.2.9 Economic Classification of Exports

(Unit: Rs million , %)

Year	Primary Commodities		Semi-manufactures		Manufactured Goods		Total	
	Value	Percentage Share	Value	Percentage Share	Value	Percentage Share	Value	Percentage Share
1969-70	531.7	33.1	375.4	23.3	701.5	43.6	1,608.6	100
1970-71	650.3	32.6	472.2	23.6	876.0	43.8	1,998.4	100
1971-72	1,510.4	44.8	913.8	27.1	947.2	28.1	3,371.4	100
1972-73	3,365.6	39.4	2,583.3	30.2	2,602.3	30.4	8,551.2	100
1973-74	4,007.3	39.4	2,293.8	22.6	3,860.1	38.0	10,161.2	100
1974-75	4,931.5	48.0	1,308.2	12.7	4,046.6	39.3	10,286.3	100
1975-76	4,902.2	43.7	2,067.5	18.4	4,283.2	37.9	11,252.9	100
1976-77	4,622.4	40.9	1,888.1	16.7	4,783.4	42.4	11,293.9	100
1977-78	4,634.2	35.7	1,911.5	14.7	6,434.7	49.6	12,980.4	100
1978-79	5,473.7	32.3	3,488.6	20.6	7,962.7	47.1	16,925.0	100
1979-80	9,838.3	42.0	3,519.3	15.0	10,052.5	43.0	23,410.1	100

Source: Statistics Division

Table 1.2.10 Economic Classification of Import

(Unit: Rs million, %)

Year	Capital Goods		Industrial Raw Material: Capital Goods		Industrial Raw Material: Consumer Goods		Consumer Goods		Total	
	Value	Percentage Share	Value	Percentage Share	Value	Percentage Share	Value	Percentage Share	Value	Percentage Share
1969-70	1,655.0	50.4	344.0	10.5	957.0	29.1	329.0	10.0	3,235.1	100.0
1970-71	1,885.4	52.3	381.9	10.6	949.8	26.4	385.3	10.7	3,602.4	100.0
1971-72	1,482.1	42.4	366.6	10.5	851.5	24.4	795.2	22.7	3,495.4	100.0
1972-73	2,498.3	29.8	830.2	9.9	2,584.6	30.8	2,484.7	29.5	8,398.3	100.0
1973-74	3,975.3	29.5	904.0	6.7	5,385.9	40.0	3,214.0	23.8	13,479.2	100.0
1974-75	6,152.2	29.4	1,802.2	8.6	8,257.1	39.5	4,713.5	22.5	20,925.0	100.0
1975-76	7,158.2	35.0	1,261.0	6.1	7,709.4	37.7	4,336.7	21.2	20,465.3	100.0
1976-77	8,750.2	38.0	1,463.6	6.4	9,147.7	39.7	3,650.7	15.9	23,012.2	100.0
1977-78	9,315.7	33.5	1,920.8	6.9	11,023.5	39.6	5,554.7	20.0	27,814.7	100.0
1978-79	10,970.5	30.1	2,160.2	5.9	15,415.7	42.4	7,841.7	21.6	36,388.1	100.0
1979-80	16,679.0	35.5	2,915.7	6.2	19,834.4	42.3	7,500.0	16.0	46,929.1	100.0

Source: Statistics Division

1.2.2 Trend of Agriculture and Industry

(1) Agriculture

As mentioned in Sub-section 2.1.1, the agriculture accounts for some 30% of the GNP. It has heavy weight with the Pakistani economy. Particularly in 1978-79 and 1979-80, the agriculture registered a remarkable annual growth of 4.2% and 6.0%, respectively, on a real GDP basis (as compared with an average annual growth rate of 2.9% during the period of 1972-73 to 1979-80). As shown in Table 1.2.1, the annual growth rate as compared with the preceding year of major crops and minor crops is 5.2% and 2.4% in 1978-79 and 6.0% and 6.5% in 1979-80, respectively, while the average annual growth rate during the period of 1972-73 to 1979-80 is 2.8% for the major crops and 4.4% for the minor crops. The output of major crops is given in Table 1.2.11. The recent increase in agricultural output as shown in this table is attributed largely to the favourable weather conditions.
The effects of popularization of new kinds of crops, increase in volume of fertilizers, chemicals and other input goods, increase in capacity of irrigation systems and other political measures have also contributed to such increase in agricultural output.

Table 1.2.11 Production of Principal Crops

(Unit: 1,000 tonnes)

Crops	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	(P) 1979-80
Wheat	7,442	7,629	7,673	8,691	9,144	8,367	9,944	10,895
Rice	2,330	2,455	2,314	2,618	2,737	2,950	3,272	3,224
Bajra	304	351	266	308	311	318	317	278
Jowar	302	378	266	281	261	284	252	244
Maize	706	767	747	802	764	821	798	871
Barley	109	139	137	130	124	121	129	128
Total - Foodgrains	11,193	11,719	11,403	12,830	13,341	12,861	14,712	15,640
Gram	553	610	550	601	649	614	538	265
Total - Food Crops	11,746	12,329	11,953	13,431	13,990	13,475	15,250	15,905
Sugarcane	19,947	23,911	21,242	25,547	29,523	30,077	27,326	27,200
Rapeseed & Mustard	287	292	248	267	296	236	243	225
Sesamum	10	12	8	11	12	13	19	23
Cotton	704 (3,947)	659 (3,704)	634 (3,567)	514 (2,890)	435 (2,446)	575 (3,233)	473 (2,662)	747 (4,200)
Tobacco	63	66	77	58	73	73	68	63
Total - Cash Crops	21,009	24,940	22,209	26,397	30,339	30,974	28,130	28,258
Total - Principal Crops	32,755	37,269	34,162	39,828	44,329	44,449	43,380	44,163

Source: Ministry of Food Agriculture and Cooperatives

Note: (P) - Provisional
Figures in brackets indicate 000 bales for cotton.

However, it should be considered that the favourable weather conditions permitted these measures to produce fruit.

(2) Industry

Recently industrial production shows a considerably upward tendency with its annual actual growth rate being 9.2% in 1977-78, 4.8% in 1978-79 and 8.1% in 1979-80 as against 4.1% on the average from 1972-73 to 1976-77 on a GDP basis. Seeing it by industries, cement, fertilizer and vegetable ghee industries have shown a significant increase in production due to the increased production capacity brought about by expanded investment in equipment. Such increased production is observed all over the industries excluding sugar manufacturing, cotton cloth, tires & tubes and sulfuric acid that can be statistically grasped. Production of these industries is shown in Table 1.2.12.
With these industries classified into consumer goods (sugar, vegetable ghee, cotton cloth, beverage, dairy products, tobacco, carpets, leathers, wooden products, etc.), intermediate goods (rubber, chemical, petroleum & coal products, ceramics & masonry products, various kinds of non-ferrous metals, etc.) and capital goods (metal products, electric machinery, transportation

Table 1.2.12 Production of Selected Manufacturing Industries

Item	Unit	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
1. Food Manufactures									
(i) Sugar	000 tonnes	429	608	502	630	736	861	607	586
(ii) Vegetable Ghee	000 tonnes	187	225	272	277	326	360	422	451
(iii) Sea Salt	000 tonnes	161	111	139	151	138	224	163	172
(iv) Beverages	000 dozen bottles	13,167	15,039	21,421	26,361	28,878	41,976	53,356	48,020
2. Tobacco Manufactures									
Cigarettes	Million Nos.	27,623	27,477	26,804	27,454	28,379	31,304	32,536	34,647
3. Textile Manufactures									
(i) Cotton Yarn	Million KG	376.1	379.5	351.2	349.7	282.6	297.9	327.8	362.9
(ii) Cotton Cloth	Million Sq. Mts.	588.6	592.2	555.9	520.3	408.3	391.3	339.4	342.3
(iii) Art Silk & Rayon Cloth	Million Mts.	5.3	8.7	8.1	9.9	17.5	15.6	14.0	N.A.
(iv) Jute Textiles	000 tonnes	34.5	36.5	45.4	42.0	33.9	33.4	37.0	41.8
4. Rubber Manufactures									
(i) Motor tyres	000 Nos.	168	249	239	166	148	182	183	204
(ii) Motor tubes	000 Nos.	162	177	214	143	137	159	197	201
(iii) Cycle tyres	000 Nos.	2,542	3,252	3,033	3,180	3,461	3,675	3,731	3,647
(iv) Cycle tubes	000 Nos.	3,283	3,862	4,161	4,219	4,131	5,030	4,154	5,017
5. Non-Motaille Manufactures									
Cement	000 tonnes	2,876	3,145	3,320	3,196	3,071	3,224	3,022	3,343
6. Chemical/Fertilizers									
(i) Urea	000 tonnes	533.1	575.5	599.5	605.3	593.6	594.9	620.5	640.5
(ii) Superphosphate	000 tonnes	45.7	22.6	31.7	58.6	66.1	75.0	98.5	101.2
(iii) Ammonium Nitrate	000 tonnes	65.6	63.5	58.8	70.8	64.5	47.1	81.1	199.0
(iv) Ammonium Sulphate	000 tonnes	58.2	90.4	95.1	98.3	100.0	95.6	97.9	98.9
(v) Nitro-phos-phate	000 tonnes	-	-	-	-	-	-	40.4	137.2
(vi) Soda Ash	000 tonnes	74.2	81.2	77.1	78.6	55.3	68.8	71.4	79.4
(vii) Sulphuric Acid	000 tonnes	42.5	34.0	37.0	46.2	45.2	51.8	56.5	57.4
(viii) Caustic Soda	000 tonnes	35.4	37.5	36.8	38.3	23.6	35.0	36.0	39.9
(ix) Chlorine gas	000 tonnes	6.3	6.8	4.9	5.5	4.2	5.7	7.9	8.6
(x) Paints and Varnishes	000 litres	5,665	6,147	6,184	7,123	7,193	7,924	8,286	8,031
(xi) Polishes &	million	498.1	462.2	530.6	507.2	604.1	641.4	730.6	1,024.3

	Cement	000 tonnes	2,876
6.	Chemical/Fertilizers		
	(i) Urea	000 tonnes	533.1
	(ii) Superphosphate	000 tonnes	45.7
	(iii) Ammonium Nitrate	000 tonnes	65.6
	(iv) Ammonium Sulphate	000 tonnes	58.2
	(v) Nitro-phos-phate	000 tonnes	-
	(vi) Soda Ash	000 tonnes	74.2
	(vii) Sulphuric Acid	000 tonnes	42.5
	(viii) Caustic Soda	000 tonnes	35.4
	(ix) Chlorine gas	000 tonnes	6.3
	(x) Paints and Varnishes	000 litres	5,665
	(xi) Polishes & creams for footwears	million grams	498.1
	(xii) Safety Matches	Million Boxes (40-60 sticks)	338.6
7.	Transport Equipment		
	Bicycles	000 Nos.	211.7
8.	Manufacture of Machinery		
	Sewing Machines	000 Nos.	66.4
9.	Electric Appliances		
	(i) Pedestal Fans	000 Nos.	34.1
	(ii) Ceiling Fans	000 Nos.	152.7
	(iii) Table Fans	000 Nos.	36.2
	(iv) Electric Bulbs	Million Nos.	10.7
	(v) Electric Tubes	000 Metres	565
10.	Iron and Steel Industry		
	M.S. Products	000 tonnes	183.9
11.	Paper and Board		
	(i) Paper Board	000 tonnes	20.2
	(ii) Chip Board	000 tonnes	17.7
	(iii) Straw Board	000 tonnes	-
	(iv) Printing Paper	000 tonnes	6.3
	(v) Writing Paper	000 tonnes	16.9
	(vi) Packing and Other Paper	000 tonnes	4.0

3,145	3,320	3,196	3,071	3,224	3,022	3,343
575.5	599.5	605.3	593.6	594.9	620.5	640.5
22.6	31.7	58.6	66.1	75.0	98.5	101.2
63.5	58.8	70.8	64.5	47.1	81.1	199.0
90.4	95.1	98.3	100.0	95.6	97.9	98.9
-	-	-	-	-	40.4	137.2
81.2	77.1	78.6	55.3	68.8	71.4	79.4
34.0	37.0	46.2	45.2	51.8	56.5	57.4
37.5	36.8	38.3	23.6	35.0	36.0	39.9
6.8	4.9	5.5	4.2	5.7	7.9	8.6
6,147	6,184	7,123	7,193	7,924	8,286	8,031
462.2	530.6	507.2	604.1	641.4	730.6	1,024.3
368.3	466.8	589.6	769.0	1,136.9	1,274.0	820
178.5	210.4	217.8	211.5	244.7	280.1	279.4
75.5	55.5	64.0	53.4	61.8	61.6	67.3
32.4	37.6	30.9	30.7	38.0	38.6	66.7
144.8	140.7	107.2	126.0	147.0	150.9	201.0
13.7	14.9	10.1	8.1	11.2	7.0	2.4
10.9	15.0	17.4	14.9	17.5	20.6	20.3
642	604	564	413	464	1,238	1,414
218.1	224.0	220.7	269.6	315.3	362.4	420.4
21.5	13.9	9.7	9.9	12.2	23.8	25.3
14.4	13.2	11.4	11.6	10.2	25.9	24.1
-	0.1	-	-	-	-	-
4.8	4.0	2.4	3.2	2.8	3.0	3.7
16.6	15.4	16.1	15.7	17.8	22.5	20.4
3.7	3.7	2.7	4.1	1.6	3.8	6.1

Source: Pakistan Statistic Year Book 1979 equipment, etc.) industries, statistical values given in this table indicate for the most part those of consumer goods and intermediate goods. Production of capital goods is not grasped as dynamic statistics of production to a full extent. According to the Census of Manufacturing Industries taken every five years, the production ratio of consumer goods, intermediate goods and capital goods in 1975-76 is calculated at 66.2%, 18.1% and 14.6%, respectively, as is shown in Table 1.2.13.

Table 1.2.13 Change in Composition of Added Value of Manufacturing Industries

(Unit : 1,000 Rs)

Item	1955		1965-66		1975-76	
	Value	%	Value	%	Value	%
Consumer Goods	249,455	67.5	1,867,516	65.6	7,265,473	66.2
Intermidiate Goods	97,594	26.4	494,069	17.4	1,981,231	18.1
Capital Goods	19,436	5.3	338,925	11.9	1,598,188	14.6
Unknown	3,056	0.8	145,911	5.1	127,531	1.1
Total	369,541	100.0	2,845,911	100.0	10,972,423	100.0

Source: Census of Manufacturing Industries 1955, 1965-66, 1975-76.

Turning to the key industries in Pakistan, the cotton spinning industry having a long history, in the first place, was established in 1950's and made a rapid growth since then. However, it has long been in stagnant condition after the oil crisis. Table 1.2.14 shows the position held by this industry in the whole manufacturing industries.

As is obvious from table, this industry holds slightly lower than 20% for the production and the added value, slightly higher than 30% for the number of employees and 25% for the exports in 1975. However, this industry is now faced with many problems such as obsolescence of equipment, stagnancy of international market and labour problems. Nearly 50% of the existing spindles amounting to 3.8 million in number are held by obsolete ones mainly of Chinese or Soviet make which have been operated for more than 20 years. However, the cotton spinning industry circle based mainly on the private capital takes a negative attitude for new investment in equipment for fear of the government policy for the nationalization of industries continued from the former government. Furthermore, since Singapore, Indonesia, Brazil, etc., having been importing countries of cotton products some years ago, have newly launched into the international market, in addition to Korea, Taiwan and Turkey, the situation does not warrant optimism about the future international market of this industry.

In the aspect of labour force, this industry is under the influence of recent trend among workers going to Middle East to work.

Table 1.2.14 Weight of Cotton Industry in the Whole of Manufacturing Industries

(Unit: %)

	1955	1965-66	1975-76
Number of Enterprises	4.7	6.8	4.6
Fixed Capital	47.2	29.4	25.6
Number of Employees	42.4	38.4	32.8
Production	29.4	18.9	17.0
Added Value	39.2	23.4	16.2
Exports	4.8	22.1	25.1

Source: Prepared from the editions of 1955, 1965-66 and 1975-76, "Census of Manufacturing Industries". Provided that the export ratios were calculated from the editions of 1955, 1965-66 and 1975-76, "Pakistan Economic Survey".

As one of industries to which priority is given by the Government, there is a chemical fertilizer industry. In view of the fact that this country is basically an agricultural country, this industry has a very important meaning. The current domestic equipment capacity of chemical fertilizers is at the level of 89 thousand tonnes for phosphatic fertilizer and 731 thousand tonnes for nitrogenous fertilizer.

In 1979-80, the self-supply ratio of chemical fertilizers in total is still at the low level of 38%.

On the other hand, Pakistan is far behind other countries in the capital goods industry. In view of this, the government has established HMC (Heavy Mechanical Complex, completed in 1971) at Taxila and PMTF (Pakistan Machine Tool Factory, completed in 1968) at Karachi, as the nucleus of the engineering industries in the public sector covering the north and south areas, respectively. Further, HFF (Heavy Foundry and Forge, completed in 1977) has been established adjacent to the HMC to ensure a stable supply of materials to it. The HFF is providing steel castings and forgings not only for the HMC but also for other engineering industry. In the steel industry, supporting the engineering industry, there is no steel maker or large-scale; small-scale melters and re-rollers are scattered chiefly at Lahore and Karachi. However, the majority of them are producing only bar and section steels for use in construction. With this in view, the government is pushing forward the construction of Pakistan Steel in the eastern part of Karachi, which is the coastal integrated steelworks having annual capacity of 1.1 million tonnes.

According to the present plans of construction and operation, the blast furnace will start blowing-in during 1981 and, for the time being, billets, and pig iron will be produced for the purpose of supplying them to domestic users as a substitute for imports. In 1984, the hot strip mill and cold strip mill will be completed, whereby hot sheets, cold sheets and formed sections will be supplied.

In the Pakistan's engineering industry, PECO (Pakistan Engineering Co.), KSEW (Karachi Shipyard & Engineering Works) and others chiefly in the private sector (in addition to HMC and PMTF) are producing and constructing a variety of equipment and plant, including paper mills, vegetable ghee plants, flour rice mills, fertilizer plants, chemical and petro-chemical plants, oil refineries, steel section rolling mills, textile machinery, engines and turbines, pumps and compressors, boilers, sugar mill machinery, cement plants, etc. However, the engineering industry is now at a very low rate of operation. This is generally caused by the following facts:

1) The capital goods market varies over a wide range and the existing scale of domestic market is not enough to meet the economic scale of production.

2) The dependency on import of raw materials and spares is very high.

3) Related subsidiary industries have not yet been grown to full extent.

4) Due to insufficient competitive power caused by backwardness in technological development and shortage of skilled labour, it is impossible to participate in the international export market.

Therefore, it is to be desired for the Pakistani engineering industry to ensure a stable state of capital goods market, a stable supply of raw materials and a sufficient supply of labour. Nevertheless, the future step to be taken by the engineering industry is not to establish heavy and chemical industries at a rapid rate, but to expand gradually the domestic capital goods market in due regard to the agricultural industry peculiar to Pakistan and the formation of social capital, to improve the technological level and foster the skilled labour, and further to secure sufficient competitiveness to participate in the international export market.

As shown in Fig. 1.2.1, the existing structure of energy supply which forms the basis for industrial production is: hydraulic power 18%; natural gas 38%; oil 38% and coal 5%.

Particularly, natural gas and hydraulic power have been increasing in supply at a rapid rate. This suggests that the policy adopted to reduce the dependency on oil supply is producing a successful result. In view of the availability of resources in Pakistan, the nation's energy policy will hence be directed mainly towards the development of hydraulic power and natural gas.

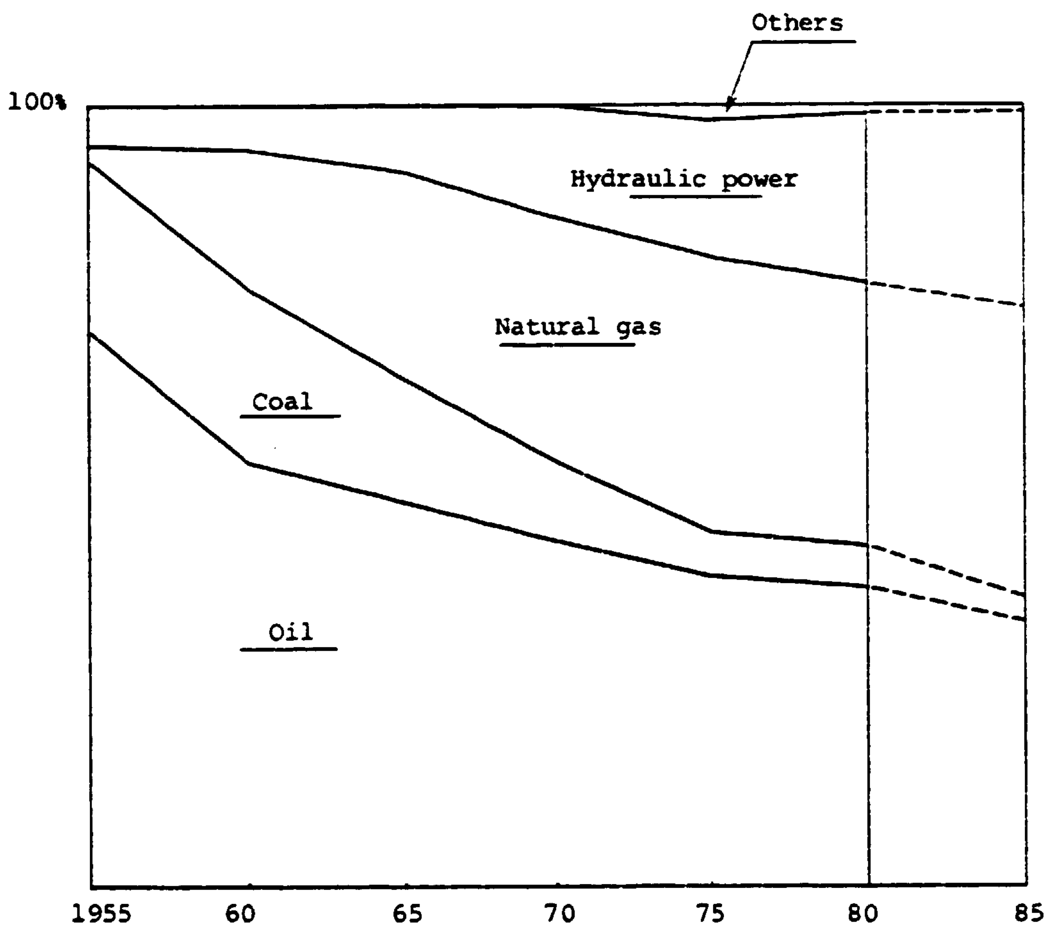


Fig. 1.2.1. Energy Supply in Pakistan

Source : Pakistan Statistic Year Book, Pakistan Economic Survey, Fifth Five-Year Plan

Table 1.2.15 represents the regional distribution of industrial production. From old times, agricultural production and related industries were growing chiefly in Punjab. Karachi, the new capital city of Pakistan after its Independence, showed a rapid growth of trade and industry as the only port city in Pakistan and with the inflow of a stream of Muslim refugees after the separation of India and Pakistan. According to the Census of Manufacturing Industries (1975-76), the output in percentage by districts is 43% in Panjab, 49% in Sind, 8% in N.W.F.P. and only a negligible level in Baluchistan.

Table 1.2.15 Regional Distribution of Industrial Production

(Unit : Rs million)

	No. of Business Establishments	Total Fixed Capital	No. of Employed Workers	Output	Total Added Value
Whole of Pakistan	3,248(100.0)	8,871(100.0)	506,601(100.0)	30,674(100.0)	10,972(100.0)
Sind	1,362 (42.0)	4,096 (46.2)	234,498 (46.3)	15,061 (49.1)	4,899 (44.7)
Karachi	1,208 (37.2)	2,755 (31.1)	181,446 (35.8)	12,465 (40.6)	3,808 (34.7)
Hyderabad	66	303	31,784	1,013	439
Punjab	1,725 (53.1)	3,969 (44.7)	235,829 (46.6)	13,160 (42.9)	4,844 (44.2)
Faisalabad	294	467	46,472	1,997	660
Shekhupura	83	767	16,628	1,831	542
Lahore	483	456	38,832	1,776	556
Rawalpindi	91	458	18,810	1,424	734
N.W.F.P.	147 (4.5)	792 (8.9)	34,790 (6.9)	2,394 (7.8)	1,197 (11.0)
Peshawar	68	363	12,836	974	528
Baluchistan	14 (0.4)	13 (0.2)	1,484 (0.3)	59 (0.2)	32 (0.3)

Note: The figures given in parentheses are the percentage.

Source: Census of Manufacturing Industries (1975-76) by Ministry of Finance

Table 1.2.16 shows the export records of principal manufactured goods. As is apparent from this table, agriculture-related manufactured goods including cotton yarn, cotton cloth and clothing based essentially on the processing of farm products account for the large proportion of exports. The rest, except petroleum products, are labour-intensive and traditional products.

Table 1.2.16 Main Industrial Exports

(Unit : Rs million)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Cotton Yarn	1,941	1,811	851	1,422	1,172	1,060	1,956	1,571
Cotton Cloth	1,247	1,417	1,313	1,359	1,603	1,741	2,135	1,691
Clothing	97	167	245	328	418	139	377	752
Carpet	282	457	456	719	912	1,171	1,765	1,574
Leather	545	419	367	596	647	637	1,247	1,032
Ghee Products	96	176	164	197	182	203	272	241
Sporting Goods	136	188	204	189	199	195	210	180
Medicines	37	103	116	133	134	146	131	122
Medical Appliance	45	85	129	131	134	161	211	171
Petroleum Products	129	176	139	192	269	608	608	1,300
Cement	106	167	280	51	6	3	-	-
Others	525	1,088	1,091	1,034	996	2,282	2,537	1,164
Total	5,186	6,254	5,355	6,351	6,672	8,346	11,451	9,798

Note: The figures in the year marked with an asterisk are for the period ranging from July to March.

Source: Pakistan Economic Survey

1.2.3 Population and Labour Force

For the past twenty years, the population of Pakistan sho·ed an average yearly increase of 2.9%, amounting to 80,230,000 in 1979-80 (see Table 1.2.17).

The percentage increase in population every ten years is 2.5% in the 1949-50 to 1959-60 period, 2.9% in the 1959-60 to 1969-70 period ard 3.0% in the 1969-70 to 1979-80 period, indicating a higher rate of increase in recent years.

Table 1.2.17 Population and Its Annual Growth Rate

(Unit: Million person, %)

Year	Population
1949 - 50	35.31
1954 - 55	39.87
1959 - 60	45.03
1960 - 61	46.20
1961 - 62	47.53
1962 - 63	48.90
1963 - 64	50.31
1964 - 65	51.76
1965 - 66	53.26
1966 - 67	54.79
1967 - 68	56.37
1968 - 69	58.00
1969 - 70	59.70
1970 - 71	61.49
1971 - 72	63.34
1972 - 73	65.24
1973 - 74	67.20
1974 - 75	69.21
1975 - 76	71.29
1976 - 77	73.43
1977 - 78	75.63
1978 - 79	77.90
1979 - 80	80.23
1959-60 to 1949-50	2.5
1969-70 to 1959-60	2.9
1979-80 to 1969-70	3.0
1979-80 to 1959-60	2.9
1979-80 to 1949-50	2.8

Source: Pakistan Economic Survey 1979-80

According to the Census of Pakistan (1972), the population of Pakistan presents a concentrated distribution in Punjab and Sind, the population of these two provinces accounting for 79% of the total (see Table 1.2.18). In the 1961 to 1972 period, the average increase in population at Karachi and Lahore is 5.7% and 4.8%, respectively, approximately two times that over the whole of Pakistan. Lately, there is an increasing tendency towards the drift of pupulation to cities.

The labour force in 1979-80 is 23,650,000, while the number of empolyed persons as estimated by the Planning Division is 23,250,000. As for the distribution of employed persons by major industry divisions in 1974-75, the agriculture division shows the highest percentage (55%), followed by the manufacturing division in 14%.

Since the oil crisis, there has been a considerable emigration of workers from Pakistan to oil-producing countries in the Middle East. The number of emigrants is about 118,000 in the year 1979. This will probably contribute to the reduction in unemployment rate in Pakistan. However, in recent years, such emigration has been affecting the economic development in Pakistan as the emigrants are relatively skilled and educated labour.

Table 1.2.18 Area, Density and Population by Province in 1972

	Population (1000 persons)	(%)	Density (person/Km^2)
N.W.F.P.	8,389	12.8	113
Peshawar	273	0.4	
Fedrally Administrated Tribal Area	2,491	3.8	92
Federal Capital Territory Islamabad	235	0.4	259
Punjab	37,610	57.6	183
Lahore	2,170	3.3	
Sind	14,156	21.7	100
Karachi	3,515	5.4	
Paluchistan	2,429	3.7	7
Quetta	158	0.2	
Total	65,309	100.0	82
Urban	16,594	25.4	
Rural	48,716	74.6	

Source: 1972 Census of Pakistan

Table 1.2.19 Percentage Distribution of Employed Persons by Major Industry Division

Major Industry Division	1971-72	1974-75
Total employed persons	100.00	100.00
Agriculture, forestry, hunting & fishing	57.32	54.80
Mining and quarrying	0.45	0.15
Manufacturing	12.47	13.63
Electricity, gas and water	0.37	0.49
Construction	3.41	4.20
Wholesale and retail trade and restaurants and hotels	9.89	11.09
Transport, storage and communication	4.84	4.87
Financing, insurance, real estate and business services	0.86	0.67
Community, social and person services	7.27	9.78
Activities not adequately defined	3.12	0.33

Source: Pakistan Statistic Year Book 1979

Table 1.2.20 Labour Force Emigration from Pakistan

(Unit: 1,000 workers)

Year	1972	1973	1974	1975	1976	1977	1978	1979
Workers	4.5	12.3	16.3	23.1	41.7	80.3	81.9	118.3

Source: The same as Table 1.2.19

2. EXISTING IRON AND STEEL INDUSTRY IN PAKISTAN

2.1 Raw Materials

2.1.1 General Aspects of Raw Material Requirement for Pakistani Iron and Steel Industry

The Pakistani iron and steel industry depends mainly on the process of "electric furnace steelmaking - ingotmaking - rolling" using scrap as a principal raw material. Therefore, raw materials necessary for this process are scrap, limetone, fluorite, ferroalloys, etc. However, since Pakistan Steel now under construction near Karachi is the so-called "integrated steel mill" based on the process of "blast furnace - basic oxygen furnace", it will use iron ores and coal as principal raw materials. Therefore, iron ores, coal, manganese ores, limestone, dolomite, fluorite, scrap, ferroalloys, fire clay, etc. are regarded as necessary raw materials for the future iron and steelmaking in Pakistan.

Of these raw materials, limestone, dolomite, fluorite and locally generated scrap will be easily procured in Pakistan, but other raw materials will depend enevitably on the import for the time being. Although it is known that there are some occurrences of iron ores and coal, the principal raw materials for blast furnace ironmaking process in Pakistan, they have not as yet been developed to a substantial degree in view of the quality, reserves and transportation. Only coking coal produced at Sharigh, Baluchistan State, will be supplied to Pakistan Steel in a quantity of 80,000 tonnes per year.

Limestone is found in abundance in Sind, Punhab, NWFP and Baluchistan and its quality is also good for iron and steelmaking.

Although dolomite has so far been produced only in a quantity of about 20,000 tonnes per year, it was already confirmed that there are some potentials of dolomite in Sind and NWFP. Dolomite deposits in Sind are now being developed for Pakistan Steel,

Fluorite is now being produced in a quantity of approx. 500 tonnes per year and is used in the ceramic industry or like in addition to the iron and steel industry. Considerably large fluorite deposits were confirmed in Balauchistan and NWEP. These deposits will also be developted for pakistan Steel.

Fire clay is now produced in a quantity of approx. 50,000 tonnes per year at the large deposits in Punjab, Sind and NWFP. Its production will be doubled after the start-up of Pakistan Steel.

As for raw material for ferroalloys, it is known that there are some potentials of chrome ore in Pakistan. Since there was not enough demand to permit any growth of ferroalloy industry in the country so far, small deposits of chromite at Baluchistan have been only mined and exported aborad. It is a very unrealizable possibility that the special steelmaking industry will grow there in the near future. However, the technologies in the both fields of special steelmaking and surface treatment of steel sheets will be developed in future with the progress of iron- and steelmaking technologies in Pakistan, then wide-range research and development of chrome ore will be also considered for the export of chrome ore itself, production of chromium for ferroalloy manufacturing and tin-free steelmaking, etc.

Scrap is largely classified into domestic scrap, imported scrap and ship breaking scrap. Of scrap consumption of approx. 648,000 tonnes per year now in Pakistan, domestic scrap is said to account for 40%, imported scrap for 36% and ship breaking scrap for 24%.

As for the procurement of raw materials by Pakistan Steel, refer to Item (2) (b) in 2.2.4.

2.1.2 Detail of Raw Materials

(1) Iron ore

(a) Occurrence of iron ore resources in Pakistan

The occurrence of iron ores in Pakistan has been reported by the Pakistani governmental agencies and some foreign consultants. According to these reports, the origin of the Pakistani iron ores divides into four types from the viewpoint of genesis:

1) Sedimentary origin,
2) Metamorphic or hydrothermal origin,
3) By-product or co-product of porphyry copper deposits, and
4) Lateritic origin .

The total reserves of Origin 1) are said to be more than 400 million tonnes and the typical ore of this group occurs in the region of Kalabagh, Punjab. These ores are, in general, of very low grade (30 to 35% Fe), and exist in the form of complex ores composed of iron oxides, carbonates and silicates. Economical beneficiation of these ores is considered difficult. However, PCSIR is carrying out the beneficiation tests of these ores.

The ores of Origin 2) are relatively high grade (more than 50% Fe) in the crude state. As the principal component is magnetite, beneficiation by magnetic separation is relatively easy.

Ten million tonnes of iron ore in Pachinkoh and Chigendik, Nokundi (Baluchistan) with an average iron content of 45% to 50% have been proved by PIDC. The chance of proving additional 5 million tonnes or more reserves are very bright. There is a possibility that proved reserves may be enhanced by 10 million tonnes if the geophysical anomalies prove productive.

The ores of Origin 3) are generally extracted from porphyry copper deposits as a by-product or co-product, which will be low grade magnetite with a huge amount of ore reserves. An example will be observed at Saindak, Baluchistan.

The ores of Origin 4) are characterized by high alumina (approx. 30% Al_2O_3) and phosphorus contents. Lateritic type ore reserves of over 16 million tonnes are located near Ziarat in Sibi District, Baluchistan with an average iron content of 29%. The ores of this type are not effectively exploited not only in Pakistan but in any other regions of the world.

(b) Explortation of iron ore

Due to the complex mineralogy and chemistry which makes its metallurgy problematic, no commercial explortation of these iron ores has been undertaken. Pakistan's first integrated steelworks being set up at Karachi, is based on imported iron ores. This is because under the current technology although it is technically possible to use the local iron ore for ironmaking, it is not economically feasible.

PMDC and FIDC are, however, working for developing a suitable process so that the local iron ores after processing could be used with imported iron ores in Pakistan Steel in collaboration with PCSIR and UNIDO. Work would continue in carrying out more detailed and denser exploration of iron ore deposits and confirmation and final evaluation of Nokundi iron ores.

(2) Coal

(a) Occurrence of coal in Pakistan

Detailed geological investigations have been carried out in a number of known coal bearing areas of Pakistan since Independence. Geological investigations have also been carried out in areas considered geologically fovourable for the existence of coal, and this led to the discovery of new coal fields. During the course of these investigations, a large amount of data on coal were being collected.

According to these data, the coal deposits of Pakistan are associated with tertiary rocks and show a high range of variation even within the same bed. On the basis of analytical results these coals may be classified as lignite to sub-bituminous showing non-coking or weakly coking properties.

They have low contents of fixed carbon, high sulphur and ash, and low to medium calorific values which range between 7,400 to 12,400 BTU/lb.

The major coal fields are distributed in different parts of Punjab, Sind, NWFP and Baluchinstan. The total recoverable reserves of coal are estimated at 442 million tonnes. Among the known coal fields of Pakistan, the most significant are the followings:

1) Makerwal, Punjab
2) Sharigh, Sor-range and Deghari, Baluchistan, and
3) Lakhra, Sind.

At present about 80% of coal production which stands at about 1,250 thousand tonnes per year, is mainly consumed by brick-kiln industry as run of mine without any treatment. Other consumers of coal are railways, small scale industries, Defense Services and domestic users.

With the energy crisis giving the World, greater use of this natural resources is being made in Pakistan to reduce the dependence on imported resources of energy. For this purpose, Lakhra coal field (Sind) is being developed with a view to mining about one million tonnes of coal from this area for the power generation plant. Another project under commission is for the establishment of a coal washing plant to convert Sharigh coal of approx. 80,000 tonnes per year into coke at Pakistan Steel, Karachi.

The chemical and physical characteristics of the indigenous coals indicate that these are young (tertiary) and of low rank. Washability studies to improve the grade of Sharigh coal have been carried out by a number of foreign firms. The results of their investigations may be summarised as follows:

a) The coals are friable and contain high ash ranging from 21 to 39%.

b) They are easily washable and clean coal contains 8 to 10% ash.

c) The per cent recuperation in case of Sharigh is 72.

Coking studies on pilot plant have been carried by CERCHAR, France. It would be worthwhile to blend indigenous coal with foreign coking coals to a certain amount.

Table 2.1.1 shows coal production in Pakistan.

Table 2.1.1 Coal Production in Pakistan

Year	Production (1,000 tonnes)
1970-71	1,324
1971-72	1,255
1972-73	1,204
1973-74	1,129
1974-75	1,314
1975-76	1,138
1976-77	1,112
1977-78	1,196
1978-79	1,261

Source: Statistics Division

(b) Situation in coal industry

Having fallen from grace for some time, coal has again sprung into prominence. The world coal industry is now revitalised. and buoyant, with the promise of unprecedented growth. The factors which have given coal its new role are the recurring rise in oil prices and the international problems connected with the supply of oil and its non-renewable sources. Added attention is being given to the exploration and development of coal world-wide, recognising its new role. Coal consumption is expected to triple over the next two decades to meet world energy demand. This new coal boom will have a ripple effect far beyond the mining industry and on a scale as yet unheard of.

It will require massive investments in railways, ports and ships to transport coal. It will give rise to new trading patterns with the USA, Canada, Australia, China and South Africa emerging as world leaders for coal production and export.

The world's resources of coal for exceed those of any other energy minerals. Coal has, therefore, a long-term future both in steelmaking and thermal power generation as a source of liquid and gaseous fuels when the reserves of oil and gas begin to wane.

(c). Future of coal

The major contributory events and facters in shaping the future of coal are as follows: -

1) The biggest single factor was the oil shock of 1973, the haunting memories of which still persist in the industrialised world. Oil prices raised four times in 1973, have risen five fold compared to pre-crisis and are expected to keep on climbing. On the contrary, coal prices have risen on a much slower rate as compared with oil prices.

2) To coal-producing countries not endowing with significant oil and gas reserves, coal offers growing economic and strategic advantages over oil for electricity generation. Accordingly, there has been growth in the demand for electricity generation.

3) International problems connected with the supply of imported oil highlighted by the oil embargo of '73 and the events connected with the Islamic Revolution in Iran, which cut off a major source of world oil supply.

4) World reserves of oil and gas are much smaller than those of coal and are currently being depleted at a much faster rate. Renewable energy sources such as solar, wind, tide and geothermal are incapable of meeting more than a small production of energy needs and are not expected to reach the stage of commercial development until at least a decade from now.

5) Because of the global energy crisis, which is basically petroleum oriented, new technologies to convert coal to a clean and economical energy source will provide substantial grwoth opportunities to coal producers.

(3) Limestone and dolomile

(a) Limestone

The occurrence of high quality limestone has been widely spread over Pakistan and provided a cheap supply of raw material for the cement, iron and steel, chemicals and various other industries. The reserves are huge and unlimited. The present production is about 3 million tonnes per year. Past growth in production of limestone is given in Table 2.1.2.

The production of limestone is projected to increase to meet the increasing demand from new cement plants and Pakistan Steel. According to the Fifth Five-year Plan the production of limestone will grow to about 10 million tonnes in the year 1982-83.

Table 2.1.2 Limestone Production in Pakistan

Year	Production (1,000 tonnes)
1970-71	2,987
71-72	2,628
72-73	2,846
73-74	3,258
74-75	3,008
75-76	2,968
76-77	3,288
77-78	3,578
78-79	3,298

Source: Statistics Division

(b) Dolomite

The deposits of dolomite in Pakistan are very large and can provide a substantial quantity for industrial purposes. Fairly large deposits of dolomite are present in Hazard and Mardan districts of NWFP. Some deposits are located in Rawalpindi and Campbellpur districts of Punjab. The deposits are sufficient to sustain the projected output which has been targeted at 275,000 tonnes for 1982-83 by the Fifth Five-year Plan.

(4) Scrap

(a) Scrap situation in Pakistan

There are three supply sources, i.e. imported scrap, imported ships to be demolished (ship breaking scrap) and locally generated scrap.

Table 2.1.3 gives the situation of imported scrap, ship breaking scrap and locally generated scrap in Pakistan. As is clear from this table, the supply of imported scrap including ship breaking scrap accounts for the greater part of the total supply of scrap.

According to this table, the breakdown of scrap in the year 1979-80 is as follows:

Imported scrap	243 thousand tonnes
Ship breaking scrap	158 thousand tonnes
Locally generated scrap	247 thousand tonnes

Of these, remeltable scrap represent 90% of imported and locally generated scrap and approx. 20% of ship breaking ferrous scrap as noted in Table 2.1.3. Thus, remeltable scrap amounted to 473 thousand tonnes, and the rest was re-rollable scrap to 175 thousand tonnes in 1979-80. Of the total of 472 thousand tonnes of remeltable scrap, approx. 20 thousand tonnes were used as raw material for iron castings. This means that 453 thousand tonnes of remeltable scrap were melted in electric furnaces in the year 1979-80.

(b) Supply of scrap in future

As for the demand and supply of scrap in the world, it may become tight in future even if the increase in the occurrence of scrap due to the economic development is considered. Detailed considerations are discussed at (3) (a) in 4.2.2.

Table 2.1.3 Scrap Situation in Pakistan

(Unit: 1,000 tonnes)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Imported Scrap	50.1	48.2	131.9	136.2	123.8	210.0	114.0	243.0
Ship Breaking Scrap (Ferrous scrap)	50.9	28.6	120.6	100.7	202.0	190.0	336.0	158.0
Locally Generated Scrap	18.3	106.6	100.1	118.7	151.8	100.0	120.0	247.0
	119.3	183.4	352.6	355.6	477.6	500.0	570.0	648.0

Source: Statistics Division, Government of Pakistan and Hearings.

Notes: It is estimated that 90% of imported scrap and locally generated scraps is remeltable, while the remaining 10% is re-rollable and that 20% of ship breaking ferrous scraps is remeltable, while the remaining 80% is re-rollable.

(5) Other auxiliary raw materials

(a) Fluorite

Fluorite is used as flux in the manufacture of steel.

The known deposits are estimated at 98,000 tonnes in Koh-i-Dilband and Koh-i-Maran areas in Balucahistan. Another 30,000 tonnes of indicated reserves are available in Swat-Dir area, NWFP. Present production is around 500 tonnes per year. With the advent of basic steel industry it is planned to increase the production of fluorite to approx. 5,500 tonnes by 1982-83 based on the Fifth Five-year Plan.

(b) Fire clay

Sizable deposits of fine clay occur in Mianwall Sargodha and attach districts of Punjab province. Thatta and Dadu districts of Sind and D.I. Khan districts of NWFP. The total reserves of fire clay are estimated to be over 100 million tonnes. Fire clay is used in the form of bricks as a lining in refractories of steel industry. The current production is around 50,000 tonnes per year. Table 2.1.4 shows fire clay production in Pakistan.

Table 2.1.4 Fire Clay Production in Pakistan

Year	Production (1,000 tonnes)
1970-71	28.5
1971-72	21.7
1972-73	19.1
1973-74	17.2
1974-75	24.7
1975-76	41.0
1977-77	39.1
1977-78	63.1
1978-79	52.4

Source: Statistics Division

(c) Chromite

The main deposits of chromite are located near Muslim Bagh, Zhob District, Baluchistan. These deposits contain ore with a chrome iron ratio of 3:1 to 3.6:1. Small deposits of chromite have also been in Chigai and Kharan Districts, Baluchistan and in Malakand, Mohmand and North Waziristan Agencies in NWFP. The reserves of chromite in Zhob District have been estimated about 4.4 million tonnes. The reserves of other deposits have not been determined so far. However, chromite is being mined since the turn of the century. All the chromite produced are exported abroad. Its production over the past ten years has been shown in Table 2.1.5. The export is encountering difficulties due to continuing recession and protectionism in the developed world.

Table 2.1.5 Chromite Production in Pakistan

Year	Production (tonnes)
1970-71	29,876
1971-72	29,997
1972-73	18,997
1973-74	9,344
1974-75	10,597
1975-76	12,360
1976-77	10,015
1977-78	9,847
1978-79	4,885
1979-80	3,835

Source: Statistic Division

The Baluchistan Development Authority had also considered an export oriented scheme for the setting up of a ferro-chrome plant based on the chromite reserves of Muslim Bagh. This ferro-chrome plant would require 36,000 tonnes of chromium ore to manufacture 14,400 tonnes of high carbon ferro-chrome per year. However, this project had been also suspended due to recession of iron and steel industries in the world.

2.1.3 Ship Breaking Industry

(1) Outline of ship breaking in Pakistan

The real attempt of ship breaking in Pakistan started at 1950.

During the early days of the industry, out-dated Pakistan ships were purchased locally and dismantled at Ghas Bandar in the Karachi Port Trust area.

With the increase in ship breaking activity there, the fear of the channel being blocked by the scrap ships happened and the activities had to be suspended. The ship breakers had to look for an alternate site to continue their activities, and in 1967 they found Gadani beach, about 55 km north-west of Karachi, in Baluchistan. Eversince the ship breaking industry was expanding steadily and gradually. During the years 1971-75, the ship breakers from East Pakistan (now Bangladesh) came and their experience added new dimension to this industry.

And also the Pakistani textile industry was faced with problems as cotton exports were nationalized in 1973. The finances lying with the private sector had to find some outlet. The easy outlet was found in the ship breaking industry. A large number of industrialists, especially textile mill owners, diverted money to the ship breaking industry.

The total input of tonnage scrapped in the Pakistani ship breaking industry has increased 2 times in 1976-77. Pakistan's share in the total scrappage of the world has also increased. This has brought Pakistan to No. 3 position in the world only after Taiwan and Spain.

The ship breaking capacity is about 100 ships a year providing about 400,000 tonnes of scrap per year at present. Table 2.1.6 and 2.1.7 show the situation of Pakistani ship breaking in the world.

Table 2.1.6 Demolition of Ships

(Unit: 1,000 LDT)

Year / Item	1975-76	1976-77	1977-78	1978-79	1979-80
World Total	5,080	5,180	5,170	5,900	4,380
Pakistan	130	265	395	300	300
Share of Pakistan %	2.6	5.1	7.6	5.1	6.8

Source: Fact finding surveys, 1981.

Table 2.1.7 Share of Ship Breaking in the World

(Unit: %)

Year / Country	1975-76	1976-77	1977-78	1978-79	1979-80
Taiwan	47	48	56	55	47
Spain	24	22	19	22	20
Pakistan	3	5	8	5	7
Korea, Rep.	3	4	5	6	5
Others	23	21	12	12	21
Total	100	100	100	100	100

Source: Fact finding surveys, 1981.

(2) Factor for ship breaking

The world ship breaking industry is located in two distinctly separate areas. One is in Europe and the other large area is in Asia. Most of the countries on the top of the list are from Asia. It can be also noted that most of the countries involved in the ship breaking industry are developing or less developed.

The ship breaking industry is being effected by complex international and national events. There are some factors putting their effects: -

(a) International freight market and unemployment of ships

Low freight rates in international shipping market makes the shipping business unprofitable and the ship owners are forced to offer their ships in scrap market. Low freight rates would not make it possible for them to sell their ships for future trading. The only way left out for them is in the scrap market. The low freight rates is the cause of either:

(i) Scarcity of cargo to be filled, or

(ii) Surplus of tonnage available for lifting the cargo

(b) High operating cost and low profitability in shipping business

Oil prices were increased many times since 1973. Crew wages and other expenses were also increased sharply. World-wide inflation were the major factor responsible for high operating costs. Many shipping companies were unable to run the ships with adequate or even with any profit. The course left open for them was to either lay up the ships and tied up the capital or sell it.

(c) Age of ship

Taking the ships out of service and dismantling them is a continuous process. New ships are made and old ships are scrapped. There are a number of factors which determine the suitable age of a ship for scrapping. On an average this age is between 20-25 years. For instance, in case of bulk carriers it can be simply calculated that approx. 8.4 million DWT (4.5% of the total bulk carriers) was more than 20 years of age as of Dec. 1979. This tonnage is more likely to be scrapped in the near future. Tonnage of over-aged ships are added in this figure every year and the tonnage actually scrapped is deducted.

(d) Steel industry as hinterland

Scrapped ships usually provide steel in re-rollable and remeltable forms. It is, therefore, significant and important that there exists a consuming industry up to some extent, i.e., steel industry as a condition developing ship breaking industry at any country.

(e) Labour

The ship breaking industry is highly labour intensive industry. The fact remains that cheap labour is readily available in Pakistan and this is one of the cause of this industry in this country. As discussed earlier that most of the countries having this industry are in Asia. The reasons lies in the fact that being the labour intensive industry it require cheap labour which is available in these countries.

(3) Problems remaining unsolved in Pakistani ship breaking

In Taiwan, No. 1 position in ship breaking, ships are dismantled at dry docks with most advanced mechanical systems and facilities. On the other hand, ship breaking in Pakistan is still of a primitive nature, i.e., simple manual process to dismantle ships. The main complaint of the ship breakers is in the long dismantling period which blocks huge capital and pushes the cost upward. They said that due to considerable amount of time in the import of ships and poor sea conditions many ships have sunk into the sea while many others have changed their direction and become parallel to the shore.

With manual system, a ship of 10,000 LDT takes about six months to be scrapped - when mechanized the job will be done in about two months' time. Ships of 3,000 to 10,000 LDT are generally being imported in Pakistan for breaking. The Gadani beach is easily available to break ships having draft of up to 12 feet (usually 19,000 LDT). Recently it is reported that a ship breaker purchased about 20,000 LDT-class ship. The larger a size of ship is, the better the recovery of scrap is. However, it is difficult for ship breakers to find 20,000 LDT-class ships with 12 feet draft.

Accordingly, mechanization is necessary because ships up to 4,000 LDT will not be easily available in the world market in the future, but mechanization is not materialized yet due to lack of capital and infrastructure. Port Qasim would be also considered as a site proposed for mechanization.

(4) Recovery analysis of ship breaking

The old ships for scrapping are sold in the world market on the basis of its light displacement tonnage (LDT). The recovery by breaking is a certain percentage of the LDT and this percentage differs from ship to ship depending on the type of ship. However, for estimation, the average recovery may be taken as 85% of LDT, that is, the loss of 15% of LDT. The gradewise recovered materials are shown in Table 2.1.8.

Table 2.1.8 Gradewise Recovered Materials

(Unit: %)

Items	Cargo Vessel	Passenger Vessel	Tanker
Re-rollable Scrap	70	65	70
Meltable Scrap	10	8	10
Cast Iron Scrap	6	6	6
Non-ferrous Scrap	2	2	2
Wood	2	9	2
Misc. Ferrous Materials	10	10	10
Total	100	100	100

(5) Supply of old ships for breaking

According to Lloyds' certificates, the tonnage of ships sold for breaking, is about 4 million registered tons per year.

This works out to roughly 500-600 vessels per year. This gives an index of the activity and importance of ship breaking industry in the world. However, the availability of vessels depends on the age of the vessels and the profitability of running them as freight carriers.

Replacement of old vessels by new vessels having bigger capacity is continuous process. Having regard to age, during next 20 years, a very sizable tonnage will be available for breaking.

(6) Economics of scrap from ship breaking

As mentioned in (4), more than two thirds of the scrap from ship breaking are re-rollable. These re-rollable scrap is main feed stock for the re-rollers, especially for small-scale re-rollers*, in Pakistan.
If these small-scale re-rollers want to survive, they will have to depend upon the ship breaking scrap as their main feedstock, even though they will have to purchase them at a higher price than melters. Because this is more meritorious than using imported billets of high price and/or locally made billets of high in price and also poor in quality. Small-scale manufacturers are mainly producing steel bars for the use of general construction works, because they know by experience that they can ship the products without assay and inspection (non-guaranteed) if they manufacture steel bars using re-rollable scrap as the main material.
In Pakistan, therefore, even those ship breaking scrap used as remeltable scrap in other countries are used as re-rollable scrap to manufacture thin bar and flat bar by the small-scale re-rollers. Those remeltable scrap are thus comparative small and account for only 15% of the total consumption of remeltable scrap at the present in Pakistan.

The ship breaking industry in Pakistan has been closely related with the re-rollers as mentioned above, and at least the present situation, i.e.

the ship demolition of 300,000 - 500,000 LDT/y will be maintained in future. This forecast seems proper in view of their demolishing capacity relying on manual system and the tonnage of small-size old ships offered in the scrap market of the world. Therefore it seems that the ship breaking in a scale presently made (300,000 - 500,000 LDT/year) may be continued in future.

Old ships to be demolished are imported at C&F 150 $/LDT Pakistan, on the other hand, the re-rollable scrap is currently priced at about C&F 200 $/t Pakistan, and thus more than 50 $/t of foreign currency can apparently be saved. But the actual savings of foreign currency are larger than this, because recollected non-ferrous materials can be sold at high prices, i.e. copper at 2,000 $/t copper and brass at 1,500 $/t brass. Further the recollected engines and boilers can be sold. Tax and other expenses are 41% of C&F 150 $/LDT and the breaking cost is 775 Rs/t scrap. Thus, the total cost for the scrap from old ships imported is about 3,165 Rs/t scrap. The re-rollers purchase them at an average delivered price of 4,200 Rs/t, which is a good business for ship breakers. By the way, local ingots are priced at delivery about 4,500 Rs/t or above while the imported billets are priced at delivery about 5,000 Rs/t or above.

2.2 Existing Facilities for Pakistani Iron and Steel Industry

2.2.1 Existing Steelmaking and Re-rolling Facilities

(1) Classification and location

Existing steel makers in Pakistan are roughly classified into the following three categories according to the facilities in their possession: "melters" who produce and sell steel ingots obtained by melting scrap in electric arc furnaces or induction furnaces, "semi-integrated mills" who have both steelmaking and rolling facilities and "re-rollers" who have no steelmaking facilities and specialize only in rolling. More detailed description of these three categories of steel products is given below:

(a) Melters

"Melters" mean steel producers who are not possessed of any re-rolling mill but possess only steelmaking shop facilities, including melting furnaces, ingot making and continuous billet casting equipment. Accordingly, these melters produce crude steel in the form of ingots, billets and the like, together with cast steel products and forged steel products. As shown in Appendix to 2-1, four companies in the public sector, and 31 to 35 companies in the private sector, including Ahmed Investment Ltd., General Steel Industry and Karim Aziz Industries Ltd., fall under this category of steel makers. In the aggregate, they have a crude steel production capacity of about 286,000 tonnes per year, accounting for about 47% of the total production capacity of all Pakistani steel producers.

As for their geographical location, about 90% of them are located in Punjab.

(b) Semi-integrated

"Semi-integrated mean steel makers having both steelmaking and rolling mill facilities. The former is composed of melting furnaces, ingotmaking and continuous casting equipment for making ingots, billets and the like, and the latter of rolling mill facilities for rolling the ingots and billets produced in steelmaking shops into finished steel products, such as bars and sections. As shown in Appendix to 2-2, one company, Pakistan Engineering Co., in the public sector, and 19 companies in the private sector, including Nowshera Engineering Co., Ltd. and Ittefaq Foundries fall under this category of steel makers. They have a crude steel production capacity of about 320,000 tonnes per year, accounting for about 53% of the total production capacity of all Pakistani steel makers.

As for their geographical location, about 80% of them are located also in Punjab.

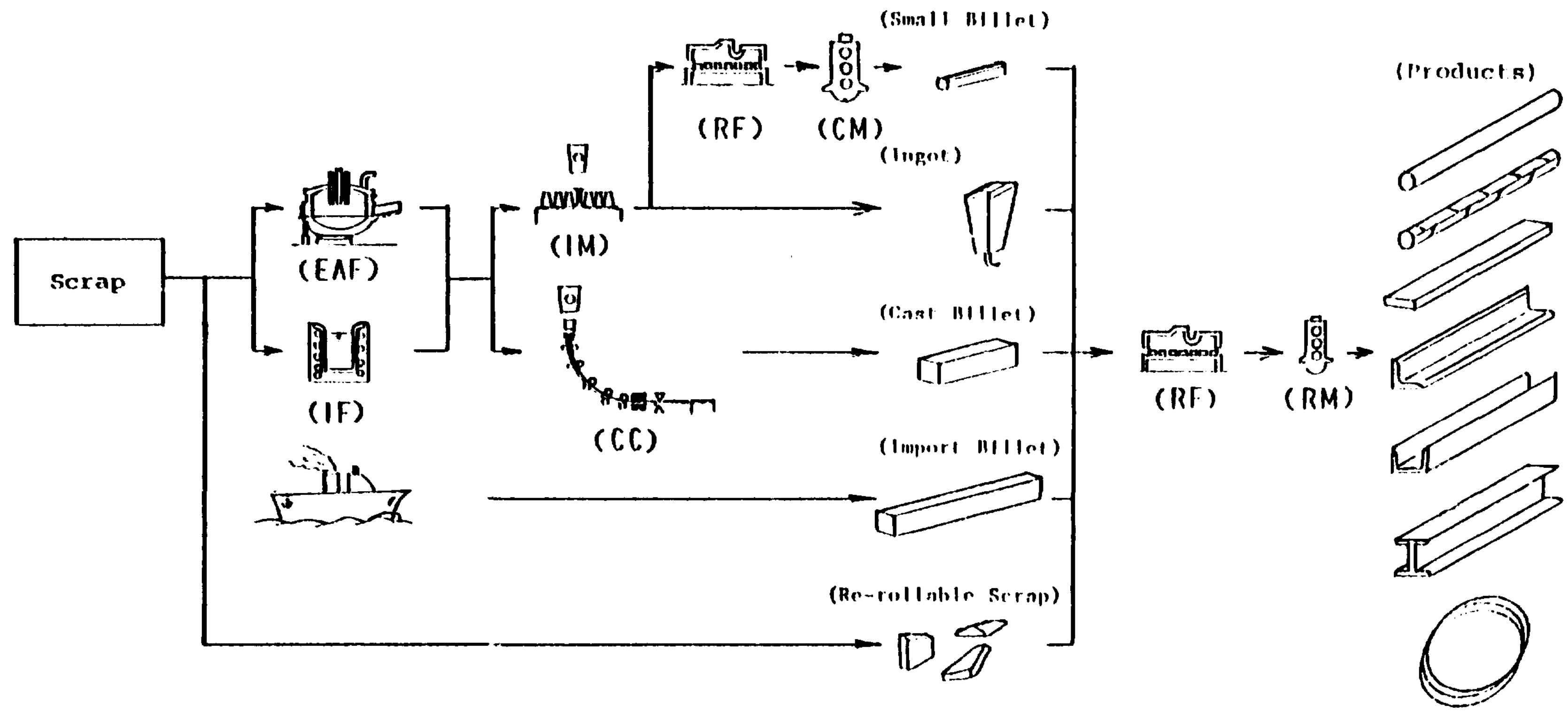
(c) Re-rollers

Exact number of "re-rollers" existing in Pakistan is not known. According to the report of the Pakistan Steel Re-rolling Mills' Association, Pakistan has about 700 re-rolling mills, including those of semi-integrated steel mills, of which 500 mills are now in operation. However, this Association has only 86 members, that is, 48 re-rollers in the Lahore region and 38 re-rolers in the Karachi region. This represents only a little over 10% of the total number of re-rollers in Pakistan. In addition, it is reported that an overwhelming majority of small re-rollers produce rolled steel bars without business license. It is therefore difficult to know all about re-rollers. Only two companies in the public sector, that is, Metropolitan Steel Corporation Ltd. and Quality Steel Works Ltd., fall under the category. All other re-rollers belong to the private sector. Major re-rollers in Pakistan are shown in Appendix to 2-3. Nearly 70% of them are located in Punjab and the rest in Sind.

Annual total production of rolled products in Pakistan, including those of semi-integrated producers, is estimated to be 574,000 tonnes. The greater part of this production is represented by rolled products for building and general construction services, that is, steel bars such as plain and deformed reinforcing bars, twisted ribbed bars (such as Tor steels), flat bars and square bars, and steel shapes such as angles, channels and I-beams.

(2) Manufacturing process for steel products

Typical manufacturing process for steel products in Pakistan is schematically shown in Fig. 2.2.1.



Source: ISIJ

(EAF) : Electric Arc Furnace
(IF) : Induction Furnace
(IM) : Ingot Making
(CC) : Continuous Casting
(RF) : Reheating Furnace
(CM) : Cogging Mill
(RM) : Re-rolling Mill

Fig. 2.2.1 Manufacturing Process of Steel Products

With the exception of Pakistan Steel under construction at the outskirts of Karachi, there is no blast furnace in Pakistan. This means that the manufacturing process of steel products in Pakistan starts from the melting of scrap in electric furnaces.

At present, the tonnage of scrap used for metling is estimated at 473,000 tonnes per year. Such scrap is roughly classified into three groups: imported scrap, ship breaking scrap and locally generated scrap. Main scrap for melting is locally generated scrap. Ship breaking scrap obtained by ship breaking is good in quality, but at present, some 80% of it is supplied directly to re-rolling mills as re-rollable scrap.

Melting of scrap is carried out in electric arc furnaces or induction furnaces. These two types of melting furnaces account for 75% and 25% of the total crude steel production in Pakistan, respectively.

Ingot making or continuous casting follows the melting in electric furnaces. Continuous casting equipment now in operation in Pakistan are only those Noor Steel, whose production is only of the order of 12,000 tonnes per year, in the other words about 3% of the total crude steel production in Pakistan which is estimated to be 388,000 tonnes per year. The rest of crude steel, or over 97%, is treated by ingot casting process.

Unit weight of ingots for rolling is 65 to 250kg and their section ranges from 80mm by 80mm to 200mm by

200mm. Ingots are supplied directly to rolling mills, but they are often rolled into small billets of 50mm by 50mm to 65mm by 65mm in size at cogging mills before they are supplied to rolling mills.

In addition to cast billets, ingots and small rolled billets mentioned above, the rolling mills receive imported billets which are supplied through Trading Corporation of Pakistan. These imported billets have a section of 75mm by 75mm to 130mm by 130mm. These sizes are too large to be treated in general re-rolling mills in Pakistan. These large billets are used for the most part by re-rollers in public sector and major re-rollers in private sector, who are having cogging mills. Under these circumstances, re-rolling mills of Quality Steel, Metropolitan Steel and Razaque Steel use excusively such imported billets as initial materials.

On the other hand, re-rollable scrap accounts for a little less than 30% of all the materials used by re-rollers. It is estimated that scrap of ship breaking origin represents 70% of this re-rollable scrap, or 126,000 tonnes per year. Ship breaking scrap is good in quality but, from its nature, its chemical composition and other properties are unknown. This scrap is used for the most part for manufacturing plain reinforcing bars and partially for hoop.

In rolling mill, these materials are rolled into bars, sections and other products on single-axis drive type-arrangement mills of three-high stands.

(3) Nominal capacity and actual production

(a) Steelmaking

(i) Nominal capacity and actual production

At present, about 60 steelmaking shops exist in Pakistan. About 70 to 80 electric arc furnaces and induction furnaces with a unit capacity of the order of 0.5 to 15 tonnes per heat are installed in these steelmaking shops. Total nominal capacity of these steelmaking shops is estimated to be about 606,000 tonnes per year on a crude steel basis of ingots and billets.

In these steel-making shops, scrap imported from America, U.K. and Middle East, locally generated and ship breaking scrap are melted in electric furnaces to produce plain carbon steel for reinforcing bars and small shapes as well as special steel for steel casting and forging. The actual total production of such carbon steel and special steel is estimated to be about 388,000 tonnes per year. Products of these steelmaking shops are supplied to re-rolling mills, forging and machinery shops.

(ii) Public sector

Steelmaking shops are classified into those of public sector and private sector.

The public sector includes five companies: Heavy Foundry & Forges Ltd. (HFF), The Pakistan Engineering Co., Ltd. (PECO), Karachi Shipyard & Engineering Works, Pakistan Railways and Wah Industries. These companies have relatively large-scale steelmaking shops. These shops are equipped with facilities capable of producing special steel, plain carbon steel and cast iron. The total crude steel production capacity of these shops is estimated to be about 188,000 tonnes per year. However, their utilization rate is very low, varying between 15% and 50% of the nominal capacity with an average of 26 to 27%. The reasons of such low utilization rate include problems of price and quality of scrap, change for the worse of the situation of scrap supply and stortage of orders. Consequently, the actual total production of these shops is estimated to be only about 50,000 tonnes per year.

In addition to the above-mentioned shops, a steel-making shop of Special Steel of Pakistan, Ltd. belongs to the public sector. This steelmaking shops has an annual production capacity of about 40,000 tonnes of low-alloy steel, stainless steel and other special steel, but it is now in shut-down.

(iii) Private sector

It is reported that the private sector includes about 51 to 60 steelmaking shops, whether large or small in scale. Relatively large steel makers having an annual production capacity of 12,000 to 48,000 tonnes in the private sector are Ahmed Investment Ltd., Ittefaq Foundries Ltd., Nowshera Engineering Co., Ltd., Punjab Steel Ltd., Orient Technical Works, Allah Ditta Abdul, Javed Perrez Corp. Ltd., Kamran Steel Re-Rolling Mills, Nawaz Shehbaz Ltd., Rashid & Iron Foundry, Hydarg Steel Industries Ltd., Sind Steel Corporation, General Steel Industries, Karim Aziz Industries and Noor Steel. These 15 companies accout for about 70% of the total crude steel production capacity of the private sector. The remaining 30% is shared by 36 small steel makers. Most steelmaking shops in the private sector are designed to produce plain carbon steel used for manufacturing reinforcing bars, small shapes and other similar products. The total production capacities of these shops is estimated to be about 400,000 to 410,000 tonnes per year. Their utilization rate is fairly high owing to a relatively favourable demand for reinforcing bars and small shapes.

However, because of price and supply conditions of scrap, shortage of power supply in Sind and other factors, this utilization rate varies between 50% and 120%. But, on the average, it is kept at some 80%. Consequently, the actual total production of these shops is estimated to be about 330,000 to 340,000 tonnes per year.

(b) Re-rolling

Typical re-rolling method used in Pakistan consists of rolling on single-axis drive arrangement of three-high stands and manual tongs operation. With such method, both production capacity and actual production of rolled products depend largely upon technical skill and morale of rolling operators as well as kind and size of products. Except for certain major re-rollers, most re-rolling mills in Pakistan are currently operated only for about 8 to 12 hours in the daytime.

At present, virtually no statistics and no data concerning production capacity and actual production of re-rollers in Pakistan are available, and even the meaning of the production capacity is not clearly defined. However, according to the results of the survey covering mainly major re-rollers, the rate of the actual production to the production capacity, that is utilization rate, varies between 52% and 86% for re-rollers in the public sector, and it is estimated to be 70% on the average in this sector. On the other hand, this rate for re-rollers in the private sector is estimated also to be some 70% though it presents a very wide dispersion between 48% and 100%.

The Pakistan Steel Re-Rolling Mills' Association also estimates the utilization rate of all re-rolling mills in Pakistan to be about 70%.

Assuming daringly, on the basis of these informations, that the current utilization rate of re-rolling mills in Pakistan is about 70%, their annual production capacity can be estimated to be 820,000 tonnes per year from the actual production of 574,000 tonnes per year in 1979-80. It is however important to note that the re-rolling mills in Pakistan are operated at this supposed utilization rate mostly for reasons of business or economic nature, such as production cut-down due to slack market, shortage of cheaper raw materials, etc., and not because of mill equipment or other technical limitations.

(c) Outline of Iron Foundries

Major iron foundries in Pakistan include Pakistan Engineering Co., Ltd. (PECO), Heavy Foundry and Forges Ltd. (HFF), Karachi Shipyard & Engineering Works, Ittefaq Foundries Ltd., Nowshera Engineering Co., Ltd. and Ahmed Investment Ltd. In addition, it seems that many other small iron foundries exist in Pakistan. In these iron foundries, there are sanitary goods, soil and rain water pipes, machine parts, motor covers, engine blocks, rolling mill housings and rolls, ingot moulds, which are manufactured by melting and refining the materials such as pig iron, cast iron and steel scrap in cupolas of 1 to 5 tonnes per hour, or induction or electric arc furnaces of 1 to 3 tonnes per heat.

According to the "Report on Basic Metals", these iron foundries have a production capacity of about 250,000 tonnes per year. It is however considered that the actual production capacity is pretty smaller than this figure because of outworn and obsolete equipment. From the actual consumption of pig iron in these iron foundries, their actual production is estimated to be about 93,000 tonnes per year. Assuming that the annual production capacity is 250,000 tonnes, the utilization rate is estimated to be around 37%.

2.2.2 Technical Considerations of Existing Facilities

(1) Steelmaking facilities

(a) Melting furnaces

Fig 2.2.2 shows the types and nominal capacity of existing melting furnaces for steelmaking. As is clear from this figure, melting furnaces for steelmaking now in operation in Pakistan are small electric arc furnaces with a capacity of the order of 0.5 to 15 tonnes per heat and induction furnaces. The latter is used generally for remelting of special steel, and accounts for about one half of the total number of melting furnaces for steelmaking installed in Pakistan, or about 25% of their total production capacity. This constitutes a characteristic feature of the Pakistani steel industry. It may be said that most of these melting furnaces are of old types and low in efficiency.

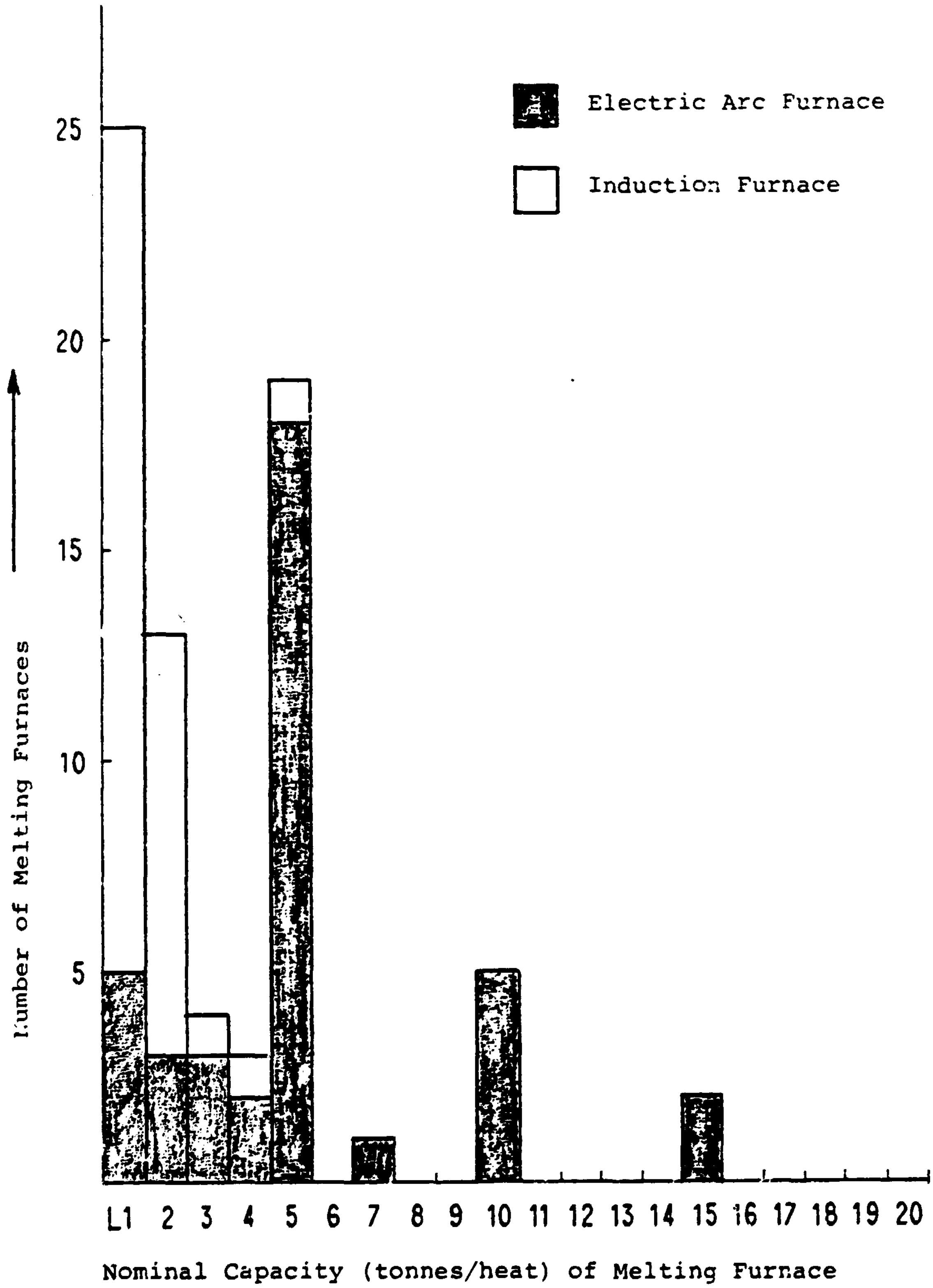


Fig. 2.2.2 Relation between Type and Nominal Capacity of Existing Melting Furnaces

Fig 2.2.3 represents a relation between nomial furnace capacity and rated transformer capacity of electric arc furnaces. As is clear from this figure, existing electric arc furnaces in Pakistan are generally small-size ones with a small transformer capacity. On these electric arc furnaces, most operations of scrap treatment, preparation, charging of auxiliary materials into furnaces and hot repair of furnace lining after tapping are manually carried out. In addition, it seems that dust collecting equipment during melting and refining are not yet provided on these existing electric arc furnaces except for those of HFF which are provided with local hood type dust collectors.

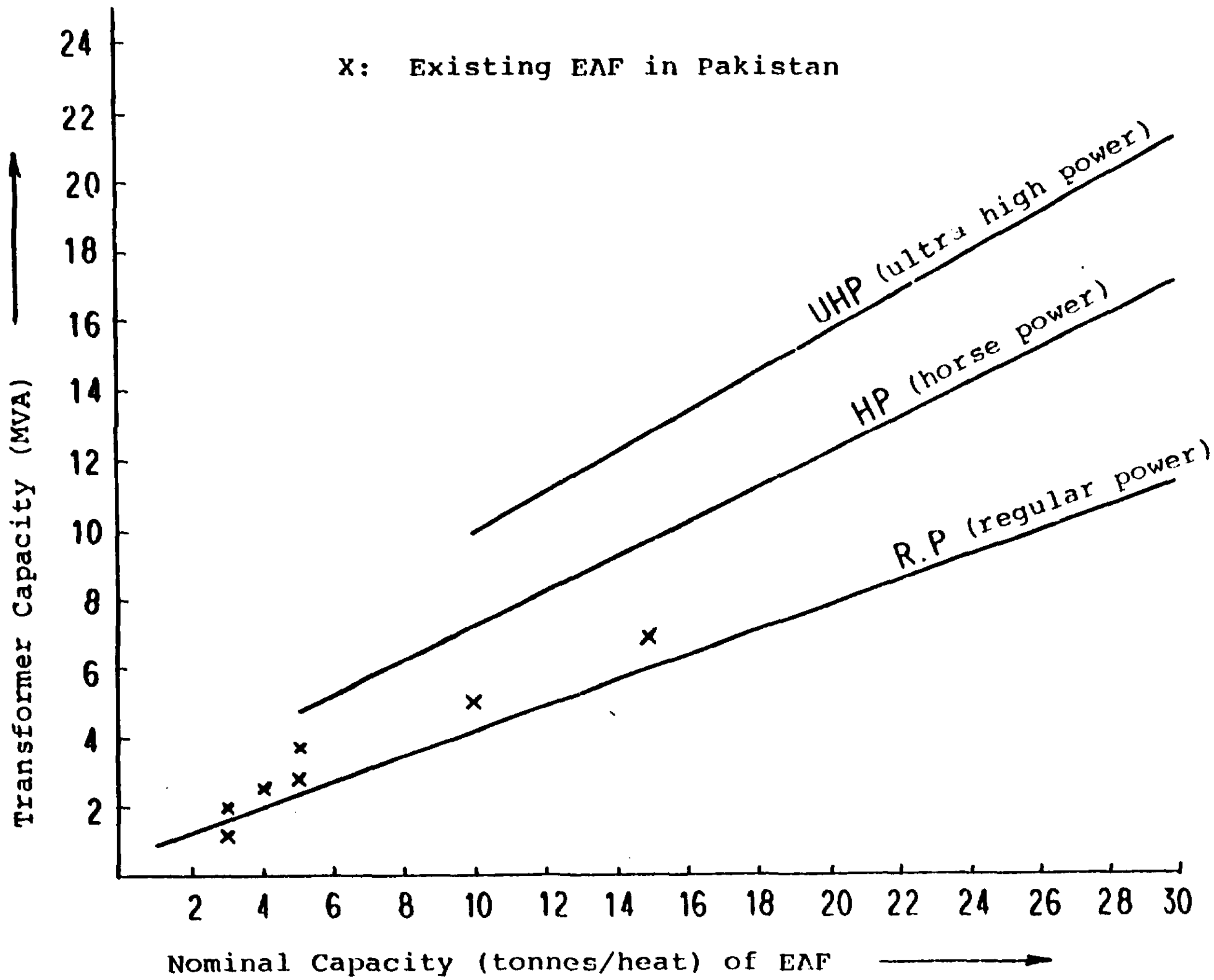


Fig. 2.2.3 Relation between Nominal EAF Capacity and Rated Transformer Capacity of EAF

(b) Comparison of Pakistani melting furnaces with Japanese ones

(i) Electric arc furnace

Table 2.2.1 compares the operation data of typical electric arc furnaces (EAF) in Pakistan with those of small-, medium- and large-sized EAFs in Japan.

The Japanese EAF-A listed in this table is the EAF where oxygen of about 6 Nm^3/tonne is blown in to accelerate the melting and shorten the time of refining process, while EAF-B is the EAF where oxygen fuel burners are equipped, and oxygen of about 20 Nm^3/tonne is blown in to accelerate melting and shorten the refining time as much as possible. Further EAF-C is an HP EAF and D is a UHP EAF. In the present Japan, small-sized EAF with a capacity less than 10 tonnes is used for small quantity production of stainless steel, high speed steel, etc., but they are not used for manufacturing mild carbon steel.

EAF has different capacities according to the conditions of auxiliary facilities, raw materials and the operation method of each steelworks. It cannot be compared with each other by using their nominal capacity (tonne/heat) and rated transformer capacity (MVA) alone. In comparison be .ween the Pakistani EAF-B and the Japanese EAF-A listed in Table 2.2.1 the Pakistani EAF-A is operated in very low efficiency with the steel making time (min/heat) and the heats per day being under 50% of those of the Japanese EAFs and the output per hour (tonne/hour) not reaching even 30% of that of the Japanese EAFs.

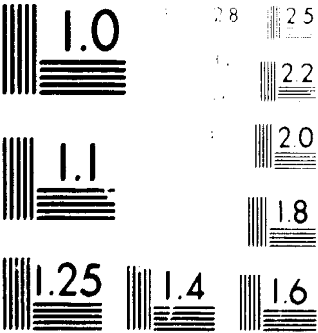
Besides it is operated at very high manufacturing costs with the electric consumption (kWh/tonne) about 30% higher, the electrode consumption about 25% higher and the refractories (wall and roof bricks) consumption as high as about 300% larger than those of the Japanese EAFs.

Further its annual output (tonnes/year) is very small and the operation is never economical as compared with the Japanese EAFs. However, if improvement works on the operation techniques are enforced, the operation data similar to the Japanese EAFs will be able to be obtained, as far as the steel making time (min/heat) and heats per day (heats/day) are concerned. But in a small-scale furnace, the introduction and improvement of the equipment are limited. Neither increase of the hourly output (tonne/h) nor reduction of the unit consumption of the electric power, electrode and refractories can be much expected.

Table 2.2.1 Comparison of Electric Arc Furnaces

Name of electric arc furnace				Pakistan A	Pakistan B
Specification of furnace	Nominal capacity (t/heat)			5 x 4EAF Operation 3/4	10 x 3EAF Operation 1/3
	Actual tapping weight (t/heat)			7	13
	Shell inner dia. (mm)			3,100	3,700
	Rated transformer capacity (MVA)			2.8	5.0
	Oxygen fuel burner (set)			0	0
Steel making time	Preparation time (min/heat)			45	45
	Melting time (min/heat)			135	150
	Refining time (min/heat)			60	45
	Steelmaking time (tap to tap) (min/heat)			240	240
Number of heats per day (heat/day)			$\frac{\Sigma \text{ Heats}}{\Sigma (\text{Nos of EAF} \times \text{operation days})}$	6	5.5
Productivity (t/hr)			$\frac{\Sigma \text{ Cast products weight}}{\Sigma \text{ Steel making time}}$	1.8	3.3
Yield	Tapping (%)		$\frac{\Sigma \text{ Tapping molten steel weight}}{\Sigma \text{ Charging materials weight}}$	-	92.5
	Casting (%)		$\frac{\Sigma \text{ Cast products weight}}{\Sigma \text{ Charging materials weight}}$	90	90
Production quantity of cast products (t/year)				55,000	15,100
Carbon steel ratio of cast products				100	100
Unit consumption per cast product	Electrode (kg/t)			9.0	6.0
	Electric power (kWh/t)			800	670
	Oil or gas (ℓ or kg/t)			0	0
	Oxygen (Nm^3/t)			0	0
	Calcined lime (kg/t)			CaO 31 $CaCO_3$ 13	CaO 15 $CaCO_3$ 10
	Fluorite (kg/t)			1.6	2
	Refractory	Roof (kg/t)		8～12	5.5
		Wall (kg/t)			7.5
		Repair (kg/t)		Dolomite 40	28
Continuous casting ratio (%)				Under construction	

SECTION 1


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

.2.1 Comparison of Electric Arc Furnaces

	Pakistan		Japan			
ce	A	B	A	B	C	D
	5 x 4EAF Operation 3/4	10 x 3EAF Operation 1/3	20 x 2EAF Operation 2/2	30 x 2EAF Operation 2/2	70 x 1EAF Operation 1/1	100x1EAF Operation 1/1
	7	13	26	34	70	114
	3,10C	3,700	3,960	4,800	5,791	6,700
	2.8	5.0	12.0	12.5	35.0	60.0
	0	0	0	2	3	3
	45	45	13	11	75	10
	135	150	72	76	54	59
	60	45	31	12	24	15
	240	240	116	99	93	84
Heats / f EAF x operation days)	6	5.5	12	15	15	17
ast products weight / Steel making time	1.8	3.3	12.4	19.5	43.4	80.0
ing molten steel weight / ing materials weight	-	92.5	94.5	92.8	92.5	94.1
ast products weight / ing materials weight	90	90	90.7	88.4	89.4	91.9
	55,000	15,100	190,000	261,000	328,000	484,000
	100	100	90	75	95	100
	9.0	6.0	4.8	4.5	4.0	4.2
	800	670	516	465	455	455
	0	0	0	5ℓ	5ℓ	3ℓ
	0	0	6	33	32	27
	CaO 31 $CaCO_3$ 13	CaO 15 $CaCO_3$ 10	19	27	41	30
	1.6	2	9	4	3	1
	8～12	5.5	1.9	0.5	1.5	1.8
		7.5	2.4	1.8	1.0	1.2
	Dolomite 40	28	17	12	7	4
	Under construction		100	75	100	100

(ii) Induction furnace

Table 2.2.2 shows the typically planned operation data of induction furnace (IF) in Pakistan, and the actual operation data of IF in Japan. Recently the induction furnace in Japan is only used for melting stainless steel, high speed steel, heat resisting steel, bearing steel, cast steel and cast iron, and there is no case where it is used for melting mild carbon steel.

On the other hand, the equipment specifications and operation records of the Pakistani IF are unknown. The comparison of IFs between the two countries is thus difficult. A copy of main equipment specifications and operation records of the IF used for remelting stainless steel and heat resisting steel in Japan is attached here.

Judging from the actual operation records of Japanese IF, the Pakistani IF-A production plan of 28,800 tonnes/year is very difficult to achieve, because the steel making time (min/heat) must be controlled at about 72 minutes for this purpose even if the operation days are assumed to be 330 days/year. As for the electric power consumption the figures of Japanese IFs are for high alloy steel when intermittent operation is made. Therefore it seems that 700 kWh/tonne of the electric power consumption planned for the Pakistani IF-A can be achieved if the operation conditions are satisfactory. However since IF has a small furnace inner volume and requires advanced skill for the refining operation, high grade scrap in respect of shape and chemical components must strictly be selected and continuously supplied.

Table 2.2.2 Comparison of Induction F

Name of induction furnace			Pakistan		
			A	B	
Specification of furnace	Nominal capacity (t/heat)		2.2 x 2IF	0.5 x 2IF	
	Actual capacity (t/heat)		-	-	
	Volume of molten steel (m^3)		-	-	
	Transformer capacity (KVA)		1,000	750	
	Type of frequency converter		-	-	G
	Frequency (Hz)		-	-	
	Kind of lining materials		-	-	
Steel making time	Melting time (min/heat)		-	-	
	Refining, tapping charging time,etc (min/heat)		-	-	
	Steel making time (tap to tap) (min/heat)		-	-	
Kind of steel			Plain carbon steel	Stainless steel	S s
Production quantity of cast products (t/year)			28,800	1,100	
Life of lining (heats)			-	-	
Unit consumption of electric power (kWh/t)			700	-	
			Under construction		

SECTION 1

Table 2.2.2 Comparison of Induction Furnace

	Pakistan		Japan			Remarks
	A	B	A	B	C	
	2.2 x 2IF	0.5 x 2IF	1.0	1.0	5	
	-	-	1.2	0.9	4.3	
	-	-	0.21	0.14	0.69	
	1,000	750	666	600	1,225	
	-	-	Generator	Thyristor	Generator	
	-	-	1,000	1,000	1,000	
	-	-	Magnesia	Magnesia	Silica	
	-	-	80	60	210	
	-	-	40	60	60	
	-	-	120	120	270	
	Plain carbon steel	Stainless steel	Stainless steel	Heat resisting	Stainless steel	
	28,800	1,100	-	-	-	
	-	-	-	80	20	
	700	-	900	850	850	
	Under construction					

SECTION 2

(2) Ingot/Billet-making facilities

(a) Ingotmaking facilities

Ingots currently made in Pakistan are small-size ingots having a unit weight of 65 to 250 kg, except for special-size ingots for forging and ingots made by Ittefaq Foundries Ltd., which have a unit weight of 700 to 1,000 kg. Most ingots are cast by bottom pouring method. Ladle nozzle opening and closing devices are of the stopper type, and any automatic types such as slide valve type have not yet been employed.

As for continuous billet casting facilities, Ittefaq Foundries Ltd., Punjab Steel and Ahmed Investment Ltd. are now constructing continuous casting machines for small-size billets having a section of 75 mm by 75 mm to 130 mm x 130 mm. Another continuous billet casting machine has just been completed and put in operation at Noor Steel in Karachi. Thus, in Pakistan, the production of billets by continuous casting has only just made its beginning.

(b) Comparison of Pakistani billet continuous casting machine with Japanese ones

Table 2.2.3 compares the designed operation criteria of a billet continuous casting machine (BCCM) now under construction in Pakistan with the actual operation records of an about the same-size BCCM in Japan. As for the equipment capacity, it is found that there is no particular problem except for Pakistani BCCM-A as a result of trial calculation using the annual capacity formula prepared by Japan Iron and Steel Federation. It can be said Pakistani BCCM-A has not such capacity when it produces minimum size billets. The billet size of 75 mm sq - 80 mm sq is very small. By the way, the smallest billet in operation in Japan has the size of 90 mm sq. Accordingly casting troubles due to clogging of the tundish nozzle and break out are likely to occur in the actual operation. An advanced casting technique will be needed.

Table 2.2.3 Comaprison of Billet Continuous

Name of billet continuous casting machine			Pakistan A	Pakistan B
Type of machine			Curved mould bending type x 2 *	Curved mould bending type x 1
Casting capacity (t/heat)			-	-
Capacity of ladle and tundish	Ladle (t)		12	9
	Tundish (t)		-	-
Charging method of dummybar			Bottom side	Bottom sid
Cutting method of strand			Shear	Shear
Datum radias of curvature (mm)			6	-
Number of strand			1	2
Size of billet	Max. dimension (mm)		125 sq	130 sq
	Nominal dimension (mm)		-	-
	Min. dimension (mm)		80 sq	75 sq
	Max. lergth (mm)		4,000	4,500
Casting speed and casting time	Casting speed (m/min)		Max. Normal 2.5~3.5	Max. - Normal -
	Casting time (min/heat)	Σ cc time / Σ cc heats	-	-
Annual production quantity (t/year)			60,000	-
Carbon steel ratio of cast products (%)			100	100
Average number of series casting heats (heats)			-	-
Successful cast heats rate (%)		Σ successful cc heats / Σ cc heats	-	-
Casting time ratio (%)		Σ Casting time / Σ Calendar hour	-	-
Yield and unit consumption of cast product	Casting yield (%)	cc products / steel	-	-
	Fuel (oil, gas, etc) (10^3 Kcal/)		-	-
	Electric power (kWh/t)		-	-
	Water (m^3/t)		-	-
	Refractory of tundish (kg/t)		-	-
Treatment rate of vacuum degassing and ladle refining		Treated quantity / cc products	0	0

SECTION 1

* Under construction

Comaprison of Billet Continuous Casting Machines

	Pakistan		Japan		
	A	B	A	B	C
	Curved mould bending type x 2 *	Curved mould bending type x 1 *	Curved mould bending type x 1	Curved mould bending type x 1	Curved mould bending type x 1
	-	-	34	42	115
	12	9	30	63	140
	-	-	1.3	6.[illegible]	8.0 x 2
	Bottom side	Bottom side	Bottom side	Bottom side	Bottom side
	Shear	Shear	Shear	Shear	Shear
	6	-	8.5	3	7
	1	2	2	4	8
	125 sq	130 sq			150 sq
	-	-	130 sq	100 sq	135 sq~150 sq
	80 sq	75 sq			135 sq
	4,000	4,500	6,800	3,800	7,000
	Max. Normal 2.5~3.5	Max. - Normal -	Max. 4.3 Normal 2.9	Max. 3.0 Normal 2.5	Max. 1.8 Normal 1.3 -
s	-	-	43	90	91
	60,000	-	228,000	350,000	640,000
	100	100	100	100	100
	-	-	7	6	3
heats s	-	-	97.7	99.8	99.7
me our	-	-	63	85	75
s l	-	-	96.2	99.7	99.0
	-	-	14.5	17.9	6.4
	-	-	12.5	6.5	15.3
	-	-	8.6	0.4	0.4
	-	-	0.95	0.83	1.72
ntity ts	0	0	0	0	0

(3) Increase of productivity and yield

It is essential for decreasing in the production cost of steel to cut the costs of scrap and other raw materials as a large portion of the production cost. However, this factor depends largely on the international scrap market and can hardly be controlled by an individual enterprise. To cope with this problem, it is important to seek for the stable supply of scrap on the level of the Government or a group of enterprises.

Other steps to decrease the production cost of steel include improvements in productivity and yield. These steps can be taken by each enterprise from an independent standpoint. Accordingly, technical comments for improving productivity and yield are briefly described below.

(a) Increase of productivity

If the productivity is improved, an increase in production leads to reduction in fixed cost, increase in utilization rate and shortening of steelmaking cycle, or top to top time. As a result the heat loss, the consumption per tonne of steel of power (kWh/tonne), electrodes (kg/tonne) and refractories (kg/tonne) are reduced. Thus, the improvement in productivity contributes largely to the decrease in production cost of steel. Main approaches to this improvement are as follows.

(i) Acceleration of melting and shortening of refining period by injection of oxygen gas

It seems that the injection of oxygen gas is not much employed in existing melting furnace in Pakistan.

Table 2.2.4 gives the unit consumption of power and electrodes for EAF of several shops. Since these furnaces have a handicap of small heat size, their unit consumption of power and electrodes is very high. Possible causes of this high unit consumption include low utilization rate of furnaces with long steelmaking cycle, or top to top time, use of iron ores for decarburization during melting and refining, and use of limestone or incompletely calcined lime as flux. Charging of iron ores or limestone causes the endothermic reaction in the furnace, which seems to have a close relation with prolongation of melting and refining period, and high level of unit consumption of power and electrodes.

Table 2.2.4 Unit Consumption of Power and Electrodes in Existing Melting Furnaces in Pakistan

Factory	Unit Consumption: Electric Power	Unit Consumption: Electrode	Remarks
A	780 kwh/t	7.7 kg/t	
B	800	9.0	5-tonne EAF
C	600	7.0	
D	780	5.0	
E	670	6.0	10-tonne EAF

Note: Unit consumption of 5 to 10-tonne EAF are generally 500 to 600 kWh/tonne of steel for electric power and 5 to 6 kg/tonne of steel for electrodes.

It is therefore recommended for the acceleration of melting and decarburization by injecting oxygen gas to use the completely calcined lime as flux. In case of lack of carbon source due to the supply condition of scrap, the injection of oxygen gas will produce very satisfactory results a low-sulphur carbon source being injected.

(ii) Decrease in steelmaking cycle time and in unit consumption of power and electrodes by mechanizing the charging operations of auxiliary raw materials

In most existing electric arc furnaces in Pakistan, flux and alloy materials are charged by hand through a furnace charging door partly as they are small-size furnaces. This means that the charging door is put in open position for a longer period of time. As a result, the volume of cold air entering the furnace is increased. Thus, the unit consumption of power and electrodes as well as the steelmaking cycle time are increased. In particular, it is said that the consumption due to surface oxidation represents about 50% of the total consumption of an electrode.

It is therefore recommended to introduce small charging machines of fork lift type with a view to reduction in unit consumption of power and electrodes, improvement in productivity and labour saving.

(iii) Extension of service life of refractories and increase in utilization rate by installation of water cooling boxes on furnace wall

The service life of furnace wall depends on that of refractory bricks located in hot spots. In view of this fact, it is recommended to install a simple water cooling box at each hot spot. With this approach, the service life of the furnace wall will be increased by about 1.5 to 2 times, depending upon the area occupied by cooling boxes. In addition to the reduction in unit consumption of refractory bricks, an increase in utilization rate of furnaces can be obtained as a result of extension of the relining interval. Further, the improvement in productivity can also be expected.

(iv) Decrease in number of scrap charging and prevention of electrode breakage by adoption of the pretreatment of scrap

Imported scrap, especially that of Middle East origin, is supplied untreated. Such scrap is therefore large in size for the most part. In addition, it seems that such scrap contains, in considerable quantities, rubber, wood pieces, dirts, oil and other foreign matters. The use of this scrap as it leads to various disadvantages, that is, increase in melting time due to increase in number of scrap charging, increase in unit consumption of power due to heat loss, increase in frequency of electrode breakage due to presence of poor-conductors, degrading in quality of steel due to presence of tramp elements, etc. In case of use of such scrap, it is therefore necessary to carry out the pretreatments, such as removal of impurities, sizing and pressing.

(b) Increase of yield

The most effective approach to the improvement of yield is the replacement of the ingotmaking with the continuous casting. If the ingotmaking is replaced with the continuous casting, the yield of rolled products from molten steel, will be increased by 4 to 6%, though this figure will vary from one steelmaking shop to another. In replacing the ingot making with the continuous casting, it is important to adopt or make provisions for the series casting operation with a view to further increase of yield. As for the size of billets by continuous casting, it is important to select the larger billet size because the continuous casting of billets having a smaller section may lead to a higher frequency of occurrence of accidents such as breakout, resulting in increase of loss, hence decrease of yield.

(4) Re-rolling Mills

Table 2.2.5 gives the technical data of several re-rolling mills in Pakistan.

Table 2.2.5 Technical Data of Surveyed Rolli

Public Section

Name of Company	Location	Reheating Furnace (1)	Re-Rolling Mill: Size of Mill	Re-Rolling Mill: Type & Number of Stands	Re-Rolling Mill: Motor Capacity (HP or KW)	Production per Operation hour (tonnes/hour)	Annual Producti: Estimated Capacity A (tonnes/annum)	Annual Producti: Actual Productic (tonnes/an
PECO/Kotlakpat Works	Punjab	P 10t/hxl	20"	3Hixl 3Hix4	680 kW 680 kW	80t/12h at 2 1/2" sq	21,000	18,000
		P x 1	10"	3Hixl 3Hix5	230 kW 230 kW	8-30t/12h	6,000	5,000
PECO/Badami Works	Punjab	P x 3 15t/h in total	16" 15" 8"	3Hix5 3Hix5 3Hix5		25-40t/12h 20-35t/12h 8-20t/12h	9,000 7,500 3,000	10,218
Quality Steel Works Ltd.	Sind	P 6t/hxl	12"	16" 3Hixl 12" 3Hix4	400 HP 600 HP	40-50t/10h	18,000	8,015
		P 3t/hxl	10"	3Hix5	400 HP	30t/10h	4,200	3,627
		P 2t/hxl	8"	3Hix5	300 HP	20t/10h	3,300	3,[illegible]11
Metropolitan Steel Corp. Ltd.	Sind	P x 1	HOOP (12")	3Hix3 3Hix6	1100 kW 450 kW	80t/20h	25,000	70,132
		P x 1	BAR (12")	3Hixl 3Hix4	400 kW 750 kW	80-90t/20h	36,000	
		P 10t/hxl	STRUCTURE (12")	3Hixl 3Hix4	DC 250 kW DC 500 kW	80-120t/20h	18,000	
		P x 1	(10")	3Hixl 3Hix5	400 kW 250 kW		16,000	

SECTION 1

.2.5 Technical Data of Surveyed Rolling Mills

Motor Capacity (HP or KW)	Production per Operation hour (tonnes/hour)	Annual Production: Estimated Capacity A (tonnes/annum)	Annual Production: Actual Production B (tonnes/annum)	Utilization rate B/A x100%	Raw Material (2)	Steel Grade (3)	Rolled Products (4) (mm)
680 kW	80t/12h	21,000	18,000	86	LI		R: 3/8" - 1 1/8"
680 kW	at				5" x 6",	Mild	A: 3/4" - 4 1/2"
	2 1/2" sq				6" x 7"	Steel	S: 2" - 4"
230 kW	8-30t/12h	6,000	5,000	83	7" x 8"		
230 kW							
	25-40t/12h	9,000 }			LI & SB	SAE1015	R: 3/8" - 3 1/2"
	20-35t/12h	7,500 }	10,218	52		to 1045	D: 10mm - 36mm
	8-20t/12h	3,000 }					B: 1 1/2" - 2 1/2"
							C: 3"x1 1/2"- 5" x 2 1/2"
							I: 3"x1/2" - 6"x3"
							A: 3/4" - 5
							F: 1"x1/8"x4"x5/8"
							S" 3/8" - 5"
400 HP	40-50t/10h	18,000	8,015 }		IB	SAE1020	R: 3/8" - 3"
600 HP			}	57		to 1045	D: 3/8" - 2 1/4"
							T: 3/8"
400 HP	30t/10h	4,200	3,627 }		50mm sq.		C: 35mmx40mm - 4" x 2"
300 HP	20t/10h	3,300	3,011 }		to 100mm sq.		A: 3/4" - 3"
							H: 3/4" x 1/8" - 4" x 1/2"
1100 kW	80t/20h	25,000 }			IB	SAE1022	R: 6 - 76
450 kW		}			50mm sq.	to 1060	D: 10 - 36
					to 150mm sq.		T: 10 - 38
400 kW	80-90t/20h	36,000 }					W: 6 - 10
750 kW		}	70,132	73			A: 20 - 75
C 250 kW	80-120t/20h	18,000 }					C: 35x45 - 102 x 51
C 500 kW		}					I: 76x38 - 102 x 45
400 kW		16,000 }					H: 18 x 1.2 - 25 x 1.5
250 kW							S: 12 - 50

Table 2.2.5 Technical Data of Surveyed Roo

Private Sector

Name of Company	Location	Reheating Furnace (1)	Re-Rolling Mill: Size of Mill	Re-Rolling Mill: Type & Number of Stands	Re-Rolling Mill: Motor Capacity (HP or KW)	Production per Operation hour (tonnes/hour)	Annual P: Estimated Capacity A (tonnes/annum)	Annual P: Actual Produc (tonne
Frontier Industries Ltd.	NWFP	P x 1	14"	3Hix5	500 HP	30-40t/8h	12,000	under const
Nowshera Engineering Co., Ltd.	NWFP	P x 1	12"	3Hix5	500 HP	50-60t/12h	15,000	
		P x 1	8"	3Hix5	200 HP	20-30t/8h	6,000	
		B x 2	6"	3Hix5	100 HP	8-10t/8h	2,500	
Ittefaq Foundries Ltd.	Punjab	P, 10t/hxl	20"	3Hix1	1200 HP	100t/16h	24,000	21
				3Hix2				
				3Hix3	750 HP			
		P x 1	10"	3Hix6	400 HP	30t/8h	9,000	7
		P x 1	8"	3Hix5	300 HP	23t/8h	6,900	5
Kamran Steel Re-Rolling Mills Ltd.	Punjab	P, 20t/hxl	14"	3Hix5	480 HP	25-30t/11h	8,000	6
		P, 30t/hxl	18"	3Hix5	1,000 HP	40t/11h	12,000	u c
Javed Pervez Co., Ltd., Nawaz Scehlaz Ltd.	Punjab	P, 9t/hxl	12"	3Hix5	400 HP	25-35t/8h	15,000	12
		P, 4t/hxl	8"	3Hix6	275 HP	20-35t/8h	6,900	5
Punjab Steel, Ltd.	Punjab	P x 1	12"	3Hix5	500 HP	20-25t/12h	6,000	6
		P x 1	8"	3Hix5	300 HP	15t/12h	4,500	3

SECTION 1

.5 Technical Data of Surveyed Rooling Mills (Cont'd)

...tor ...apacity ... or KW)	Production per Operation hour (tonnes/hour)	Annual Production: Estimated Capacity A (tonnes/annum)	Actual Production B (tonnes/annum)	Utilization rate B/A x100%	Raw Material (2)	Steel Grade (3)	Rolled Products (4) (mm)
500 HP	30-40t/8h	12,000	under construction		LI 4"x5", 5"x6", 6"x7"	MS, MC	I: 4" - 6"
500 HP	50-60t/12h	15,000			LI 3"x4", 4"x5" 4 1/2"x5 1/2"	MS, MC	R: 1/4" - 3" S: 1/4" - 3" F: 1" x 1/8' - 3" x 3/8" D: 1/4" - 1 1/2" A: 3/4" - 3"
200 HP	20-30t/8h	6,000					
100 HP	8-10t/8h	2,500					
1200 HP	100t/16h	24,000	21,000	88	LI 3"x4", 4"x5" 6"x7"	SAE1008 to 1045	R: 3/8" - 3" D: 3/8" - S: 2 1/2" A: 3/4" - 3" C: 3 I: 200x100, 150x75
750 HP							
400 HP	30t/8h	9,000	7,000	78			
300 HP	23t/8h	6,900	5,000	73			
480 HP	25-30t/11h	8,000	6,000	75	LI 3"x4", 6"x7"	MS	I: 4"x2" - 10"x5" C: 4"x2" - 6"x3" A: 3" - 6"
1,000 HP	40t/11h	12,000	under construction				
400 HP	25-35t/8h	15,000	12,000	80	LI, SB	MS, LC	R: 3/8" - 1 1/4" D: 3/8" - 1 1/4"
275 HP	20-35t/8h	6,900	5,850	85			
500 HP	20-25t/12h	6,000	6,000	100	LI 3"x4", 4 1/2"x5 1/2" 5"x6"	SAE1008 to 1045	R: 3/8" - 1 1/4" I: 3" - 8"
300 HP	15t/12h	4,500	3,600	80			

SECTION 2

Table 2.2.3 Technical Data of Surveyed Rolli

Private Sector

Name of Company	Location	Reheating Furnace (1)	Size of Mill	Type & Number of Stands	Motor Capacity (HP or KW)	Production per Operation hour (tonnes/hour)	Estimated Capacity A (tonnes/annum)	Actua Produ (tonne
Hardware Manufacturing Co., Ltd.	Sind	P x 1	12"	3Hix5	600 HP	30-40t/11h	30,000	14,4
		P x 1	8"	3Hix5	350 HP	15-20t/11h		
		P x 1	8"	3Hix5	350 HP	15-20t/11h		
Ahmed Enterprise Ltd.	Sind	P x 2	16"	3Hix2	600 HP	50-60t/8h	18,000	
Razaque Steel Ltd.	Sind	P x 1	13"	3Hix3	350 HP	43-55t/11h	16,000	10,
				3Hix2	350 HP			
		B 5tx1	6"	3Hix5	225 kW	12-16t/11h	3,500	3,
		P x 1						
Amil Investment Ltd.	Sind	P x 1	10"	3Hix5	300 HP		6,000	3,
		B x 1	7"	3Hix5	250 HP			
Pakistan Oil Expellers & Steel Re-Rolling Mills Ltd.	Punjab	P x 1	12"	3Hix5		14-15t/h	4,200	2,
		P x 1	9"	3Hix5				
		P x 1	8"	3Hix5				
		P x 1	6"	3Hix5				

NOTE: Legend - (1) Re-heating Furnace

P: Pusher type furnace
B: Batch type furnace

(2) Raw Material

LI: Locally made Ingot
SB: Small rolled Billet of ca 50mm sq.
IB: Imported Billet
RS: Re-rollable Scrap

(3) Steel G

MS: Mi
MC: Me
LA: Lo

SECTION 1

ʼechnical Data of Surveyed Rolling Mills (Cont'd)

)	Production per Operation hour (tonnes/hour)	Estimated Capacity A (tonnes/annum)	Actual Production B (tonnes/annum)	Utilization rate B/A x100%	Raw Material (2)	Steel Grade (3)	Rolled Products (4) (mm)
	30-40t/11h 15-20t/11h 15-20t/11h	30,000	14,425	48	LI: 3"x4" 4 1/2"x5 1/2" SB: 2"x2"	MS, MC	R: 3/8" -2" D: 50 - 65 S: 50 A: 1" - 3"
	50-60t/8h	18,000			LI: 4 1/2"x 5 1/2"		S: 2" - 3"
	43-55t/11h	16,000	10,000	91	IB: 50mm sq. 100mm sq.	MS	R: 3/8" - 1 1/2" D: 3/8" - 1 1/2" T: 3/8" - 1 1/2"
	12-16t/11h	3,500	3,000	86			S: 50
		6,000	3,000	50	IB: 50mm sq. 70mm sq. RS	MS	A: 3/4" - 2" C: 40 x 35
	14-15t/h	4,200	2,432	60	LI: 3"x4", 5"x6" RS		R: 1/4" - 3" A: 1" - 3" I: 6" x 3" D, F, C

:de Ingot
led Billet of ca 50mm sq.
Billet
e Scrap

(3) Steel Grade

MS: Mild Steel
MC: Medium Carbon Steel
LA: Low Alloy Steel

(4) Rolled Products

R: Round Bar
D: Deformed Bar
T: Twisted Ribbed Bar
S: Square Bar or Square Billet
A: Angle
C: Channel
I: I Beam
B: T Bar
W: Wire Rod
H: Hoop
F: Flat Bar

SECTION 2

(a) Materials for re-rolling

Materials used in re-rolling mills in Pakistan are roughly classified into three categories: small ingots, rolled billets and re-rollable scrap. Although continuous-cast billets are also available, they are currently supplied by only one company, Noor Steel in Sind.

The cross section of small ingots produced in Pakistan ranges from about 80mm by 80mm to 200mm by 200mm, but ingots of 100mm by 100mm to 125mm by 125mm in size represent the greater part. As for rolled billets, the size of a large portion of imported rolled billets is of the section over 100mm by 100mm. These small ingots and rolled billets having such a relatively large section are rolled into small billets of about 50mm by 50mm in size and 1 to 2m in length on cogging mills having rolls of 300mm or more in diameter before they are supplied to re-rolling mills. Such cogging mills which are no more than unmodernized three-high mills are installed only in the public sector and at several major re-rollers in the private sector. This means that materials used by an overwhelming majority of re-rollers in Pakistan are small billets of about 50mm by 50mm in size, supplied from these cogging mills, or re-rollable scrap obtained mainly by ship breaking. The re-rollable scrap, of which chemical composition in unknown from the nature of the case, can not be rolled into deformed bars or twisted ribbed bars, but can be rolled only into conventional round bars.

(b) Reheating furnace

Small batch-type and pusher-type reheating furnaces are used. They are constructed by re-rollers themselves in most cases. Most reheating furnaces of major re-rollers are of the pusher type, but their capacity is 10 tonnes per hour at most. Heating is done by combustion of natural gas having a heating value of around 9,000 Kcal/Nm^3. Furnace temperature and fuel consumption controls are scarcely controlled. In most cases, the discharging of hot billets from the reheating furnace as well as their introduction into mills are carried out by manual operation.

(c) Rolling mills proper

Most re-rolling mills currently operated in Pakistan are small three-high stands of un-modernized types. The mill modulus is low and their efficiency is also low. Some re-rollers operate conventional two-high stands. All cogging mills are also three-high mills. High-efficiency cogging mill, such as two-high reversing type, does not exist in Pakistan.

Mill roll diameter varies from 100mm to 500mm according to the size of stock as well as kind and size of products. Rolling mills having rolls of 250mm or less in diameter represent the greater part. So-called "single-axis drive arrangement", where five three-high stands are arranged in a train and driven by a single A.C. motor, is the typical mill layout in Pakistan. As an exceptional mill layout, there is a hoop mill of Metropolitan Steel, where the finishing train consists of two-high stands arranged in tandem and driven individually at rolling speed of 7 to 10 m/sec by an associated D.C. motor.

In case of reciprocating rolling on three-high stands, the time of handling operations carried out on both entry and delivery sides of the stand is longer than the net rolling time with stock being rolled by mill rolls. Normally, the rolling efficiency depends upon such handling time in this case.

In Pakistan, these handling operations are carried out by manual operation with use of tongs by tongs men placed on both entry and delivery sides of stands. Such handling operations are not mechanized but in only two mills: hoop mill of Metropolitan Steel and 20-inch beam mill of Ittefaq Foundries.

In case of manual rolling operation by tongs the size and weight of a rolled stock are limited. Finishing speed is also limited to about 3 m/sec at maximum. Under these limitations, the improvement in productivity necessarily depends on the operators' skill. Therefore, this improvement can not be expected so much.

On existing single axis dive arrangement mills involving manual handling by tongs operations, the productivity of rolled products is 1 to 5 tonnes per hour, depending,of course,upon the size of rolled products. In these mills, it seems that the limitation of productivity will be 10 tonnes per hour.

To increase further the productivity, it will be necessary, in case of heavy products, to reduce the rolling cycle time and increase the unit weight of rolled stock through mechanization and automation of handling operations on entry and delivery sides of mills, for example, by installing tilting tables as in the 20-inch beam mill of Ittefaq Foundries. In re-rolling mills manufacturing small rolled products, it will be necessary to increase widely the rolling speed through elimination of tongs operations, for example, by installing such repeaters as used in mills of Metropolitan Steel and Razaque Steel. For this purpose, a semi-continuous rolling mill arrangement where a roughing train consisting of three-high stands is combined with intermediate and finishing trains consisting of two-high continuous stands, or a continuous rolling mill arrangement consisting entirely of two-high stands, should be adopted.

(d) Finishing facilities

In most re-rolling mills, transportation and cooling of rolled products are carried out by hand in concert with the current low speed and low efficiency rolling. The greater part of existing cooling beds take the form of product storages constructed simply of brickwork. It is required for the increase in unit weight of rolled stock and rolling speed of finishing train to employ the automatic operation of transportation of rolled products from the rolling mill by means of roller table or the like and the cooling bed mechanization by adoption of a rake type or pusher type. The cooling bed facilities of Ittefaq Foundries got the start of such mechanization.

At present, cropping and cutting-to-length of rolled products are carried out with saw or shear in some shops but, in the greater part of shops, these operations are still carried out by hand with chisel and hammer.

In some shops, steel shapes are straightened on a roller straightener, but in most shops, these products are shipped as-rolled without straightening.

Angles produced mainly for the construction of pylons of 11kV and 132kV transmission lines of WAPDA are shipped pickled and galvanized. For this purpose, galvanizing facilities are installed at major producers, including Quality Steel, Metropolitan Steel, Pakistan Engineering and Nowshera Engineering.

For bar products, it seems that straightener is not commonly used in Pakistan. Only bar twisting equipment exist in mills manufacturing twisted ribbed bars. Bar products are shipped as-rolled and uncropped at the both ends unless otherwise specified by customers.

Wire rod rolling facilities are operated by Metropolitan Steel, where conventional laying reels have been replaced with pouring reels.

(e) Rolled products

Rolled products currently manufactured in Pakistan include bars and shapes. In addition, wire rods, wires and welded pipes are produced in small quantities. However, flat products such as plates, sheets and strips are not produced at all.

(i) It seems that bar products account for about 60% of all rolled products produced in Pakistan. The greater part of these bar products is represented by round bars. The Pakistan Steel Re-rolling Mills' Association estimates the proportion of round bars in the total production at 45%. In addition to round bars, deformed bars, twisted ribbed bars, flat bars, square bars and others are produced. The size range is very wide, going from 6.4mmϕ up to 80mmϕ or so. It seems however that small bars below 25mmϕ represent the greater part.

The steel grade of bars is the mild steel having a carbon content of 0.25% or less, which is the most popular grade for steel products. Deformed bars are made of a medium carbon steel having a carbon content of the order of 0.35% to guarantee the minimum yield point specified by British standard and other standards. For production of these deformed bars and twisted ribbed bars, either steel ingots with chemical analysis clearly analysed or imported billets must be used.

(ii) It is estimated that steel shapes represent about 30% of all rolled products produced in Pakistan. Their product mix includes angles, I-beams, channels, T-bars and other products of various forms.

Their size range is limited to small and medium sections up to about 80mm, centring on small sections of 50mm and under. Recently, however, heavy I-beams with web size exceeding 100mm are also being produced mainly by major companies.

For all types of shapes, the mild steel having a carbon content of 0.25% or less is used.

(f) Rolling operation

In a word, the rolling technology currently employed in Pakistan is compatible with the main rolled products in Pakistan, that is, mild steel reinforcing bars.

The yield of products relative to materials is about 88 to 95%. Cobble rate is as high as 2 to 3%. Mill adjustment is scarcely made during rolling operation and the product shape accuracy is therefore low. These conditions are compatible only with the rolling of reinforcing bars. In case of rolling on single aixs drive arrangement of three-high stands of unmodernized type with tongs operations by tongs men, such conditions are considered inevitable.

Except for some major companies, the unit consumption of major items, such as fuel gas, electric power and mill rolls, is rarely controlled, and yield and cobble rate are not clearly known.

Surface conditioning operation of rolled stock and inspection operation of products are scarcely observed. Over-filled round bars as well as steel shapes out of tolerance on shape and dimensions seem to be shipped in considerable quantities.

However, when the main rolled products are plain reinforcing bars which can be manufactured without any technical standard, nor specification it may be considered that such a rolling operation will be reasonable and most economical at present.

Such equipment for inspection of chemical composition and mechanical properties as already installed at some major enterprises will be required only for the production of bars for drawing purpose and round bars for general and mechanical structure purpose. For production of heavy shapes and wire rods, mechanized rolling mills will be introduced.

(g) Comparison of Pakistani rolling mills with Japanese ones

Table 2.2.6 has been prepared to compare large-sized rolling mills in Pakistan with the Japanese typical rolling mills (A - F) for reference.
The rolling mills A and B were constructed during 1940's and are still in operation. They are conventional medium-sized steel bar mills of a 3 Hi parallel-arrangement type. They are selected as their equipment specifications are most closely like those of Pakistani large-sized rolling mills. But as shown in the table, the hourly output differs largely between the two groups. Even the max. hourly output in the Pakistani mills is 1/5 or so of that of a comparable Japanese mill. The mills C through F are the typical and modern rolling mills in Japan; C is a medium-sized steel bar mill with tandem V-H arrangement. D is a 4 strands-rolling Morgan type wire rod mill. E is a medium-sized shape steel mill. F is a high-speed small-sized steel bar mill where 2 strands rolling is also possible. These modern mills have 15-20 rolling stands which are 2-3 times

larger in number than those of the Pakistani mills. In one of these Japanese mills, the total capacity of main motor exceeds 20,000 kW, showing that how much the progress in rolling mill depends on the development of electric motor. The rolling speed of 3 m/sec in a 3 Hi type parallel arrangement without repeater which is said to be practically the highest limit, shows a remarkable difference from the improved high speed in a mill with the tandem arrangement. This high-speed rolling has made it possible to increase the rolling product amount per hour in a new mill to about 100 tonnes/hour and construct a mill with the production capacity of 1,000,000 tonnes/year. It is very difficult to compare the present Pakistani "large-sized" mills with the Japanese mills on this level. The difference of cobble rate between the Pakistani and Japanese mills, i.e. between 2.5% achieved by Metropolitan Steel in Pakistan and 0.1% or 0.02% performed by these modern mills in Japan, shows the difference of rolling techniques between the two countries at present.

It may generally be said that the present Pakistani level of rolling technology in respect to the rolling facilities and operation techniques is similar to the Japanese level in 1950's and 1960's when Japanese iron and steel industries started remarkable development. The present large-sized rolling equipments like PECO and Ittefaq in Pakistan will soon or later reach the levels of production efficiency and output of Japanese mills A and B through improvement of their facilities, mechanization of auxiliary equipment and technical innovation. However to obtain further higher efficiency and more output, it will be necessary for them to introduce continuous type large-capacity high-speed rolling mills.

Table 2.2.6 Comparison of Rolling Mills

Rolling Mill	Reheating Furnace (1)	Roll Dia.	Type and Number of Stands	Main Motor Capacity	Max. rolling speed (m/sec.)	Hourly Output (tons./hr.)	Annual Production (tonnes)	Cobble rate %
			Rolling Mill Equipment					
PECO/Kotlakpat Works	P 10t/h x 1	20"	3Hi x 1 3Hi x 4	680 kW 680 kW	3	6 to 7	18,000	-
Ittefaq Foundry Ltd.	P 10t/h x 1	20"	3Hi x 3 3Hi x 3	900 kW 560 kW	3	6 to 7	21,000	-
Metropolitan Steel Corp. Ltd.	P x 1	16"	3Hi x 3 3Hi x 6	1,100 kW 450 kW	7	4	25,000	2.5
A	P 40t/h x 1	20"	3Hi x 4	1,800 kW	3	30	135,000	0.4
B	P 30t/h x 1	22"	3Hi x 3	1,500 kW	3	27	240,000	0.01
C	W 250t/h x 1	740-420	2Hi x 16 V-H*	14,850 kW	12	116	780,000	0.02
D	W 180t/h x 1	550-160	2Hi x 15 and Block Mill 4-strands rolling	13,550 kW 10,400 kW	65	172	1,020,000	0.03
E	P 60t/h x 2	400-350	2Hi x 16	4,450 kW	13	90	360,000	0.1
F	W 130t/h x 1	500-330	2Hi x 20 2-strands rolling	13,400 kW	17	95	480,000	0.2

Note: (1) Reheating Furnace - P: Pusher type W: Walking type
(2) Initial Material - I: Ingot B: Billet
(3) Rolled Products - S: Square bar, A: Angle, I: I beam, W
C: Channel, R: Round bar, D: Deformed 1

* V-H means alternate arrangement of vertical-horizontal stands

Rolling Mills A to F are Japanese ones

SECTION 1

..le 2.2.6 Comparison of Rolling Mills

..ment ..ity	Max. rolling speed (m/sec.)	Hourly Output (tons./hr.)	Annual Production (tonnes)	Cobble rate %	Yield %	Unit Consumption: Fuel Consumption Kcal/tonne	Unit Consumption: Electric Power Consumption kWH/tonne	Initial Material (2) mm	Rolled Products (3) mm
W W	3	6 to 7	18,000	-	96	—	—	I: 5" x 6" 6" x 7" 7" x 8"	S: 50-100 A: 100-150
W W	3	6 to 7	21,000	-	85-95	—	—	I: 3"x4", 4"x5 5"x6", 6"x7	I: 150x75 to 200x100
W W	7	4	25,000	2.5	-	—	—	B: 50 to 100 sq.	W: 6-10 H: 18-25
W	3	30	135,000	0.4	94	430,000	40	B: 110 sq. 150 sq.	I: 75-150 C: 75-125
W	3	27	240,000	0.01	95	285,000	26	B: 115 sq. 130 sq.	R: 50-105 S: 45-100
[illegible]	12	116	780,000	0.02	97	375,000	80	B: 180 sq.	R: 28-102 S: 45- 85
[illegible]	65	172	1,020,000	0.03	99	226,000	132	B: 115 sq.	W: 5.5-13
[illegible]	13	90	360,000	0.1	95	384,000	64	B: 135 sq.	A: 25-75
[illegible]	17	95	480,000	0.2	97	359,000	69	B: 115 sq.	R: 13-42 D: 13-41 W: 10-38

P: Pusher type W: Walking type

I: Ingot B: Billet

S: Square bar, A: Angle, I: I beam, W: Wire rod, H: Hoop,

C: Channel, R: Round bar, D: Deformed bar

..gement of vertical-horizontal stands

..panese ones

SECTION 2

(5) Security, environmental control and others

Even if the shop facilities are modernized and improved, it will be impossible to obtain stabilization of product quality, increase of productivity and decrease in production cost of products unless technique and skill of operators are levelled up so that they can properly operate such facilities. In addition, it will be essential to keep the working environment safe and favourable. Furthermore, it will also be important to further endeavour to control the environmental pollution so as to enhance the coexistence and coprosperity with local communities in future.

For these purposes, it will be most important that law and regulations concerning security, sanitary and pollution control as well as industrial standards and quality of products should first be established on the level of the Government and that each enterprise should establish its own standards on the basis of national regulations and industrial standards, while carrying out personnel training and other necessary activities to level up the technique and skill of each employee.

In addition, supporting systems for raw materials, refractories, electrodes, mill rolls and other materials have a great influence on the increase in steelmaking efficiency, product quality, yield and the like. Consequently, it will also be important for each c. a group of enterprise to standardize purchase specifications, acceptance inspection procedures and the like for these materials so that materials of stabilized quality may be procured in a stable manner.

2.2.3 Current and Future Aspects of Utilities and Transportation in Pakistan

(1) Electric power

(a) Outline of current situation

In Pakistan, WAPDA (Water and Power Development Authority) supplies nearly 80% of all electric power throughout the country, with the exception of some areas where KESC (Karachi Electric Supply Corporation), REPCO (Rawalpindi Electric Power Company) and MESCO (Multan Electric Supply Company) possess licenses.

Service networks of WAPDA are roughly divided into 1) North trunk network, 2) Northern Sind network, 3) Karachi network and 4) Quetta network. The network 1) includes Tarbela, Mangla, Warsak, Small Hadel, Multan, Faisalabad and Shabdahra power stations, and the network 2) includes the Guddu power station. Hyderabad and Kotri power stations are included in the network 3). These three networks 1) to 3) are linked with each other. At present, the Quetta network is independent.

Next to WAPDA, KESC supplies nearly 20% of power over a service area of 940 square miles centering on Karachi City. In addition, this company supplies its surplus power to WAPDA through its own 132kV transmission line connected to WAPDA's Karachi-Hyderabad network.

In 1981, WAPDA has an installed capacity of 3,225MW, of which 54% is represented by hydraulic turbine generators at Tarbela dam, Mangla dam, etc., 32% by steam turbine generators and 14% by gas turbine generators. It is estimated that WAPDA has also a short-circuit capacity of the order of 3,500MVA on 500kV lines in the Northern region, such as Lahore, Rawalpindi, Faisalabad, Multan and Peshawar.

For KESC covering the Karachi region, it is estimated that this company probably has an installed capacity of the order of 580 MW.

In general, Pakistan suffers from some shortage of electric power. In particular in the Karachi region, the power supply to large consumers, such as electric arc furnaces, is limited during peak consumption hours in the evening. It is estimated that this region suffers from a consierable shortage of electric power. In addition, because of high percentage of hydro-electric generation, it seems that there exists a fluctuation in power generation between seasons: the power generation is in excess during wet season and in shortage during dry season.

(b) Outline of future plan

Tables 2.2.7, 2.2.8, 2.2.9 and 2.2.10 show power station construction plan for 1981-90, total generating capacity, transmission line installation plan and other data, which were furnished by WAPDA. From these plans, it is expected that the construction of fairly large-scale iron and steel mills will become possible in both Northern and Southern regions of Pakistan, because the short-circuit capacity on 500kV lines will largely be increased from 3,500MVA in 1980 up to 8,400MVA in 1984 and 15,400MVA in 1990.
Meanwhile, electric power development by KESC will be 1,000 MW up to 1990 in addition to 580 MW capacity at present as shown in Table 2.2.9.

Table 2.2.7 Generation Programme for Future

2-79

Sr. No.	Name of Power Station	Installed Capacity MW	Date of Commissioning
1.	Warsak Units 5 & 6	80	Feb. 1981
2.	Kotri Gas Units 5 & 6	50	May 1981
3.	Mangla Units 7 & 8	200	Jun. 1981
4.	Second Quetta Gas Turbine	25	Jan. 1982
5.	Tarbela Unit 5	175	Feb. 1982
6.	Tarbela Unit 6	175	May 1982
7.	Tarbela Unit 7	175	Aug. 1982
8.	Tarbela Unit 8	175	Nov. 1982
9.	300MW Gas Turbines	300	Jan. 1984
10.	Pipri D-2 Steam (KESC)	200	Dec. 1984
11.	Guddu Unit 4	210	Aug. 1985
12.	Pipri D-3 Steam (KESC)	200	Dec. 1986
13.	Tarbela Unit 9	406	Jan. 1987
14.	Lakhra Steam (Coal Fired) Stage-I	300	Feb. 1987
15.	Tarbela Unit 10	406	Apr. 1987
16.	Tarbela Unit 11	406	Jul. 1987
17.	Tarbela Unit 12	406	Oct. 1987
18.	Tarbela Unit 13	406	Jan. 1988
19.	Mid Country Thermal Stage-I	400	Apr. 1988
20.	West Wharf Station (KESC)	130	Dec. 1988
21.	Mid Country Thermal Stage-II	400	Feb. 1989
22.	Pipri D-4 Steam (KESC)	200	Dec. 1989
23.	Lakhra Steam Stage-II	300	Feb. 1990
24.	Kohala	700	Dec. 1990

Source: WAPDA

Table 2.2.8 Expansion Plan of Power Generation by WAPDA

Year	Total Installed Generating Capacity (MW)	
1981	3225	
1982	3950	
1983	3950	
1984	5372	interlink with KESC in Jun. 19
1985	5582	
1986	5782	
1987	7706	
1988	8642	
1989	9242	
1990	10242	

Source: WAPDA

Table 2.2.9 Power Development Plan by KESC

Year	Capacity
1983	200 MW
1984	200
1986	200
1988	200
1990	200

Source: KESC

Table 2.2.10 Transmission Programme

Sr. No.	Name of Scheme	Date of Commissioning
	A. On-Going Schemes	
1.	220kV D/C Tarbela-Mardan Transmission Line	1982-83
2.	220kV D/C Faisalabad-Sahiwal Transmission Line	1983-84
3.	2nd 500kV Tarbela-Faisalabad Transmission Line	1984-85
4.	500kV Faisalabad-Multan Guddu-Karachi Transmission Line	1984-85
	New Schemes	
5.	220 kV D/C Mardan-Peshawar Transmission Line	1984-85
6.	500/220kV Dadu-Grid Station	1984-85
7.	220kV Dadu-Khuzdar Transmission Line	1985
8.	3rd 500kV Tarbela-Faisalabad Transmission Line	1987
9.	2nd 500kV Faisalabad-Multan-Guddu Transmission Line	1987
10.	Transmission Facilities for Lakhra	1987
11.	220kV D/C Transmission Facilities for Mid-Country Steam Station Stage-I	1988
12.	Transmission Facilities for Mid-Country Steam Station Stage-II	1989
13.	500kV Faisalabad-Lahore Transmission Line	1990
14.	220kV D/C Kohala-Rawalpindi Transmission Line	1990
15.	Secondary Transmission Lines & Grid Station	1983-90

Source: WAPDA

2) Natural gas

Eleven (11) natural gas fields are known in Pakistan. So far Sui gas field in Baluchistan, and the Mari, Sari and Hundi gas fields in Sind have been put on production. Small production of natural gas is obtained as associated gas from the Dhulian and Meyal oil fields in the Potwar region of the Punjab. Table 2.2.11 shows natural gas production in Pakistan.

Table 2.2.11 Natural Gas Production in Pakistan

(Unit: million cubic metre)

Year	Production
1970-71	3,354
71-72	3,592
72-73	4,131
73-74	4,706
74-75	5,092
75-76	5,062
76-77	5,576
77-78	5,835
78-79	6,300
79-80	7,534

Source: Ministry of Petroleum and Natural Resources

As is seen from Table 2.2.12, the production from Sui Gas field accounts for approx. 85% of the total production in Pakistan. Presently the Pirkoh gas fields near Sui and the Dhodak in the southern Punjab are under development and they are scheduled to start commercial operation by the end of 1982. The remaining gas fields are left untouched because of techno-economic reasons.

At present natural gas production in Pakistan meets approx. 40% of the country's energy requirements. Of it, 35% is used for power generation, 10% for cement manufacture, 20% as stockfeed for fertilisers, 30% as fuel for other industries, and 5% for domestic heating. Since natural gas is more economical and convenient as compared to coal, its requirement still higher in every industrial field. Therefore, all the production facilities are fully loaded.

The proved reserves of natural gas are estimated at 453,000 million cubic metres (m^3) as of January the 1st, 1980 by Cedigas (France), but were 535,000 million cubic metres (m^3) in 1970 (ten years before) by same organisation.

This means that there has been little increase of the reserves in newly explored and producing gas fields these yen years, and only consumption has been made.

Out of the non-renewable sources, natural gas resources are also of concern to the nation. Instead of its being used as feedstock for chemicals and fertilisers, and agent for iron ore reduction, natural gas is being burnt for power generation and domestic purposes such as a rate that unless significatnt new discoveries are made, it will be exhausted by the early the 21st centrury.

Table 2.2.12 Production by Gas-fields in 1979

(Unit: 1,000 cubic feet/day)

Sui (Pakistan Petroleum Ltd.)	536,200
Mari (ESSO)	34,700
Sari and Hundi (OGDC)	10,400
Dhulian and Meyal (Pakistan Oilfields Ltd.)	55,100
Total:	636,400

Source: Ministry of Petroleum and Natural Resources

(3) Process water

In existing steelmaking shops, the process water required for cooling various equipment and machinery is supplied for the most part from wells located within shops or rivers running nearby. It seems that the no water is supplied from the water dept. for industrial use although the detail of water quality is not known, it is expected that the process water can be obtained in pretty large quantities. Consequently, the construction of a considerably large-scale iron and steel mills can be planned only by adopting systems for pretreatment of raw water taken from these wells and rivers, and for recirculation of water.

(4) Transportation

In the Fifth Five-year Plan, the annual growth rate of goods transportation is estimated at 7.5%. As compared with the annual growth rate of 5.0% for 1960 to 1970, 5.4% for 1970 to 1975 and 1.0% for 1976-77, it is considerably high.

This rate is estimated from the relation of GDP to goods transportation, population growth and income per capita. As a result, the volume of transportation in 1982-83 is expected to increase 1.5 times to 20,900 million tonne·mile in freight and 1.6 times to 72,000 million man·mile in passenger from the 1976-77 levels of freight 13,500 million tonne·mile and passenger 45,000 million man·mile, respectively.

Referring to its breakdown, it is estimated that the railway transport will increase 1.3 times in volume to 5,991 million tonne·mile from 1976-77 level. On the other hand, transport by road is estimated to increase 1.6 times to 11,850 million tonne·mile from the 1976-77 level of 7,590 million tonne·mile. It is therefore assumed that higher dependence will be placed upon the transportation by road.

As for other means of transportation than these, there are some raw material pipelines which is only about 5% of all means. Further, water-born transportation by rivers is limited only to local means. In view of the natural conditions that periodical flooding is inevitable, it is considered unefficient on a nationwide scale.

(i) Railways

All railways in Pakistan are owned by the federal government. The Railway Board organized under the control of the Ministry of Railway is charged with railway management.

Route-kilometres of the Pakistan Railways are 8,820km as of 1979-80. Track-kilometres including double-tracks and sidetracks are 12,607km with stations amounting to 884.

However, as is clear from the table 2.2.13, the Route-kilometres have little increased since 1972-73. Locomotives, goods wagons, coaching vehicles, etc. have also decreased in number from about 1970. All of these facts indicate the declining tendency of railway transportation.

Table 2.2.13 Capacity of Pakistan Railways

	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
(thousand) Route-kilometres	8.57	8.79	8.81	8.81	8.81	8.81	8.82	8.82	8.82	8.82
(thousand) Locomotives	1.14	1.02	0.99	0.99	0.99	1.02	0.98	0.98	0.98	1.00
(thousand) Goods Wagons	37.3	37.6	37.4	37.3	37.2	36.9	36.7	36.4	36.3	36.3

Source: Pakistan Railways Year Book of Information 1979-80

On the background of such stagnation of railway transportation, there is the development of transportation by road owing to the pervasion of motorization. In addition to this, however, the problems of Pakistan Railways' own, namely various problems as to its customer services, carriage rates, management and control and, as the greatest problem above all, the delay in equipment renewal are pointed out. Almost of all facilities such as tracks, locomotives, passenger cars, goods wagons and communication systems have become obsolete, thus leading to the lowered transportation functions. Against this background, various policies are to be adopted in the Fifth Five-Year Plan. However, it is considered not easy to achieve rapid progress and improvement of such facilities in the near future.

(ii) Transport by road

The total extension of road in Pakistan as of the end of 1979-80 is 95,222 km, only 1/3 of which is high grade roads and remaining 2/3 is low grade roads. Furthermore, road conditions are also unfavourable. In particular, almost all local roads are not straight with no street lamp, therefore, night transportation is facing much danger. It is also pointed out that roads in Pakistan are frequently closed up due to flood in case of rain because they are not well drained. These reveal the basic problems on transportation by road.

In spite of these problems, however, trucking has shown a rapid growth after the 1960's. In the middle of 1970's, it has exceeded the railway in goods transportation to such an extent that it can be proud of its transport capacity largest in the country. Although its growth rate has been slightly lowered after the oil crisis, transportation by road has become increasing important in keeping with the Pakistani industrial policy to bring up small-scale industries.

To cope with such circumstances, in the Fifth Five-Year Plan a comprehensive counterplan is employed including following points:

- to meet the rapid increase in passenger transport and goods transport with priority given particularly to the urban areas,

- to achieve the solidarity between advanced areas and local areas,
- to maintain transport by road in the public sector and improve its efficiency and operation,
- to take preventive measures against ever-increasing highway accidents,
- to promote the private investment, and
- to introduce larger lorries with the loading capacity of 20 to 50 tonnes.

Since even main roads have so far been under the control of cach state government, it appeared to be difficult to realize the integrated and systematic road administration on a nation-wide scale. The Highway Project is now in progress under the leadership of the federal government. It is therefore assumed that the federal government will excercise a greater influence toward the road administration in the future. In order to effectively push forward the Five-Year Plan mentioned above, it is desired to establish the system for enforcing the road administration itself consistently from a national viewpoint.

(5) Harbours

(a) Present situation and measures to meet it

The Karachi Port has so far filled its function as a sole foreign trade port in Pakistan. However, in recent years, it has not been able to meet the increase in cargoes to be handled. In particular since 1972, cargo-boats have often been left anchoured for as long as one month, thus resulting in various losses due to surcharge and demurrage. Therefore, it was an urgent need to take a drastic measure against it. In consideration of these conditions, it was elected to construct a new port upon decision made to the construction of an integrated steelworks, the Pakistan Steel while it is aimed to expand the capacity of Karachi Port. It is the Port Qasim now under construction at the Phitti Creek in the east of Karachi city. Its construction began in 1976. The first stage of its construction work is scheduled to be completed in 1980-81. It is also scheduled to make a survey for the purpose of constructing another harbour on the Baluchistan beach during the period of the Fifth Five-year Plan.

For this reason, also in the Fifth Five-year Plan now underway, priority is given to the following points; 1) to meet the demand of Pakistan Steel, the first priority is given to Port Qasim;

2) the demurrage problem is solved by expansion of the harbour facilities; and 3) coordination is made between Port Qasim and Port Karachi for their roles. To be concrete, while Port Qasim is planned to have a cargo handling capacity of 5.8 million tonnes, as for the Port Karachi, in addition to the re-building of five berths and construction of three additional berths with a view to raising the dry cargo handling capacity from 4.8 million tonnes to 5.0 million tonnes, it is plenned to increase the capacity of the forth oil Pier from 5.5 million tonnes to 9.0 million tonnes and, further, start with re-construction of four berths and a transit warehouse at the Juna Bander and Napier Bridge.

(b) Karachi Port

(i) Depth - The maximum depth of channel 38.5 ft (35 ft at low tide); the maximum depth of berth 28 to 34 ft.

Ships accessible - Ships of 30 to 32 ft draught are accessible.

Berth - Berth for mooring; 25
Berth for oil tanker; 1

(ii) Installed conditions of harbour equipments

Wharf crane: 60 units for 3 tonnes (East Wharf);
34 units for 2 tonnes (West Wharf);
4 units for 2 tonnes, 1 unit of electric crane for 25 tonnes and 1 unit of luffing crane for 30 tonnes (all but one for 25 tonnes is of electric horizontal type.)
(Barge Transport Wharf)

Mobile crane: 2 units for 25 tonnes truck, 70 units for 6 tonnes

Floating crane:
1 unit for 125 tonnes and 1 unit for 60 tonnes

Cargo barge: 17 barges for 250 tonnes, 2 barges for 200 tonnes, 4 barges for 3 to 4 tonnes, two 50 tonnes barges for dangerous cargoes and one 200 tonnes barge for the same.

Principal goods handled at the Karachi Port in 1978-79 are given in Table 2.2.14.

(iii) Present condition of harbour development

As for the harbour development, construction of dry cargo shipping berth, transit sheds, railway yard and berth for oil tanker as well as dredging of channels are now underway based on the credit granted by the International Development Association. Furthermore, the master plan of container berth and modern cargo handling system was made under the UN fund. Based on this master plan, more concrete plan is now being prepared.

Table 2.2.14 Principal Goods Handled at the Karachi Port (1978-79)

(Unit: Tonnes)

Imports Total	11,987,380	Exports Total	3,038,177
Crude oil	3,918,839	Petroleum products	880,297
Diesel oil	673,083	Molasses	416,081
Fuel oil	1,459,807	Rise	1,007,668
Kerosin	361,495	Cement	175
Food oil & animal fat	457,931	Cotton	55,750
Iron & steel	462,889	Cotton fabrics	8,806
Fertilizer	1,438,711	Textiles	29,712
Cement	629,531	Oil cake	42,669
Coal	2,860	Bones	6,664
Coke	55,495	Food grains	33,855
Tea	57,879	Seeds	4,161
Wood	9,767	Furs and wool	2,412
Jute	40,848	Leather	3,259
Wheat	2,176,180	Guwar & Rape seeds Extraction	62,416
Paper	66,693		
Phosphate rock	135,802		
Automobile	39,570		

Source: Karachi Port Trust Year Book 1979-80

(c) Port Qasim

The Port Qasim now under construction at the Phitti reek located about 30 miles southeast from Karachi will be the first port for industrial and bulk cargoes in Pakistan. As for the cargo handling, in order to achieve the rational management of this port and effective use of its mobility, all operations in this field will be entrusted to private enterprises.

(i) Berths and various facilities

Marginal wharf: It is a set of 7 multi-purpose berthes each of which is 200m. These berths will handle bulk, semi-bulk homogenous bagged such as wheat, cement, fertilizer, rice, phosphate rock etc. Of 7 berths, construction work of 4 berths have already been completed. These berths will have of 10 metres to accommodate ships up to 25,000 dwt. The remaining three berths will be operationed by 1982, and will have a draft of 11 metres capable of handling ships of 35,000 dwt. The back up area, 300 metres wide contains transit sheds, railway tracks, roads, for yards cargo handling and operational office with communication facilities.

(ii) Iron ore & coal berth

The iron ore and coal berth already completed, will be for the exclusive use of the first integrated steel mills (Pakistan Steel) to handle its import of raw materials. The main berth is 279 metres long and 21 metres wide to be designed to accommodate eventually ships of up to 75,000 dwt (to be completed in 1985). However, at present, ships of up to 25,000 dwt only can be accommodated. Two unloaders of 1,200 tonnes per hour capacity each, have been installed to handle cargo. The berth structure is directly connected with the stock yard of Pakistan Steel conveyor belt of 4.5km long.

Iron ore and coal are transported on this conveyor belt. The design capacity of this berth is 3.36 million tonnes per year. These berths will be put into operation in 1981 when Pakistan Steel is scheduled to begin operation.

It is estimated that dry cargoes to be handled in the marginal wharf and berth for iron ore and coal will total to 5.81 million tonnes in 1982-83.

(iii) Channels

This port is connected with the open sea of the Arabian Sea by an approach channel of 12.5m in depth and about 25km in length (from the open sea to Phitti Creek) with a width ranging between 185 to 225 metres and an inner channel of 11m deep and 150 to 200m wide is extending from the Phitti Creek to the wharf.

2.2.4 Pakistan Steel

Pakistan Steel is the integrated iron and steel works in the vast field at Bin Qasim (an area of about 41,690 thousand square metres and for the steel works about 32,880 thousand square metres for the township) located 40km east of Karachi City. Its construction started on 30th December, 1973 by the Government of Pakistan under the cooperation and assistance by the Government of USSR.

Within the steel works, coke ovens, sintering plant, blast furnaces, BOF, continuous slab & bloom castings, billet mill, hot strip mill and cold rolling plant will be installed as major facilities. And, the unloading facilities for imported iron ore and coaking coal have been installed on the jetty 4.3km apart from the steel works.

Furthermore, auxiliary production units such as refractories & lime calcination plant, repair shop & storage facilities, operative power centre, central laboratory & instrumentation buildings and metallurgical training centre, and facilities of utilities such as thermal power plant & turbo-blower station, oxygen plant and refrigeration plant will be constructed. After completion of the first stage of construction, Pakistan Steel is scheduled to start production of finished and semi-finished products such as hot rolled sheets, cold rolled sheets and billets in a quantity of 1.1 million tonnes per year.

(1) Essential production units

Essential production units contain coke oven and by-product plant, sintering plant, ironmaking plant, steelmaking plant, and rolling mills:

(a) Coke oven and by-product plant

i)	Coke oven:	2 coke oven batteries with 49 ovens
ii)	Effective volume of oven:	$30.3m^3$ each
iii)	Annual production:	970 thousand tonnes of coke
		406 million m^3 of coke oven gas
		46.5 thousand tonnes of coal tar
		17.3 thousand tonnes of ammonium sulphate
		6.8 thousand tonnes of solar oil

(b) Sintering plant

i)	Sintering machine:	2 machines with an effective area of $75m^2$
ii)	Rated capacity:	1.3 $tonnes/m^2/h$
iii)	Annual production:	1,500 tonnes of self-fluxed sinters

(c) Iron making plant

i) Blast furnace

- Rated capacity: 2 blast furnaces capable of producing 1,750 tonnes of hot metal per day
- Effective volume: 1,033m^3 each
- Hearth diameter and height: 8,200mm x 26,150mm
- Annual production: 1,230 thousand tonnes of hot metal

ii) Pig casting machine

- Number: 2 machines
- Rated capacity: 60 tonnes/h/each

(d) Steelmaking plant

i) BOF

- Number: 2 converters
- Furnace inner volume: 109m^3
- Charged amount: 130 tonnes/heat
- Tapped amount: 117 tonnes/heat
- Annual production: 1,134 thousand tonnes of molten steel

ii) Mixer: 1,300 tonnes x 1 set

iii) 2 (two) strand bow type continuous slab

- Casting machine: 2 numbers
- Size of slab: 150mm - 200mm in thickness x 700mm - 1,550mm in width x 3,000mm - 600mm in length
- Annual production: 825 thousand tonnes of slab

iv) 4 (four) strand bow type continuous bloom

- Casting machine: 1 number
- Size of bloom: 260mm sq. x 1,500mm - 6,000mm in length
- Annual production: 445 thousand tonnes of bloom

(e) 800mm billet mill: 1 number

- Size of billet: 50 mm sq. - 100mm sq. x 1,500mm - 8,000mm in length
- Annual production: 400 thousand tonnes of billet
- Pusher type furnace (100 tonnes/hour): 1 number
- Rolling mill
  2-high reversing stand: 1 number
  H-V continuous stand: Horizontal 2 numbers
  Vertical 2 numbers

(f) 1,700mm hot strip mill: 1 number

- Size of sheet products: 1.6mm - 10mm in thickness x 80mm - 1,500mm in width x 2,500mm - 6,000mm in length
- Annual production: 792 thousand tonnes of hot-roll sheets and strip in coils
- Pusher type furnace (120t/h): 2 numbers
- Rolling mill
  4-high reversing stand: 1 number
  4-high stand: 6 numbers

(g) Cold rolling mill

- Size of sheet products: 0.3 - 2.5mm in thickness x 60 - 1,500mm in width x 1,000 - 4,000mm in length

i) Shearing and slitting machine: 1 number

- Annual production: 445 thousand tonnes of hot-rolled sheets and strips

ii) 1,700mm universal four high reversing stand: 1 number

- Annual production: 200 thousand tonnes of cold rolled coils

iii) Bell type annealing furnace: 30 numbers

- Annual production: 100 thousand tonnes

iv) 1,700mm single stand temper mill: 1 number

- Annual production: 100 thousand tonnes

v) Continuous hot-dip galvanizing unit: 1 number

- Size of galvanized sheets: 0.5 - 1.5mm in thickness x 700 - 1,500mm in width x 1,000 - 4,000mm in length

- Annual production: 100 thousand tonnes of galvanized sheets

vi) Section forming mill: 1 number

- Products: 80 x 80 - 150 x 150mm angles, 140 x 60 - 250 x 80mm channels, etc.
- Annual production: 120 thousand tonnes of formed sections

(2) Construction and production schedule of Pakistan Steel

(a) Construction schedule and its progress

Since its commencement on December, 1973, about 140,500 man·month of labour have been used in the construction of Pakistan Steel up to January, 1981. The construction work is now in the advanced stage as mentioned below.

As for the essential production units, coke oven & by-product plant, raw material preparation plant, ironmaking plant and auxiliary production units such as repair shop & storage, refractory lining plant, quality control & power control centre, thermal power plant, turbo-blower station, refrigeration plant, etc. have been more than 90% completed. Next to these units, water & sewage piping lines, railways, etc. have been also about 80 to 90% completed. Further, prior to completion of these equipments, the facilities such as iron ore and coal berth, process water, sea water and natural gas pipe lines seem to have been nearly

100% completed. Judging from the progress of the whole construction, it is assumed that coke ovens, sintering plants and ironmaking plant as well as auxiliary facilities necessary for operation of these plants have also been more than 90% completed. Therefore, blowing-in of No. 1 blast furnace and production of pig iron seem to become possible from September, 1981. As for smooth and "on schedule" commencement of operation and startup of these large plants, the period for about one year after commencement of operation is the most important one. During this period, troubles may often give rise to the equipment and infrastructures such as electric power, process water and natural gas pipe lines for supporting the plants from outside. And, in the worst case, such troubles may lead to great delay in the commencement of operation.

Therefore, for successful operation it is essential to prepare the detailed construction schedule including infrastructures, and to ensure more careful daily checking of progress and early discovery and solution of problems. In order to achieve this smoothly, it is important to establish a reasonable communication system for making it possible to make a prompt report and an adequate quick feedback to the report between the worksite and the upper administration department.

As for the billet manufacturing process, about 50 to 60% progress has just been made in the construction of steel-making plant BOF, and continuous bloom casting machine, billet mill and oxygen plant relating to these equipment. Continuous slab casting machine, hot strip mill and cold rolling mill at the last stage of Phase I are now at the initiary stage of construction when they have just been 0 to 25% completed. However, to secure the planned production in 1985, it is also required to bring the construction of continuous slab casting machine and hot strip mill to completion and put them into operation around September, 1983 and bring the construction of cold rolling mill to completion and put it into operation by June, 1984. Judging from the present condition of construction, considerable efforts will be required to keep this schedule.

(b) Procurement of raw materials

The annual requirements of raw materials for full operation of the Steelworks are as follows:

Basic Raw Materials

Items	Quantity (tonnes) per year
Imported:	
1) Iron ore	1,920,000 min. of 64% iron content.
2) Coking coal	1,360,000 min. of 56.2% carbon content (Local Sharigh coal to the extent of 6% will be utilised).

Basic Raw Materials

Items		Quantity (tonnes) per year
Imported:		
3)	Manganese ore	50,000 min. of 30-35% manganese content (5,000 to 6,000 tonnes of manganese ore would be available locally from Lasbella).
4)	Ferro silicon 45%	5,000
5)	Ferro manganese 75%	7,137
6)	Aluminium	575
7)	Zinc	10,000
Local:		
8)	Limestone	430,000
9)	Dolomite	242,000
10)	Fluorite	4,000
11)	Refractory clay	44,000

Contracts have been concluded for procurement of iron ore from Australia, Brazil, Canada, India and Liberia. Contract for supply of manganese ore have been concluded with suppliers from Australia.

Arrangements have been firmed up for the total annual requirements of coal (1.36 million tonnes) from Australia, Canada, USA, and Sharigh indigenous coal from Baluchistan upto 6% of the requirement will be used.

Arrangements for exploration and exploitation of indigenous raw materials viz. limestone and dolomite have been made by Pakistan Steel itself. Limestone quarries with proven reserves of 300 million tonnes are being developed at Makli (Thatta) which is the nearest source of supply of the grade required for the project. On achieving full production, the requirement of limestone will be about 1,500 tonnes per day. The quarries have already attained limestone production of 1,200 tonnes per day to meet construction phase requirement while the work for increasing the production to 2,000 tonnes per day is in progress.

Dolomite quarries at Jhimpir (Distt. Thatta) are also being developed and a reserve of 5.8 million tonnes has been established which would be sufficient to cater to the process requirements of the project for about 20 years. The requirement of dolomite on full operation of the steel mill will be 850 tonnes per day. Work on the preparation of quarry site has been completed and development of quarries is in progress. About 10,000 tonnes of dolomite from the quarry has been extracted by December, 1980.

Arrangements have been finalised with Baluchistan Development Authority for fluorite and with the Punjab Mineral Development Corporation for supply of refractory grade dolomite. For fireclay, an agreement has been signed with a private firm for supply of the material from Musakhel (Distt. Mianwali).

For transporting limestone and dolomite by railway, laying of railway sidings was undertaken by Pakistan Railways - Jungshahi Station to Makli limestone quarries (24km) and Jhimpir Station to dolomite quarry site (3.2km) and fabrication of rolling stock viz. 130 broad guage hopper wagons. The siding between Jhimpir Station to dolomite quarries has been completed by December, 1980 and from Jungshahi Station to Makli limestone quarries is expected to be completed by mid 1981.

Table 2.2.15 and 2.2.16 breakdown of iron ore and coal based on supplier-wise respectively and also table 2.2.17 shows unit consumption of raw material, supplies, consumable and utilities for production of one tonne of steel.

Table 2.2.15 Breakdown of Coal Suppliers

Country of Origin	Name of Brand	Name of Shipper	Rate of Purchase %	Approx. Q'ty Supply, 1000 tonnes
Australia	Coal Cliff	KCC	25	340
Australia	Liddel	CKA	30	408
Canada	Balmer	Kaiser	27	367
U.S.A.	Bradford		12	163
Pakistan	Sharigh	PIDC	6	82

Source: Pakistan Steel

Table 2.2.16 Breakdown of Iron Ore Suppliers

Country of Origin	Name of Brand	Name of Shipper	Rate of Purchase %	Approx. Q'ty Supply, 1000 tonnes
Australia	Mt.Newman Lump	AMAX	20% of Lump	186
Brazil	MBR Lump	CAEMI	40% of Lump	372
India	Bellery Hospet	MMTC	40% cf Lump	372
Brazil	MBF Fine	CAEMI	1/3 of Fine	366
Canada	Mt. Wright Fine	QCM	1/3 of Fine	366
Liberia	LAMCO Fine	MALM Export	1/3 of Fine	366

Source: Pakistan Steel

Table 2.2.17 Unit Consumption of Raw Materials Supplies, Consumables and Utilities for Production of One Tonne of Steel

Description	Unit	Quantity
Coking Coal	tonnes	0.9609
Iron Ore	"	1.7527
Manganese Ore	"	0.0454
Lime Stone	"	0.3909
Dolomite	"	0.2200
Power	kWh	709
Natural Gas	m^3	259
Oxygen	m^3	65
Industrial Water	Gallons	7200
Sea Water	"	70630

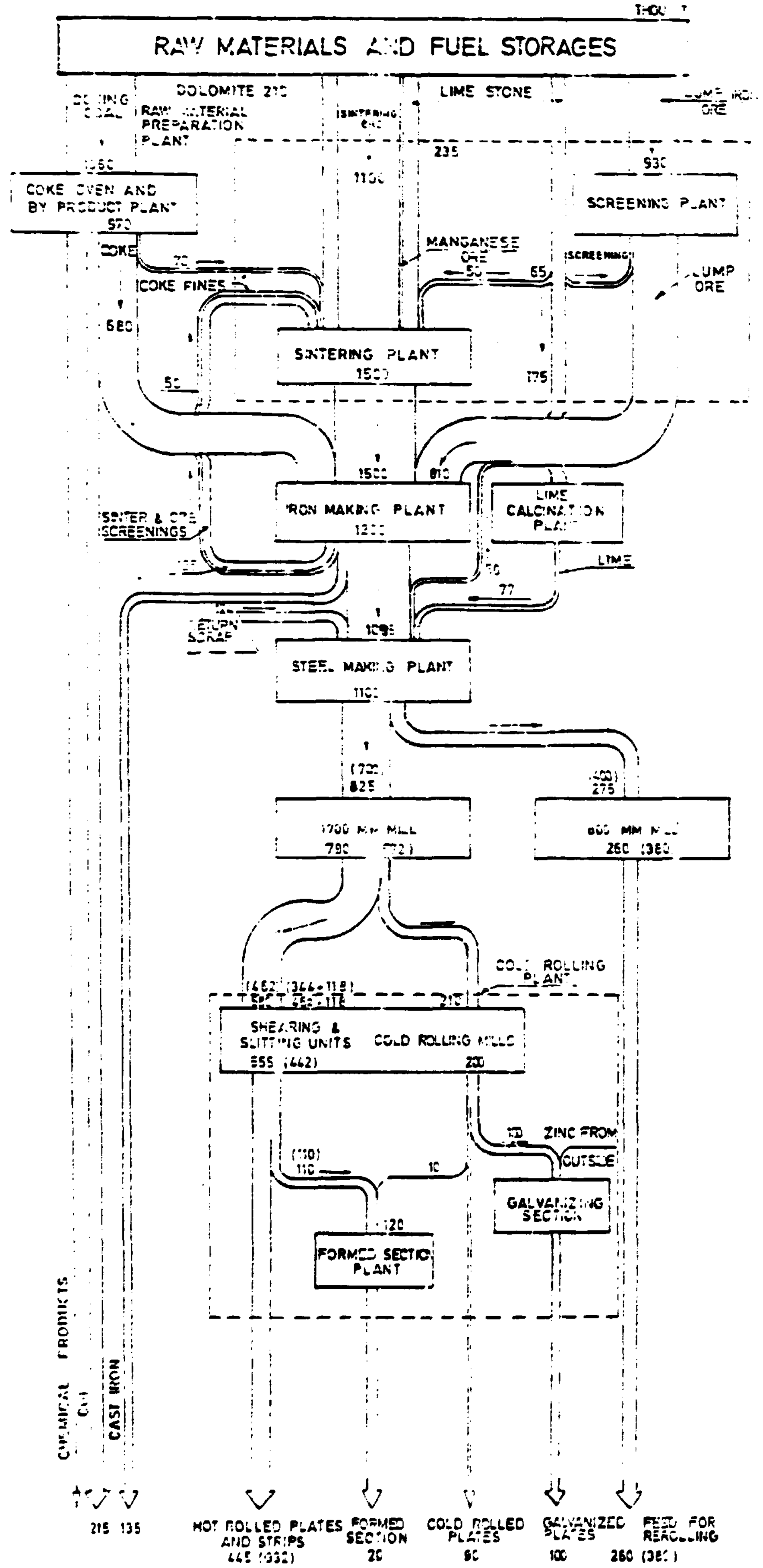
Source: Pakistan Steel

(c) Product mix and production programme of Pakistan Steel

Fig. 2.2.4 shows a basic material flow in Pakistan Steel. Tables 2.2.18, 19, 20, 21 and 22 show the product mix of billets, hot rolled sheets, cold rolled sheets, galvanized sheets and formed sections to be produced in Pakistan Steel, respectively. And, Table 2.2.23 gives the year-wise production programme of Pakistan Steel. As is also clear from these tables and figure, the main products are steel sheets that account for about 75% of total steel products. Next to the steel sheets, semi-finished products, i.e., steel billets are accounting for 25% of total. These billets are to be supplied to small re-rolling mills existing in large numbers in Pakistan. Also the billet size is considered to fall within the range of 50 to 100mm square so that they can be used in the small mills.

In addition, it is planned to sell coke 215 thousand tonnes per year for cupolas of domestic cast iron producers for sugar mills, etc. as well as pig iron 135 thousand tonnes per year for domestic iron & steel foundaries and castings.

FIG. 2.2.4 BASIC MATERIALS FLOWSHEET



Note:-

(1) FIGURE IN PARENTHESIS ( ) ARE CALCULATED ACCORDING TO THE LATEST SOVIET PROPOSAL.

(2) BLOOM CASTING CAPACITY HAS [illegible]CREASED TO [illegible] TONS BUT BILLET CAN ABSORB UPTO [illegible] TONS OF BLOOMS

PAKISTAN STEEL
PLANNING AND EVALUATION [illegible]

Table 2.2.18 Product Mix of Pakistan Steel
- Billets -

	Billet Size mm	Billet Length M	Production
1.	50x50	7 - 8	130,000
2.	60x60	7 - 8	65,000
3.	75x75	7 - 8	40,000
4.	90x90	7 - 8	15,000
5.	100x100	7 - 8	10,000
		Total:	260,000

(* Of various corner radius, size tollerance)

Source: Pakistan Steel

Table 2.2.19 Product Mix of Pakistan Steel
- Hot Polled Sheets -

	Thickness mm	Width mm	Sheet Length M	Production
1.	1.6-2.0	560-760	-	20,000
2.	1.6-2.0	760-960	-	80,000
3.	2.0-3.0	80-200	-	60,000
4.	3.0-3.7	200-400	-	20,000
5.	3.7-4.9	400-520	-	20,000
6.	1.6-2.0	1000-1220	2.5-6.0	5,000
7.	2.0-3.0	1220	-do-	15,000
8.	3.0-4.75	1220	-do-	40,000
9.	4.75-6.0	1220	-do-	45,000
10.	3.0-6.0	1500	-do-	40,000
11.	6-8	1220	-do-	45,000
12.	6-8	1500	-do-	55,000
			Total:	445,000

(** Of various thickness tolerance)

Source: Pakistan Steel

Table 2.2.20 Product Mix of Pakistan Steel
- Cold Rolled Sheets -

	Thickness mm	Width mm	Sheet Length m	Production tonne/year
1.	0.5-1.0	60-160	-	800
2.	1.0-1.5	60-160	-	4,000
3.	1.5-2.0	915	1-4	1,000
4.	2.0-2.5	915	1-4	1,000
5.	0.5-1.0	915	1-4	1,000
6.	1.0-1.5	915	1-4	2,200
7.	0.3-1.0	915	1-4	20,000
8.	1.0-1.5	915	1-4	26,000
9.	0.3-1.0	1220	1-4	3,000
10.	1.0-1.5	1140	1-4	4,000
11.	1.0-1.5	1220	1-4	4,000
12.	1.5-2.0	915	1-4	10,000
13.	2.0-2.5	915	1-4	5,000
14.	1.5-2.5	1220	1-4	4,000
15.	2.0-2.5	1220	1-4	4,000
			Total:	90,000

(Of Various Thickness Tolerance)

Table 2.2.21 Product Mix of Pakistan Steel
- Galvanized Sheets -

Thickness mm	Width mm	Sheet Length M	Thickness Tolerance mm	Production tonne/year
0.5-1.5	700-1500	1-4	± 0.05 ± 0.13	100,000
			Total:	100,000

(Max. Pack Weight 10 Ton)
(Max. Pack Height 530 mm)

Source: Pakistan Steel

Table 2.2.22 Product Mix of Pakistan Steel
- Formed Sections -

	Description of Shapes	Quantity Tonne/Year	Length of Finished Products
1)	Angles 80x80 -- 150 x 150 mm	50,000	Upto 1 m
2)	Channels 140 x 60 -- 250 x 80 mm	35,000	- do -
3)	Various shapes produced from Initial strip 50-600 mm wide	35,000	- do -
	Total:	120,000	

Source: Pakistan Steel

Table 2.2.23 Year-Wise Production Programm of Pakistan Steel

(Tonne/Year)

Description	1980-81	1981-82	1982-83	1983-84	1984-85
Coke	127,000	200,000	130,000	285,000	215,000
Pig Iron	-	310,000	550,000	375,000	135,000
Billets	-	-	200,000	300,000	260,000
Hot Rolled Sheets	-	-	-	222,500	445,000
Cold Rolled Sheets	-	-	-	-	90,000
Galvanized Sheets	-	-	-	-	100,000
Formed Sections	-	-	-	-	120,000

Source: Pakistan Steel

(3) Training

After completion of its construction, Pakistan Steel will need about 15,000 employees in total for operation and must therefore obtain number of skilled & semi-skilled cadres. However, since it is the integrated steelworks built with the essence of modern industrial technology for the first time in Pakistan, it seems generally very difficult to secure the operation personnel in Pakistan. Therefore, the Metallurgical Training Centre of the Immediate College level equipped with 11 workshops, 6 laboratories, 9 study rooms, 11 class rooms, library, auditorium, canteen, etc. is established within the premises of Pakistan Steel. This Training Centre was founded on December, 1975 for the purpose of training and bringing up skilled & semi-skilled cadres for the future of Pakistan Steel. It began actual education and training from June, 1978 and has given education and training to erection artisans and operation artisans amounting to about 2,800 and sent them out up to now. Now, it receives operation artisans and "on the job" trainees amounting to about 1,950 for training.

In this Training Centre, training courses are divided into two-year courses for automation technology, iron & steel making technology, coking technology, etc. and one-year course for rolling technology, etc. Lessons are given in the proportion of lecture to practical exercise at one to one. With the two-shift system (daytime session and night session), a staff of 92 teachers can bring up about 1,500 persons a year.

It is assumed that these trained persons having a certain level of basic knowledge and expert knowlege can play a major role upon future operation of Pakistan Steel. Further, in order to ensure more stable and efficient operation after start-up, it is important to accumulate various experiences in actual operation over long years, in addition to raising the level of basic knowledge and expert knowledge of employees as a whole. Therefore, how to fix persons allotted to their own positions for a long-term is very essential. And it is important to continue to extend the education on the ever-advancing new operation technology and industrial engineering.

(4) Expansion plan

Pakistan Steel possesses a 1.1 million tonne per year capacity of steel plant with built-in potential for expansion to 2 million tonnes per year.

(5) Comparison between equipment and processes of Pakistan Steel and practices in use in the most modern and efficient plants

The equipment and processes of Pakistan Steel will hereinafter be compared with the world's most modern plants in operation. As is known, Pakistan Steel is now under construction under USSR's supervision. The area services by the Contractor were limited and no satisfactory data collection could be made. Comparison of equipment and processes between Pakistan Steel, and a same-scale plant and the latest plant in Japan was made concerning the following points: -

(a) size of ships and freight variances, (b) Pretreatment of raw materials, (c) Iron-making, (d) steel-making and (e) rolling.

(a) Size of ships and freight variances

Port Qasim can receive only 25,000 DWT class ships at maximum due to the depth of its channel. But it is reported that this port was originally designed so as to accomodate ships of up to 70,000 DWT ships. Most of the integrated iron and steel mills in developed countries have been designed so that minimum 100,000 DWT class vessels can be accomodated in order to save freight costs as much as possible. (See Chapter 4.1).

A Japanese shipping consultant was asked to indicate how freight rates would vary for given sizes of ships. These have been tabulated as variances from the June 1981 level of cost Port Kembla in Australia/Port Qasim. Port Kembla is a coal loading port from which Coal Cliff (brand name) ships to Pakistan Steel, and can accommodate ships of up to 80,000 DWT at present. The study made assuming that the sea transportation distance between the two ports is 6,450 nautical miles, that the loading/unloading conditions are 10,000 tonnes per day at each port that bunker oil prices are $200/LT (fuel) and $350/LT (diesel) and that a ship operates between the two ports in shuttle service. Table 2.2.24 shows the freight variances.

Table 2.2.24 An Example of Freight Variances (Port Kembla/Port Qasim)

(Unit: US$)

Size of vessel, DWT	Freight variances: Market	Freight variances: New ship base
25,000	0	+1.7
35,000	-2.8	-1.1
55,000	-8.3	-4.8
70,000	-9.5	-5.9

The above table shows that, if 70,000 DWT ships are available to Port Qasim, the freight rates would become cheaper by US$6 - 9.5/ton.

Almost the same seems also true of other ports than Port Kembla.

If it is assumed that the freight rates are reduced by US $6.00/ton, the savings from the total freight for 3.3 million tons/year of iron ore and coal are,

$$6 \times 3.30 = 19.8 \doteqdot \text{US\$ } 20 \text{ million}$$

Port Qasim is disadvantageous in that it has a long channel with the total length of about 45 km. Dredging cost for this channel is unknown, it is, therefore, recommended that they will entrust a competent consultant with calculating the dredging cost and maintenance cost for the channel, and clarifying the relationship between the decrease in freight costs and the dredging costs.

(b) Pretreatment facilities of raw materials

(i) Sintering machine

Table 2.2.25 shows the comparison between Pakistan Steel No. 1 sintering machine and the same-scale and the newest sintering machines in Japan. As can be seen from Table 2.2.22, there is no large difference in parameters between Pakistan Steel No. 1 sintering machine and the same-scale Japanese machines. These small-scale sintering machines were designed during 1950's. An example of large-sized sintering machines constructed during 1970's shown in the rightest column of the table is superior to all the others in every parameter. The operation targets of Pakistan Steel are considered proper since the material conditions are the same as those in Japan.

The recent large-sized sintering machines are characterized by the provision of large-sized blowers and coolers.

Table 2.2.25 Comparison of Sintering Machines

		Pakistan Steel No. 1 Sinter P.	A	B	C
(1)	Effective grate area (m2)	75	82.5	66	500
(2)	Nominal capacity (t/d)		4,990	2,000	16,000
(3)	Daily output (t/d)	2,055	5,688	2,062	19,000
(4)	Pallet speed (m/min)	1.5	1.9	1.3	1.66
(5)	Bed depth (mm)		400	425	534
(6)	Production rate (t/h.m2)	1.3	1.55	1.31	1.64
(7)	Actual operation hours (h/d.unit)	21^h	22^h43^{min}	23^h55^{min}	22^h5^{min}
(8)	Yield (%)*	90.4	89.8	89.1	93.7
(9)	Yield of products (%)**	62	64.7	77.6	72.3
(10)	Coke breeze (kg/t.sinter)	46.7	47.9	46.9	44.1
(11)	Basicity (CaO/SiO2)	1.83	1.65	1.69	1.59
(12)	Blower suction pressure (mm Aq)		-1,600	-1,200	-2,000
	Blower capacity (m3/min)		8,000	5,000	25,000 x 2
(13)	Cooler capacity (t/h)		200	70	1,670

$$* \text{ Yield} = \frac{\Sigma \text{output}}{\Sigma \text{total of new material}} \times 100$$

(New material does not include coke breeze and returns)

$$** \text{ Yield of Products} = \frac{\Sigma \text{ output}}{\Sigma(\text{new material + returns})} \times 100$$

(ii) Coke oven

Concerning the coke oven of Pakistan Steel, the quantity of the required coal, the putput of coke and other distillates were evaluated based on the available data.

a) Output

The required quantity of coal (Q) is usually calculated by the following formula:

$$Q = \begin{pmatrix}\text{Number}\\ \text{of}\\ \text{ovens}\end{pmatrix} \times \begin{pmatrix}\text{Effective volume}\\ \text{of}\\ \text{each oven}\end{pmatrix} \times \begin{pmatrix}\text{Bulk density}\\ \text{of}\\ \text{charged coal}\end{pmatrix} \times \left(\frac{24}{\text{Cycle time of oven}}\right)$$

$$= 98 \times 30.3 \times 0.74 \times \frac{24}{15.3} = 3{,}447 \fallingdotseq 3{,}250 \text{ tonnes·coal/day}$$

(dry base).

Therefore the annual quantity of coal is,

$3{,}450 \text{ t} \times 365 = 1.26$ million tonnes/year (dry base).

According to the material flow of Pakistan Steel (Fig. 2.2.4), the required quantity of coal is 1.36 million tonnes per year, which differs by 100,000 tonnes from the above calculation result. The value 1.36 million tonnes seems to be on wet base.. If moisture is assumed to be 9% in average,

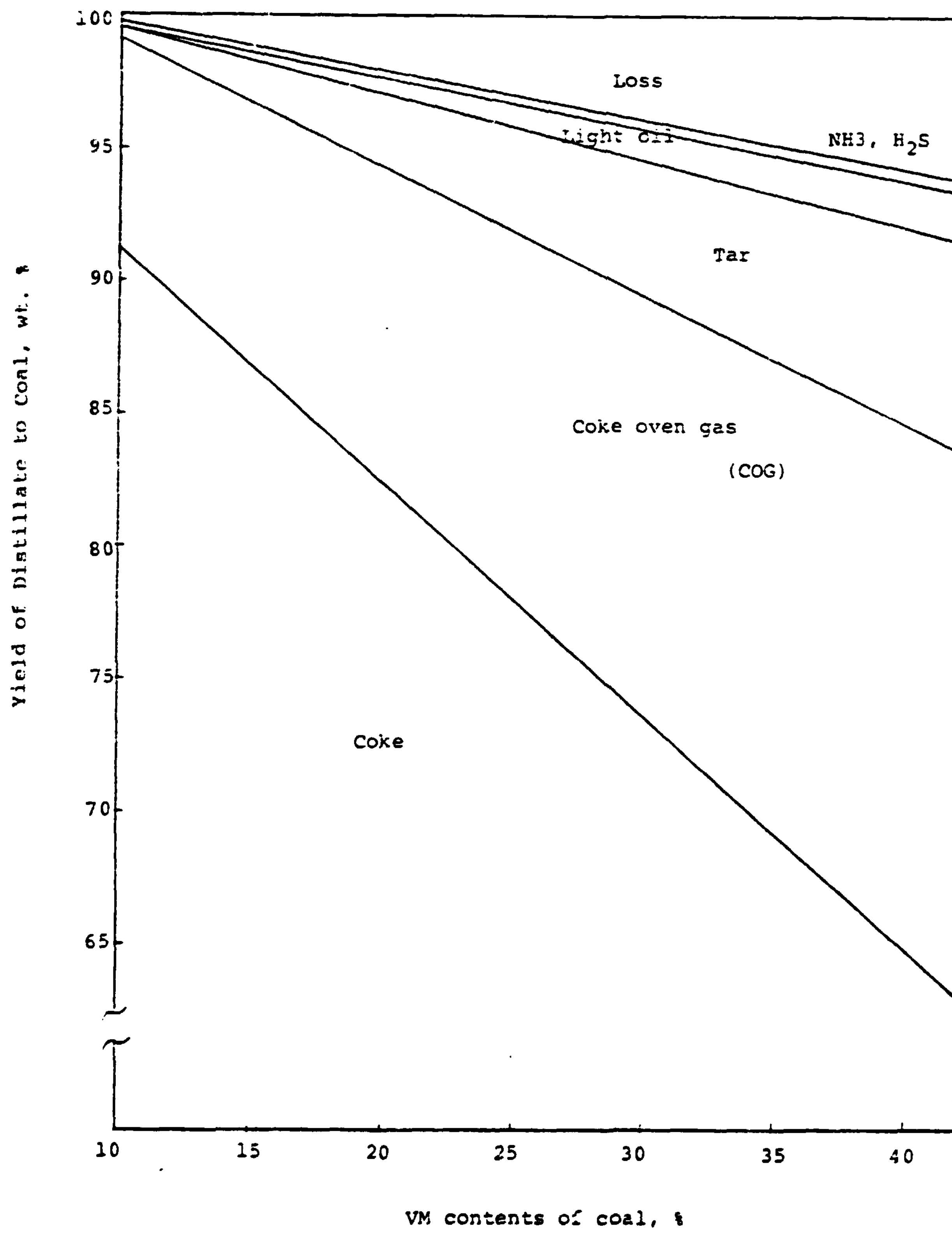
1.36 million tonnes $\times$ 0.91 $\fallingdotseq$ 1.24 million tonnes/year.

This value almost agrees with the calculated value. Concerning the yield of distillates, the relationship between the coal used and volatile matters (VM) has been established by experience (see Fig. 2.2.5). The average VM value of the coal brands used by Pakistan Steel was estimated (VM ≑ 27.5%) and the coke yield was estimated from Fig. 2.2.5 . Then the estimated yield was compared with the yield planned by Pakistan Steel. Table 2.2.26 shows the results.

Table 2.2.26 Yield of Products in Coke Oven

	Yield %	
Item	Planned	Estimated
Coke*	78.2	75.8
Coke oven gas	14.3	14.7
Coal tar	3.7	4.6
Ammonium sulphate	0.8	1.1
Oil	0.5	1.0

*Yield of coke = (Production of coke) ÷ (Charged coal, dry base)



Source: Kobe Steel

Fig. 2.2.5 Variance of Yield of Distillate VM Contents of Coal

The planned yield of coke appears to be rather too high. This is due to the length of the oven cycle time included in the above expression to obtain the required quantity of coal. This will be described in detail at subsequent b).

b) Operation

The coke oven has a shorter cycle time as compared with the same-scale coke ovens in Japan, or the average value.

The cycle time of coke oven in Japan is generally longer, because the operation in Japan usually takes about 2.5 hours of the so-called soaking time, in addition to the coking time. It is considered coke of better quality can be produced if coke is pushed out of the oven some time after extinguishing the oven fire, i.e., the coke more suitable for operation of the blast furnace can be obtained by increasing the cycle time, which will in turn increase the iron and steel production in the sum total

In Europe, however, coke are mostly produced by companies totally independent of the iron works. Coke is usually pushed out of the oven right after coking is completed (See Table 2.2.27).

It is unknown to us which method is adopted in Pakistan Steel, as there are available few data.

Table 2.2.27 Comparison of Cycle Time of Coke Oven

Item	Pakistan Steel	A*	B**
Coking time	15h 18 min	15h 24min	18h 06min
Soaking time		2h 22min	2h 40min
Cycle time of Coke oven	15h 18min	17h 45min	20h 46min

*A: Value of Japanese coke ovens as of August, 1980 equal in scale to the Pakistan Steel's coke oven.

**B: Average in Japan as of August, 1980

c) Coke for manufacturing iron and coke for iron foundry.

Pakistan Steel is planning to sell yearly 215,000 tonnes of coke to iron foundry and sugar mills, besides the coke consumed by itself. Usual distilling temperature and time are different between the two. It seems that Pakistan Steel has adopted such a production lay-out as the two kinds of coke are produced in different lots by separating the gas system in one battery. In this case, more careful production control will be necessary.

Further such as phosphorus (P) must carefully be controlled in the production of coke when they are used for manufacturing foundry iron in a blast furnace.

(c) Iron making facilities and their operation

Table 2.2.28 compares the design and operation criteria of Pakistan Steel No. 1 blast furnace with the actual operation data of a same-scale blast furnace and a latest large-sized blast furnace in Japan. As a result, these design and operation criteria can be said to be fairly reasonable for the first blast furnace operation criteria in Pakistan.

The designed criteria of pig iron rate* is 1.7, while in Japan the target of pig iron rate is set at 2 and every effort is being made to raise this rate and reduce the fuel rate under the present situation where energy costs are soaring.

The fuel rate is rather high probably because the rate of agglomerates is high in blast furnace burden. It can generally be said based on experience that when the rate of agglomerates increase by 1%, the fuel rate decreases by about 0.9 kg/t · pig.

Pakistan Steel has also the plan of manufacturing foundry pig. It seems that they will have to use one of the 2 blast furnaces for exclusively producing pig iron for steel making, and the other for manufacturing pig iron both for steel making and for

---

* Pig iron rate: $\frac{\text{Pig iron production (t/d)}}{\text{Effective volume (m}^3\text{) of blast furnace}}$

Table 2.2.28 Comparison of Blast Furnaces

	Name of Blast Furnace	Pakistan Steel No.1 BF	Japan (A)	Japan (B)	Japan (C)	Japan (D)
	Effective Volume, m^3	1.033	904	1,254	1,150	5,050
	Hearth Diameter, m	7.2	7.2	8.0	8.0	15.0
	Nominal Capacity, t/d		1,772	2,366	1,150	10,050
	Actual Production, t/d	(1,750)	1,965	2,500	1,665	10,610
	Pig Iron Rate *	1.7	2.1	2.0	1.4	2.1
	Furnace Top Pressure, g/cm^2	(1,000)	51	1,025	1,025	2,410
Hot Blast	Pressure, g/cm^2		1,100	2,010	1,800	4,330
Hot Blast	Temperature, °C	(1,200)	1,060	1,160	1,175	1,290
Hot Blast	Oxygenation, %	-	0.9	-	-	0.5
Fuel Rate	Coke Rate, kg/t·pig	(520)	495	470	433	411
Fuel Rate	Tar Rate, kg/t·pig	-	-	5	62	28
Fuel Rate	Oil Rate, kg/t·pig	-	-	-	-	5
	Ratio of Ore to Agglomeretes	35: Ore 65: Sinter	14: Ore 67: Sinter 19: Pellets	4: Ore 87: Sinter 9: Pellets	21: Ore 79: Sinter	19: Ore 71: Sinter 10: Pellets
	Remarks	( ): planned figures Oxygenation will be applied in the future.	Operation data from daily average in Aug. 80	Operation data from daily average in Aug. 80	Operation data from daily average in Aug. 80 This BF only produces pig for foundry	Operation data from daily average in Aug. 80

$$* \text{ Pig Iron Rate: } \frac{\text{Production of Pig Iron, t/d}}{\text{Effective Volume of Blast Furnace, m3}}$$

foundry use. In this case, the operation efficiency of the blast furnace will unavoidably lower on the whole. Careful quality control including the selection of raw materials as well as shceduled blast furnace operation should be required.

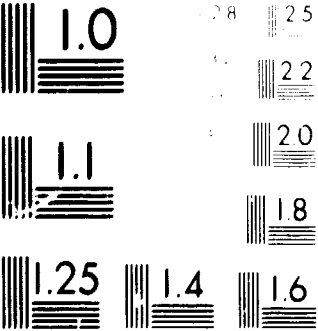
Generally speaking, they will reach the designed values about 3 years after the start of operation. From the 5th year on, they should make efforts to reduce the unit rates such as pig iron rate, fuel rate, etc.

Further, it is said that two thirds of the manufacturing cost of hot metal is formed of the raw material cost. It is, therefore, necessary to supply high quality raw materials at a stable price over a long term. However, Pakistan Steel is handicapped in the freight rates of raw material transportation as Port Qasim is small in size as mentioned previously. This is a large demerit of Pakistan Steel.

(d) Steelmaking

(i) BOF

Table 2.2.29 compares the design and operation criteria of Pakistan Steel's BOF with the actual operation values of a same-scale BOF and the latest large-scale BOF in Japan. Judging from


1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

each furnace volume (109 m^3) and oxygen blowing capacity (600 Nm^3/min), the facilities are considered to be proper. Among their facilities design and operation criteria, the 50% operation rate of the furnace seems impossible considering the number of scheduled blast stop days of BF and periodical repair days of the whole shop. By the way, in a Japanese shop where a 1/2 furnace system (one furnace operating and the other in preparation) is adopted, the average value is said to be about 43-44%. For achieving the above proposed production, therefore, the enforcement of overcharge and simultaneous operation of the 2 furnaces must be considered. Fiarly high values seem to have been planned for the unit consumption of auxiliary raw materials and of oxygen. As a result of calculation assuming that the operation techniques have been established and become stable, about 20% calcined lime, about 50% fluorite and about 10% oxygen will be able to be reduced from the planned values.

Table 2.2.29 Comparison of BOF

Name of BOF			Pakistan Steel	
Number of furnace and operation method			1/2 ***	
Furnace inner volume after brick lining (m^3)			109	
Furnace capacity	Nominal (t/heat)		117.5 130 (Max)	
	Actual (t/heat)		Unknown	
Steel making time	Oxygen blowing time (min/heat)	$\frac{\Sigma \text{ Oxygen blowing time}}{\Sigma \text{ heats}}$	24	
	Steel making time (min/heat)	$\frac{\Sigma \text{ (Oxygen blowing time, other time)}}{\Sigma \text{ Heats}}$	55	
Operation ratio of furnace		$\frac{\Sigma \text{ Steel making hour}}{\Sigma \text{ Calender hour}}$	50	
Number of heats per day	Average (heats/day)		26	
	Maximum (heats/day)		32	
Annual production quantity (t/year)		Cast products quantity	1,100,000	2,
Carbon steel ratio of cast products (%)			100	
Blending ratio of materials	Hot metal (%)	$\frac{\Sigma \text{ Hot metal wt.}}{\Sigma \text{ Charged material wt.}}$	90	
	Total pig iron (%)	$\frac{\Sigma \text{ (Hot metal wt. + pig iron wt.}}{\Sigma \text{ Charged material wt.}}$	90	
Continuous casting ratio (%)		$\frac{\Sigma \text{ Continuous cast products wt.}}{\Sigma \text{ Cast products wt.}}$	100	
Refractory life of furnace	Average (heats)		Unknown	1
	Maximum (heats)		Unknown	2
Yeild	Molten steel (%)	$\frac{\Sigma \text{ Molten steel wt.}}{\Sigma \text{ Charged materials wt.}}$	93	
	Cast steel (%)	$\frac{\Sigma \text{ Cast products wt.}}{\Sigma \text{ Charged materials wt.}}$	90	
Unit consumption of cast products	Iron ore (%)		45	
	Scale (kg/t)		-	
	Calcined lime (kg/t)		70	
	Fluorite (kg/t)		3.6	
	Oxygen (Nm^3/t)		58	
	Refractory* (kg/t)		Unknown	
	Electric power (kWh/t)		** 68	
Type of exhausted gas collector			Half boiler	

SECTION 1

Table 2.2.29 Comparison of BOF

	Pakistan Steel	Japan A	Japan B	Japan C	Japan D	Remarks
	1/2 ***	2/3	2/3 ∿ 3/3	2/3	1/2	***1/2 means one furnace in operation while the other in repair.
	109	87	118	210	221	
	117.5 130(Max)	110	160	200	250	
	Unknown	119	153	234	239	
...en blowing time / ...eats	24	19	27	17	16	
...en blowing time, other time) / ... Heats	55	33	51	34	31	
...l making hour / ...nder hour	50	48.1	49.7	46.2	30.2	
	26	65	42	60	28	
	32	85	53	76	38	
... products quantity	1,100,000	2,750,000	2,340,000	5,070,000	2,430,000	
	100	100	81	100	100	
...t metal wt. / ...arged material wt.	90	86	86	87	85	
...ot metal wt. + pig iron wt. / ...arged material wt.	90	88	85	94	87	
...ntinuous cast products wt. / ...st products wt.	100	63	89	31	99	
	Unknown	1,680	1,000	1,000	1,870	
	Unknown	2,011	1,271	1,140	2,001	
...lten steel wt. / ...rced materials wt.	93	95.0	96.0	95.0	94.5	
...st products wt. / ...rced materials wt.	90	93.5	90.5	92.5	92.5	
	45	31	0	18	14	
	-	3	27	17	16	
	70	38	47	52	52	
	3.6	1.1	1.1	1.5	1.1	
	58	47	55	49	48	
	Unknown	1.6	2.7	2.1	1.6	* including repairing materials
	** 68	36	32	22	32	**including electric power for CC shop
	Half boiler	-	OG	OG	OG	

SECTION 2

(ii) Continuous casting machine

Table 2.2.30 compares the design and operation criteria of Pakistan Steel's bloom continuous casting machine (BCCM) with the actual operation data of a same-scale BCCM and a large-scale BCCM in Japan. Table 2.2.28 compares the design and operation criteria of Pakistan Steel's slab continuous casting machine (SCCM) with the actual operation values of a same-scale SCCM and the newest large-scale SCCM in Japan.

According to Table 2.2.27, the casting yield is a rather high 97% considering that this is the first BCCM to be operated, but there is no problem in particular about the production capacity of the facilities.

As for SCCM of Pakistan Steel, judging from Table 2.2.31, there seems no particular problem about the production capacity of the facilities. However, among the steel grades to be cast, rimmed steel is also planned to be cast by CC, not by the ingot making method. This Pakistan Steel's plan of casting rimmed steel by CC seems to be impossible since no complete casting technique for rimmed steel has been established yet even in Japan. By the way, the pseudo-rimmed steel commercially cast by CC without vacuum degassing and electromagnetic stirring in Japan contains about 0.05% (C), 0.03% (Si), 0.01% (Al) and free oxygen 50 ppm. At best Japanese manufacturers have only succeeded in casting a higher grade pseudo-rimmed steel with about 0.04% (C), 0.01% (Si) and 0.006% (Al) using vacuum degassing, electromagnetic stirring and advanced CC operation techniques. Therefore, it is considered necessary for Pakistan Steel to re-check the steel grades of rimmed steel to be manufactured.

Table 2.2.30 Comparison of Bloom Continuous

Name of bloom continuous casting machine		Calculation formula	Pakistan Steel	A
Type of Machine			Curved mould bending type x 1	Curved mould bending type x 2
Capacity of ladle and tundish	Ladle (t)		130/140	45
	Tundish (t)		22	4
Charging method of dummybar			Top side	Bottom side
Cutting method of strand			Gas	Gas
Datum radias of curvature (mm)			12	9.4
Number of strand			4 str.	2 str.
Size of bloom	Max. dimension (mm)		Unknown	Unknown
	Nominal dimension (mm)		260 sq.	240 sq.
	Min. dimension (mm)		Unknown	Unknown
	Max. length (mm)		6,000	2,000
Casting speed and casting time	Casting speed (m/min)		Max. 2.0 Normal 1.1~1.2	Max. - Normal 1.4
	Casting time (min/heat)	$\frac{\Sigma \text{ cc time}}{\Sigma \text{ cc heats}}$	55	30
Anual production quantity (t/year)			Max. 400,000	432,000
Carbon steel ratio of cast products (%)			100	100
Average number of series casting heats (heats)			Unknown	12
Successful cast heats rate		$\frac{\Sigma \text{ successful cc heats}}{\Sigma \text{ cc heats}}$	Unknown	99.5
Yield and unit comsumption of cast product	Casting yield (%)	$\frac{\Sigma \text{ cc products}}{\Sigma \text{ Molten steel}}$	97	97
	Fuel (oil, gas, etc) (10^3 Kcal/t)		Unknown	43
	Electric power (kWh/t)		*	10
	Water (m^3/t)		Unknown	2
	Refractory of tundish (kg/t)		Unknown	3.8
Treatment rate of vacuum degassing and ladle refining		$\frac{\Sigma \text{ treated quantity}}{\Sigma \text{ cc products}}$	Unknown	0

SECTION 1

2.2.30 Comparison of Bloom Continuous Casting Machines

:n formula	Pakistan Steel	Japan A	Japan B	Japan C	Remarks
	Curved mould bending type x 1	Curved mould bending type x 2	Curved mould bending type x 1	Curved mould bending type x 1	
	130/140	45	200	120	
	22	4	10.5 x 2	10	
	Top side	Bottom side	Bottom side	Bottom side	
	Gas	Gas	Gas	Gas	
	12	9.4	12.5	11.9	
	4 str.	2 str.	8 str.	4 str.	
	Unknown	Unknown	250 x 250	Unknown	
	260 sq.	240 sq.	200 x 300	220 x 250	
:	Unknown	Unknown	200 x 220	150 x 180	
	6,000	2,000	10,500	6,700	
	Max. 2.0 Normal 1.1∿1.2	Max. - Normal 1.4	Max. 2.0 Normal 0.8∿1.8	Max. 4.0 Normal unknown	
:e ats	55	30	57	71	
	Max. 400,000	432,000	480,000	600,000	
	100	100	85	100	
	Unknown	12	3	5	
cc heats nts	Unknown	99.5	100	99.5	
oducts n steel	97	97	98	95.3	
	Unknown	43	18	18	
	*	10	14	26	* electric power of Pakistan
	Unknown	2	18	3	Steel for CC shop is included
	Unknown	3.8	2.8	3.7	in BOF/LQ convert
quantity, ucts	Unknown	0	32	33	

Table 2.2.31 Comparison of Slab Continuous Casting Ma

Name of slab continuous casting machine			Pakistan Steel	A
Type of machine			Curved mould bending type x 2	Curved mould bending type x 1
Capacity of ladle and tundish	Ladle (t)		130/140	245
	Tundish (t)		Unknown	18
Charging method of dummybar			Unknown	Top side
Cutting method of strand			Unknown	Gas
Datum radias of curvature (mm)			12	10
Number of strand			2	2
Size of slab	Max. dimension (mm)		Unknown	300 (t) 2,100 (W)
	Normal dimension (mm)		150-200 (t) 700-1,550 (W)	210-250 (t) 950-1,900 (W)
	Min. dimension (mm)		Unknown	200 (t) 950 (W)
	Max. length (mm)		6,000	12,000
Casting speed and casting time	Casting speed (m/min)		0.82-2.4	Max 2.5 0.7-1.4**
	Casting time (min/heat)	$\frac{\Sigma \text{ cc time}}{\Sigma \text{ cc heats}}$	Unknown	51
Annual production quantity of cast products (t/year)			(Max) 825,000	1,800,000
Carbon steel ratio of cast products (%)			100	97
Average number of series casting heats (heats)			Unknown	17
Successful cast heats rate		$\frac{\Sigma \text{ successful cc heats}}{\Sigma \text{ cc heats}}$	Unknown	99.8
Yield and unit consumption of cast product	Casting yield (%)	$\frac{\text{cc products}}{\text{Molten steel}}$	97	96.3
	Fuel (oil, gas, etc) (10^3 Kcal/t)		Unknown	17
	Electric Power (kWh/t)		*	4
	Water (m^3/t)		Unknown	0.2
	Refractory of tundish (kg/t)		Unknown	0.9
Treatment rate of vacuum degassing and ladle refining		$\frac{\text{treated quantity}}{\text{cc products}}$	0	87

SECTION 1

Comparison of Slab Continuous Casting Machines

	Pakistan Steel	Japan			Remarks
		A	B	C	
	Curved mould bending type x 2	Curved mould bending type x 1	Curved mould bending type x 1	Curved mould bending type x 1	
	130/140	245	275	280	
	Unknown	18	30	35	
	Unknown	Top side	Bottom side	Top side	
	Unknown	Gas	Gas	Gas	
	12	10	10.5	11.3	
	2	2	2	2	
	Unknown	300 (t) 2,100 (W)	305 (t) 1,550 (W)	204 (t) 1,850 (W)	
	150-200 (t) 700-1,550 (W)	210-250 (t) 950-1,900 (W)	190-260 (t) 850-1,900 (W)	204 (t) 900-1,850 (W)	
	Unknown	200 (t) 950 (W)	190 (t) 850 (W)	204 (t) 900 (W)	
	6,000	12,000	12,200	9,300	
	0.82-2.4	Max 2.5 0.7-1.4**	Max 2.0	Max 2.2 1.6**	**show the casting in practical operation
time / heats	Unknown	51	59	72	
	(Max) 825,000	1,800,000	2,200,000	1,050,000	
	100	97	100	100	
	Unknown	17	20	3	
ul cc heats / heats	Unknown	99.8	99.7	99.7	
oducts / steel	97	96.3	99.2	96.3	
	Unknown	17	10	14	
	*	4	16	9	* Electric power of Pakistan Steel for CC shop is included in BOF
	Unknown	0.2	22	22	
	Unknown	0.9	1.9	2.6	
quantity / roducts	0	87	35	0	

(e) Rolling

(i) Billet mill

Table 2.2.32 compares the billet mill of Pakistan Steel with a same-scale billet mill in Japan. Although it cannot be told anything definite due to the many unknown factors as already mentioned, the 2 Hi reversing mill and 2 Hi continuous mill are estimated to be as proper as the facilities in Japan and are up to date standard as far as this table is concerned. The twist free rolling in the 2 Hi continuous mill where vertical stands have been adopted is good idea from the viewpoint of the easiness in rolling operation. The nominal capacity of the Pakistan Steel's billet mill is 400,000 tonnes/year, which means average 60 tonnes/hour output in terms of 6800 operation hours/year. The hourly output may actually vary much with product size, but this figure of 60 tonnes/hour will be able to be achieved by these facilities. In the aspect of unit consumption, the high fuel consumption of 600,000 Kcal/product·tonne seems to have been resulted from considering heating of cold bloom, not hot bloom, and their unskilled furnace operation techniques.

Table 2.2.32 Comparison of Billet Mills

Name of Mill	Pakistan Steel 800mm Billet Mill	A	J a
Reheating Furnace	Pusher type 100 t/h x 1	Soaking pit furnace	
2-Hi Revering Mill:			
Roll dia. x Barrel length	800mmø x 1,800mm long	950mmø x 2,200mm long	
Main motor capacity	4,300 kW	3,500 kW	
Rolling speed	max. 5m/sec.	max. 5m/sec.	
2-Hi Continuous Mill:			
Number and type of stands	2-Hi horizontal type x 2 2-Hi vertical type x 2	3-Hi horizontal type x 3	
Roll dia. x Barrel length	630mmø x 1,000mm long	780mmø x 2,200mm long	
Main motor capacity	Reversing: 3,300 kW Finishing: 2,000 kW	AC 3,000 kW	
Rolling speed	max. 3m/sec.	1.8m/sec.	
Initial material size	Continuous cast bloom: 260mm sq. x 1.5∿6.0m long	Ingot: 543mm/410mm x 1.6m long	
Billet size	50mm sq, 60mm sq, 75mm sq 90mm sq, 100mm sq	97∿150mm sq.	
Production			
Practical production amount	260,000 tonnes/year	776,000 tonnes/year	
Practical operation hour	6,800 hour/year	7,000 hours/year	
Hourly output	25∿120 tonnes/hour	111 tonnes/hour	
Unit consumption			
Fuel consumption	600,000 kcal/product tonne	385,000 kcal/product tonne	
Electric power consumption	42 kwH/product tonne	29 KwH/product tonne	

SECTION 1

Table 2.2.32 Comparison of Billet Mills

n Steel llet Mill	Japan A	 B
100 t/h x 1	Soaking pit furnace	Walking beam type 100 t/h x 1
00mm long	950mmø x 2,200mm long	950mmø x 2,050mm long
	3,500 kW	4,000 kW
.	max. 5m/sec.	max. 6m/sec.
tal type x 2 l type x 2	3-Hi horizontal type x 3	2-Hi horizontal type x 1 2-Hi vertical type x 1
00mm long	780mmø x 2,200mm long	700mmø x 1,200mm long
3,300 kW 2,000 kW	AC 3,000 kW	1,000 kW x 2
	1.8m/sec.	1.4m/sec.
cast bloom:	Ingot:	Continuous cast bloom:
1.5∿6.0m long	543mm/410mm x 1.6m long	350mm x 280mm x 4.9∿5.4m long
m sq, 75mm sq mm sq	97∿150mm sq.	115mm sq.
es/year	776,000 tonnes/year	624,000 tonnes/year
/year	7,000 hours/year	4,400 hours/year
es/hour	111 tonnes/hour	142 tonnes/hour
/product tonne	385,000 kcal/product tonne	165,000 kcal/product tonne
ct tonne	29 KwH/product tonne	29 KwH/product tonne

(ii) Hot strip mill

Table 2.2.33 compares the Pakistan Steel's 1700 mm hot strip mill with a same-scale mill and a newest hot strip mill in Japan. As far as this table is concerned, the Pakistan Steel's hot strip mill is comparable to the same-scale Japanese hot strip mill in the capacity of main motor and the maximum finish speed. But its maximum product thickness of 10 mm is rather thin compared with the recent strip trend toward very thick products. This hot strip mill is said to have the nominal annual production capacity of 2 million tonnes, which means that a production efficiency as high as the Japanese level of 360 tonnes/hour output in yearly 5500 operation hours is required to achieve this capacity target.

The yearly production of 792,000 tonnes and the hourly output of 220 tonnes are proper as the design criteria of this first hot strip mill to be operated in Pakistan.

But the design criteria of yearly electric consumption of 5.5 million Kcal or 69 kWh/product tonne will be very difficult to be achieved in a few years after the commissioning. By the way, the lowest unit consumption of hot strip mills in Japan is currently 70 kWh/product·tonne.

Table 2.2.33 Comparison of Hot Strip Mills

Name of Mill	Pakistan Steel 1,700mm Hot Strip Mill	A
Reheating furnace	Pusher type: 120 t/h x 2	Pusher type 195 t/h x 2 200 t/h x 2
Number and type of stands		
Roughing stands	1-4 Hi Reversing type	1-2 Hi type 1-4 Hi Reversing type
Finishing stands	6-4 Hi type	6-4 Hi type
Work roll dia/Back-up roll dia x Barrel length	750mm/1,500mmx1,700mm^l	R 2-Hi 1,159mmøx2,032mm^l R 4-Hi 915mmø/1,382mmø x 2,032mm^l R 4-Hi 713mmø/1,382mmø x 2,032mm^l
Main motor capacity		
Roughing stand	4,500 kW	R 2-Hi: 4,000 kW R 4-Hi: 8,000 kW
Finishing stand	F1, F2: 4,500 kW F3, F4: 6,300 kW/5,200 kW F5, F6: 6,300 kW/5,500 kW F total 27,800 kW	F1-F3 : 4,500 kW x 3 F4 : 4,500 kW F5, F6: 4,500 kW x 2 F total 27,000 kW
Rolling speed		
Reversing roughing stand	120 - 300 m/min.	max. 290 m/min.
Final finishing stand	max. 780 m/min.	max. 720 m/min.
Slab size		
Thickness x width x length	150-200mm^{t}x700-1,550mm^{w}x 3∿6 m^l	260mm^{t}x1,890mm^w x8.1m^l
Products size		
Thickness x width	1.6-10mm^{t}x80-1,500mm^w	1.2-19mm^{t}x650-1,880mm^w
Coil weight	14.5 tonnes/coil	16.5 tonnes/coil
Production		
Practial production amount	792,000 tonnes/year	2,840,000 tonnes/year
Practial operation hour	5,500 hours/year	7,100 hours/year
Hourly output	220 tonnes/hour	400 tonnes/hour
Unit consumption		
Fuel consumption	740,000 kcal/product tonne	279,000 kcal/product tonne
Electric power consumption	69 kWh/product tonne	84 kWh/product tonne

SECTION 1

...arison of Hot Strip Mills

Japan		
A	B	C
...sher type 195 t/h x 2 200 t/h x 2	Pusher type 120 t/h x 4	Walking beam type 350 t/h x 3
-2 Hi type -4 Hi Reversing type -4 Hi type	1-2 Hi type 1-4 Hi Reversing type 6-4 Hi type	1-2 Hi type 3-4 Hi type 7-4 Hi type
2-Hi 1,159mmøx2,032 ml 4-Hi 915mmø/1,382mmø x 2,032mml 4-Hi 713mmø/1,382mmø x 2,032mml	R 2-Hi 927mmøx2,032mml R 4-Hi 927mmø/1,321mmø x 2,032mml F 4-Hi 722mmø/1,359mmø x 2,057mml	R 2-Hi 1,270mmøx2,250mml R 4-Hi 1,170mmø/1,630mmø x 2,250mml F1-F3 4-Hi 825mmø/1,630mmøx 2,250mml F4-F7 4-Hi 785mmø/1,630mmøx 2,250mml
2-Hi: 4,000 kW 4-Hi: 8,000 kW 1-F3 : 4,500 kW x 3 4 : 4,500 kW 5, F6: 4,500 kW x 2 F total 27,000 kW	R 2-Hi: 1,500 kW R 4-Hi: 7,500 kW F1-F3 : 5,750 kW x 3 F4, F5: 5,000 kW x 2 F6 : 3,300 kW F total 30,550 kW	R1 2-Hi : 4,500 kW R2 4-Hi : 10,000 kW R3 4-Hi : 10,500 kW R4 4-Hi : 12,000 kW F1-F5 4-Hi : 12,000 kW x 5 F6, 4-Hi : 9,000 kW F7 4-Hi : 6,750 kW F total 75,750 kW
ax. 290 m/min. ax. 720 m/min.	max. 290 m/min. max. 780 m/min.	- max. 1,627 m/min.
60mm^{t}x1,890mm^W x8.1m^l	160mm^{t}x1,880mm^{W}x7m^l	300mm^{t}x2,200mm^{W}x13.27m^l
.2-19mm^{t}x650-1,880mm^W 6.5 tonnes/coil	1.2-16mm^{t}x750-1,850mm^W 16.5 tonnes/coil	1.2-19mm^{t}x600-2,140mm^W 45 tonnes/coil
,840,000 tonnes/year 7,100 hours/year 400 tonnes/hour	2,700,000 tonnes/year 7,100 hours/year 380 tonnes/hour	5,000,000 tonnes/year 7,100 hours/year 700 tonnes/hour
79,000 kcal/product tonne 84 kWh/product tonne	405,000 kcal/product tonne 84 kWh/product tonne	267,000 kcal/product tonne 72 kWh/product tonne

(iii) Cold rolling mill

Table 2.2.34 compares the cold rolling mill of a 4 Hi reversing type under construction at the site of Pakistan Steel with the same-scale one in Japan. As far as the general facility specifications are concerned, this cold rolling mill of Pakistan Steel does not much differ from Japanese mills.

But its nominal yearly production capacity of 200,000 tonnes seems too much when compared with Japanese mills.

The production capacity may of course largely change with the thickness of products and other factors. But generally speaking, the Pakistan Steel's production plan for the cold rolling mill may be said to be too severe.

Table 2.2.34 Comparison of Cold Rolling Mi

Name of Mill	Pakistan Steel Cold Rolling Mill	A
Type of Mill	4-Hi Reversing mill x 1	4-Hi Reversing mill x 1
Roll dimension		
Work roll dia./Back-up roll dia. x Barrel length	500mmø x 1,400mmø x 1,700 mm	420mmø/1,250mmø x 1,060mm
Main motor capacity	1,000 kW x 2	2,150 kW
Rolling speed	max. 600m/min.	460m/min.
Thickness of initial material	1.6 - 4.0mm thick	1.6 - 3.2mm thick
Size of products		
Thickness	0.3 - 2.5mm	0.2 - 1.6mm (near 0.3mm)
Width	60 - 1,500mm	630 - 950mm
Coil weight	14 tonnes/coil	13 tonnes/coil
Production		
Practical production amount	200,000 tonnes/year	91,500 tonnes/year
Practical operation hour	6,700 hours/year	6,800 hours/year
Hourly output	30 tonnes/hour	14 tonnes/hour

SECTION 1

Table 2.2.34 Comparison of Cold Rolling Mills

. Steel ling Mill	A	B
ng mill x 1	4-Hi Reversing mill x 1	4-Hi Reversing mill x 1
0mmø x 1,700 mm	420mmø/1,250mmø x 1,060mm	533mmø x 1,422mmø x 2,032mm
	2,150 kW	4,750 kW
n.	460m/min.	760m/min.
thick	1.6 - 3.2mm thick	1.2 - 6.0mm thick
	0.2 - 1.6mm (near 0.3mm)	0.4 - 3.2mm (near 0.9mm)
m	630 - 950mm	610 - 1,880mm
il	13 tonnes/coil	30 tonnes/coil
es/year	91,500 tonnes/year	64,000 tonnes/year
s/year	6,800 hours/year	2,500 hours/year
es/hour	14 tonnes/hour	25 tonnes/hour

(6) Basic problems of Pakistan Steel

Here, a brief view of the steel industries in developing countries is taken as their development stage, and the market conditions required for construction of a BF integrated plant are studied. This may clarify the basic problems that Pakistan Steel is already confronted with.

(a) Developing stages of steel industries

From the stage a country meets domestic steel demand only with imports, it reaches the stage to have only rolling mills when its market grows larger. This is the first stage of steel industry. Re-rollers manufacture non-flat products such as bars and sections with small ingots and billets imported, and flat products such as welded pipes, galvanized sheets and tin plates with these material coils imported. At the second stage, ingots and billets for non-flat products are produced by domestic open hearth or electric furnaces with melting scrap locally generated or imported.

When countries go into the "take-off" stage of economic development, many of them have larger domestic steel market, and on the other hand possess a certain level of manufacturing technology and skilled labour.

With these economic conditions prepared, the construction of a BF integrated plant is to be realized. This is the third stage of steel industry. Compared to semi-integrated mill with open hearth or electric furnaces, its production scale is very large, and a large number of skilled workers, abundant material resources, capital and high technologies are indispensable for its construction and production. Thus its construction often becomes a national project. At that stage, many countries are not still fully self-sufficient.

Between the second stage and third one, there exists the stage of prevailing DR integrated mill. These mills exist or are under construction in many countries where abundant natural gas is available. Final stage of steel industry development is a stage where some BF integrated plants in a country keep stable production, and many of these steel products are exported with high international competitiveness, and its self-sufficient rates are fully over 100%.

Generally, steel industries in many countries trace these above-mentioned stages, although there exist some differences according to the conditions of market and iron resources, etc.

(b) Market conditions for the construction of BF integrated works

For construction of a BF integrated works in developing countries, it is necessary to have sufficient domestic demand for steel products. In general, countries with iron material resources are characterized by BF integrated plants' high share percentages (70 to 90%) to total crude steel production as is the case of Venezuela, Spain, Mexico and Brazil. The share percentages in countries without iron material resources like Argentina are about 50%. However, in steel exporting countries like Republic of Korea, that share is high. Thus, the market scale fully required for building the first BF integrated plant outputting 1 million tonnes/year is considered 1.5 million tonnes in developing countries with iron resources, and 2.5 million tonnes in countries without them. In terms of steel market structure by product category, the percentage of non-flat products is high in developing countries before take-off because of large quantity of steel demand for construction of the infrastructure. After a take-off, expansion of demand for flat products are remarkable along with spread of durable consumer goods. If there is a sharp increase in demand for steel products centered around flat-products in a country, its construction of a BF integrated plant is feasible, with its product mix concentrated on flat products to enjoy scale-merit. In other countries, however, it is generally advisable to start off from the construction of a BF integrated plant whose production is concentrated on non-flat products. This is because that manufacturing of flat products requires advanced technology because precision requirements on these product quality and dimension are very strict. Thus, generally speaking, it is advisable to accumulate experiences starting from production of non-flat products in the first step.

(c) Basic problems of Pakistan Steel

As previously mentioned, Pakistani steel industry is about to enter from the second stage to the third stage of its development. While Pakistan has not yet reached a take-off stage of economic development, Pakistan Steel started construction of BF integrated plant concentrated on sheet products without having any experience of manufacturing galvanized sheets and tin plates.

Therefore, the market conditions in Pakistan for a BF integrated plant are not fulfilled in terms of total domestic steel market. Looking into product-mix, we find that the sheet market has not yet been developed in this country. Pakistan Steel's hot strip mill which is currently under construction has an annual production capacity of 1.8 million tonnes. Even by collecting all the domestic demand for sheets, as described in detail in Chapter 3, sheet demand in Pakistan stands at 0.5 million tonnes in 1979-80, and will barely reach 2.0 million tonnes during year 1999-2000.

Pakistan Steel has a limit of 1.1 million tonnes in crude steel production capacity. As a substitute for currently imported billets, Pakistan Steel is also constructing a billet mill capable of producing 380,000 tonnes per year. This indicates that a forecast on the domestic market, with which the product-mix of Pakistan Steel was decided, turned out too optimistic. Despite the fact that Pakistan Steel is behind its original schedule of construction, demand for sheets are still very small in quantity. Consequently the production capacity of the hot strip mill is excessive in the view of both the iron and steel making capacity and the scale of domestic sheet demand.

The way to solve these problems is to double the Pakistan Steel's iron and steel making capacity and to export its sheet products.

As stated in Chapter 3, however, domestic price of sheets in this country is nearly 2 times the price in the international market. Pakistan Steel is to supply its sheets to domestic users for the first time. So, there is a little fear about quality, dimensional precision and stable supply of its sheets. For these reasons, we have to say that it takes many years for Pakistan Steel to have its competiveness with ones produced out of highly productive large-scale hot strip mill of Japan and EC countries.

Considering all these points, it is recommendable for Pakistan Steel to receive from advanced steel-producing countries, close technological cooperation so that the iron and steel making capacity of this plant may be utilized to the fullest extent. Also, it is necessary for Pakistan Steel to reduce the product cost to make gradually domestic prices cheaper, and endeavour to promote expansion of the domestic market.

2.2.5 Special Steels of Pakistan Ltd.

(1) Production capacity

The existing production capacity of Special Steels of Pakistan (SSP) is shown in Table 2.2.35.

(2) Principal equipment

Principal equipment of SSP is listed in Table 2.2.36. Its production capacity is mentioned in (1) above.

Table 2.2.35 Production Capacity of SSP

Name of Products	Annual Production t/y	Specification of Products: Steel Grade	Form	T/D* x Width x Lengt
Stainless Steel Cold Rolled Sheet	2,000	AISI-304	Sheet	(0.7-1.2)mm x 914mm x (1.5-
Stainless Steel Hot Rolled Sheet	3,000	AISI-304	Sheet	(1.2-2.3)mm x 914mm x (1.5-
Carbon Steel Plate/Sheet	1,000	JIS-SM50C	Plate, Sheet	(2.3-6)mm x 914mm x (1.0-1.5
Special Steel Bar	11,200	Carbon Steel: AISI-1045 1060 1080 Cr-Mo Steel: AISI-4118 4130 Ni-Cr Steel: AISI-3140 Cr Steel: AISI-5135 Stainless Steel: AISI-304	Round Square Hexagonal	(ø 22-40)mm x (4.0-6.0)m (⊡ 22-40)mm x (4.0-6.0)m (⊡ 22-40)mm x (4.0-6.0)m
Forged Product	800	Carbon Steel: AISI-1030 1035 1045	Free, Die	Free Forged (500t/y) Die Forged (300t/y)
Cast Steel Product	2,000	Carbon Steel: AISI-0030	-	Unit Weight: 5-5,000 kg
Total	20,000	-	-	-

* Thickness or diameter

SECTION 1

…ble 2.2.35 Production Capacity of SSP

Specification of Products			
…de	Form	T/D* x Width x Length	Final Treatments
	Sheet	(0.7-1.2)mm x 914mm x (1.5-2.0)m	"2D" Finish (Cold Rolled, Annealed and Pickled Sheet)
	Sheet	(1.2-2.3)mm x 914mm x (1.5-2.0)m	No. 1 Finish (Hot Rolled, Annealed and Pickled Sheet)
…C	Plate, Sheet	(2.3-6)mm x 914mm x (1.0-1.5)m	Hot Rolled
…teel: [illegible] …eel: …3 [illegible] …eel: [illegible] …: [illegible] …s	Round Square Hexagonal	(ø 22-40)mm x (4.0-6.0)m (□ 22-40)mm x (4.0-6.0)m (⬡ 22-40)mm x (4.0-6.0)m	Hot Rolled, Annealed.
…teel: …0 …5 …5	Free, Die	Free Forged (500t/y) Die Forged (300t/y)	As Forged, Annealed
…teel: …0	-	Unit Weight: 5-5,000 kg	As Cast, Annealed
	-	-	-

Table 2.2.36 Principal Equipment of SSP

Name of Shop	Principal Equipment		Materials	
Steel Melting and Steel Casting	Electric Arc Furnace (10/12t) Ingot Conditioning Equipment, etc. Electric Arc Furnace 3/4t Steel Casting Equipments	x 2 x 1 x 1 x 1	Steel Scrap, Ferro Alloy Lime Stone, Fluorite, etc.	900 Ingo 600 As-c
Blooming and Slabbing Mill	Ingot Reheating Furnace (9t/h)	x 1	900 kg, Round Ingot	90 x Bill
	Ø800 x 1,800 mm 2-High Rev. Mill (Blooming & Slabbing Combined Mill)	x 1	600 kg, Slab Ingot	12-1 Shee
	Roll Grinder and Roll Lathe	x 1		Min. Plat
Bar Rolling Mill	Billet Reheating Furnace (6t/h) Bar Rolling Mill Train (3-High Rougher: Ø450 x 1,600 x 1) (3-High Finisher: Ø300 x 600 x 3) (2-High Finisher: Ø300 x 600 x 1) Annealing Furnace, etc.	x 1 x 1	90 x 90 - 75 x 75 x 2,300 mm Billets (146 kg)	22 - Bar (Ro Hexa
Sheet Rolling Mill	Sheet-bar Reheating F'ce (4t/h) Hot Sheet Mill (Pullover) (2-High Rougher: Ø700 x 1,120 x 1) (2-High Finisher: Ø700 x 1,120 x 1) Cold Sheet Mill (Ø320/850 x 1,120: 4-High Non-Rev.) Roll Grinder, Shear, Leveller, etc.	x 2 x 1	12 - 18 mm T Sheet Bar	Stai 0.7 Carb 2.3
Forging	Air Hammer (1t x 1, 1/2t x 1) Air Drop Hammer (1t x 1, 1/2t x 1) Furnace, etc.		Bar and Billet	As F
Sub-Station, etc.	Electric Sub-Station Air-Compressor, Crane, Fork-lift, Track, Mobil crane, Testing equipment, etc.		-	-

SECTION 1

:le 2.2.36 Principal Equipment of SSP

Equipment		Materials	Products	Application of Products
(10/12t) uipment, etc. 3/4t ents	x 2 x 1 x 1 x 1	Steel Scrap, Ferro Alloy Lime Stone, Fluorite, etc.	900 kg, Round Ingot 600 kg, Slab Ingot As-cast Steel	Billet Sheet/Plate Cast Steel Product
ce (9t/h)	x 1	900 kg, Round Ingot	90 x 90, 75 x 75 mm Billet	Bar Rolling Forging
h Rev. Mill Combined Mill)	x 1	600 kg, Slab Ingot	12-18 mm T Sheet-bar	Stainless, Sheet Rolling
Lathe	x 1		Min. 6 mm, Steel Plate	Sheet/Plate
nace (6t/h) in 50 x 1,600 x 1) 00 x 600 x 3) 00 x 600 x 1) tc.	x 1 x 1	90 x 90 - 75 x 75 x 2,300 mm Billets (146 kg)	22 - 40 mm Bar (Round, Square, Hexagonal)	Semi-finished Bar Product
'ce (4t/h) ver) 0 x 1,120 x 1) 0 x 1,120 x 1) -High Non-Rev.) Leveller, etc.	x 2 x 1	12 - 18 mm T Sheet Bar	Stainless Sheet 0.7 - 2.3 mm T Carbon Steel Sheet 2.3 - 5 mm T	Stainless Sheet (Hot Sheet, Cold Sheet) Carbon Steel Sheet
/2t x 1) 1, 1/2t x 1)		Bar and Billet	As Forged	As Forged
e, Fork-lift, Track, equipment, etc.		-	-	Utility Supply, Transportation, Testing, etc.

SECTION 2

(3) Past and current situation

SSP was established in 1964 by the Vilken Group of private capital as the first special steel manufacturer in Pakistan. It was renamed "Peoples Steel Mill Ltd." in 1973, but its name was changed again in 1979 to the present one. Although construction of SSP plants was started in 1968, it was barely brought to completion in 1975 after the lapse of 7 years twice as long as the period of construction as initially scheduled under the influences of political changes and wars.

SSP has started its commercial operation from August, 1975. However, since sales could not expand as expected while the manufacturing cost continued to rise, only the amount of debts has shown a steady increase. As a result, the Economic Council of Cabinet made an official decision on December, 1979 to the effect that SSP should be closed for the reason that there is not any clear prospect of wiping out the SSP's deficit balance.

Why did the SSP's business result become worse to such a extent that SSP should be closed? According to the Japan International Corporation Agency's Report made in 1980, the reasons for it are outlined as follows:

1) Too small volume of orders received due to the small scale of market for special steel, steel forging and steel casting

2) Shortage of production technology and lackness of cost-reducing efforts

3) Shortage of funds

4) Excessive inventories

5) Undue fixed asset

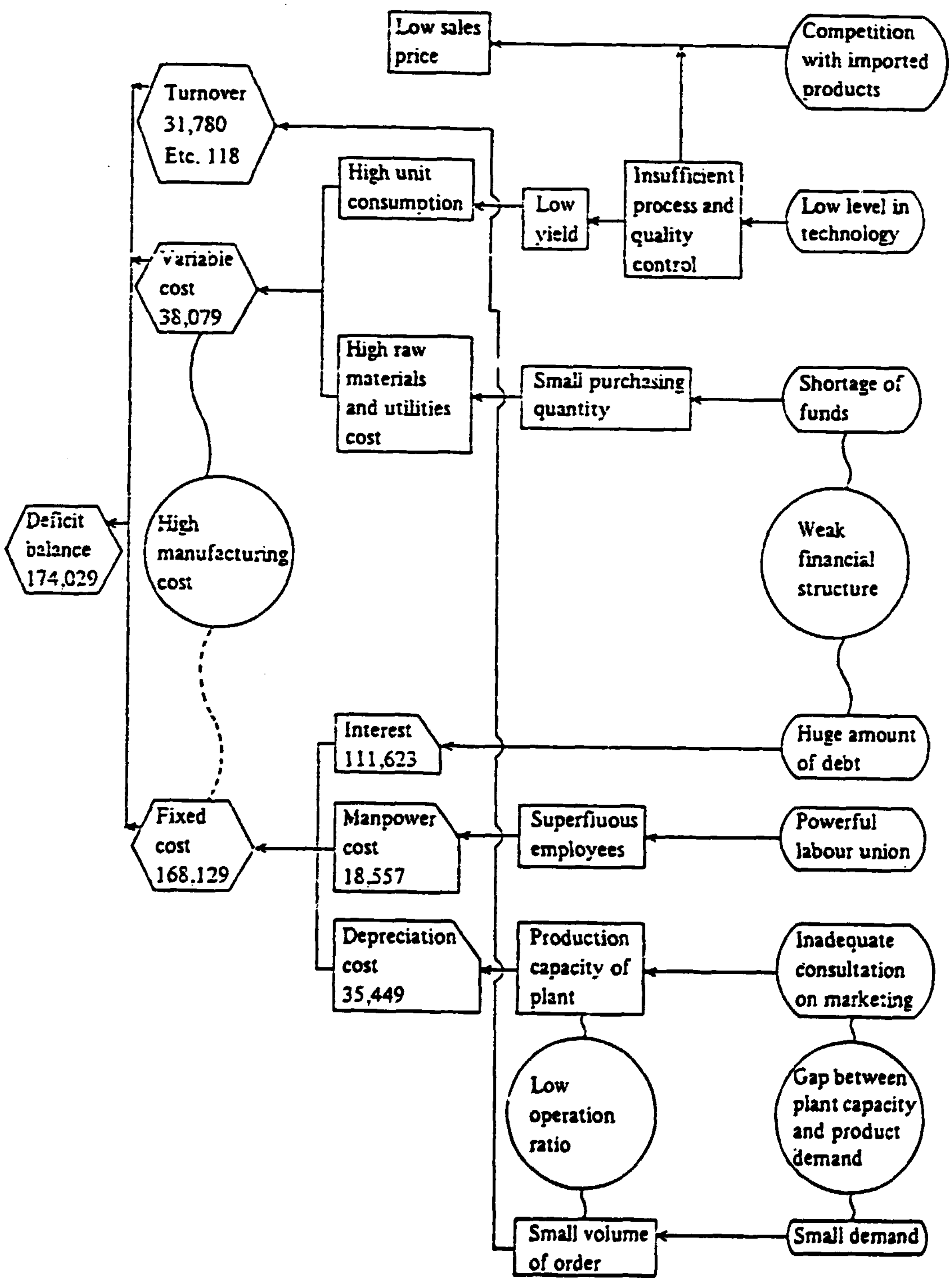
6) Higher debt ratio for total asset

7) Increase of total liabilities and net worth

8) Superfluous employment employees, unwise measures against labour union, etc.

These reasons are analysed and arranged systematically in Fig. 2.2.6.

Unit: Rs. Million



Source: JICA Report 1980

Fig. 2.2.6 Reasons for Deficit Balance SSP

Also as for the reconstruction of SSP, it was judged impossible for the reason that the internal rate of return will be - 7.174% even if the following countermeasures are taken;

1) To extend the range of kind and size of products through minimum new investment of inspection facilities.

2) As for the products which are in small demand and are not expected to have an increased demand also in future, to suspend their production even if they are included in the initial production programme.

3) To reduce the employees to the irreducible minimum.

4) To aim at the improvement of technical level through the technical cooperation extended from developed countries at least for three years.

5) To suspend the production of carbon steel.

On the contrary, SSP has prepared its own reconstruction plan depending mainly on the powerful financial aid to be given by the government such as increase in amount invested by the government and tax exemption of raw materials to aim at the effective utilization of its capital already invested.

3. MARKET STUDY FOR IRON AND STEEL IN PAKISTAN

3.1 Introduction

The apparent steel consumption in the world amounts to 721 million tonnes as of 1980. Developing countries post a steel consumption of 114.3 million tonnes, which hold only 15.9 percent (%) of the world total, in spite of their population accounting for 70% of the world population. However, the steel consumption in developing countries has recently shown a remarkable increase. Compared with the figures of 1970, it does show a 94% increase in quantity. On the other hand, the steel production in developing countries does not show a corresponding increase. As is clear from Table 3.1.1, relations between supply and demand of steel in these countries have become more and more unbalanced.

On the other hand, the total steel production capacity in the world is estimated to be nominally 981 million tonnes as of 1980. It has increased by 253 million tonnes these 10 years; each nearly 100 million tonnes in developed countries and communist countries, and about 60 million tonnes in developing countries.

The utilization rate of steel production facilities in the world which was about 80% in 1970 dropped to about 70% in 1980 due to the decreased demands mainly in U.S.A., EC countries and Japan.

The developing countries, especially middle-advanced ones, are eager to achieve selfsufficiency of iron and steel and aiming to expand their production facilities. However, as shown in Table 3.1.2, their utilization rate still remains at rather low level mainly due to the production techniques and unbalanced equipment capacities.

Incidentally, the operation rate corresponding to the effective capacity taking the balance between equipment capacity and working ability into account is comparatively high in developing countries because the demand is larger than the supply there, while it is rather low in advanced countries due to the sluggish demand.

Further the rate of the effective production capacity to the nominal capacity is about 93% in the advanced countries, while it is less than 80% in developing countries. It clearly shows that the functions of production facilities in the latter are not yet fully utilized.

Notwithstanding the problem of competition of steel with non-ferrous materials, which is described in Append[illegible] to 3-1, world steel consumption in fugure is forecasted to increase steadily. As shown in Table 3.1.3, steel consumption in developing countries will increase at a rate higher than that in developed countries. This suggests that the role of developing countries in the world steel consumption will become more and more important in the future.

Therefore, it can be said that the potential requirements for promoting the development of iron and steel industry will be increasingly high in developing countries in future.

Table 3.1.1

Year	1970	
	Production	Consumption
Developed Countries	385.2	359.6
*Developing Countries	33.9	58.9
Centrally Planned Economy	176.2	176.9
World Total	595.3	595.4

* According to the difinision by DAC

Steel Production and Consumption in the World

(Unit: million tonnes)

	1975			1980		
Balance	Production	Consumption	Balance	Production	Consumption	Balance
25.6	373.9	321.9	52.0	387.1	345.8	41.3
-25.0	49.7	90.9	-41.2	78.0	114.3	-36.3
-0.7	221.9	231.3	-9.4	252.6	261.0	-8.4
-0.1	645.5	644.1	1.4	717.7	721.1	-3.4

Source: IISI

Table 3.1.2 Steel Production Capacity and Utilization Rate in the World

(Unit: Million tonnes, %)

Item \ Year	1970	1975	1980
Production A			
Advanced countries	385.2	373.9	387.1
Developing countries	33.9	49.7	78.0
Communist countries	176.2	221.9	252.6
World total	595.3	645.5	717.7
Production capacity B1			
Nominal capacity			
Advanced countries	455.3	527.6	554.4
Developing countries	48.7	69.5	106.1
Communist countries	223.8	281.9	320.8
World total	727.8	879.0	981.3
Effective capacity B2			
Advanced countries	421.2	488.6	513.9
Developing countries	38.8	55.4	84.5
Communist countries	177.6	223.7	254.6
World total	637.6	767.7	853.0
B2/B1 (%)			
Advanced countries	92.5	92.6	92.7
Developing countries	79.7	79.7	79.6
Communist countries	79.4	79.4	79.4
World total	87.6	87.3	86.9
Utilization rate (%)			
A/B1			
Advanced countries	84.6	70.9	69.8
Developing countries	69.6	71.5	73.5
Communist countries	78.7	78.7	78.7
World total	81.8	73.4	73.1
A/B2			
Advanced countries	91.5	76.5	75.3
Developing countries	87.4	89.7	92.3
Communist countries	99.2	99.2	99.2
World total	93.4	84.1	84.1

Source: The production is from IISI. Nominal capacity in the production capacity was estimated based on the data from Japan Iron & Steel Federation. The effective capacity is from IISI.

(Note): The nominal capacity means the equipment capacities of converter, open-hearth furnace, electric furnace, etc. on steelmaking base. The effective capacity means the realistic maximum production volume expected based on the balance between the equipment capacities for ironmaking, steel making, rolling, etc. and the working ability.

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Table 3.1.3 Past Trend and Forcast of World Steel Consumption

(Unit: million tonnes)

Countries areas / Years		World Total	(Share %)	Developed Countries	(Share %)	Developing Countries	(Share %)	Centrally Planned Economy	(Share %)
1970	Actual	595.4	100	359.6	60.4	58.9	9.9	176.9	29.7
1975	Actual	644.1	100	321.9	50.0	90.9	14.1	231.3	35.9
1980	Actual	721.1	100	345.8	47.9	114.3	15.9	261.0	36.2
2000 UNIDO									
Var. I(b)		1,665.0	100	763.0	45.8	535.0	32.2	367.0	22.0
Var II(a)		1,925.0	100	763.0	39.6	795.0	41.3	367.0	19.1

(Source: IISI, Facing the Future by OECD)

Establishment of iron and steel industry in developing countries leads not only to save foreign currencies by eliminating the double handling of transportation, but also to provide large employment and stimulate the industrialization, although it is also pointed out that developing countries may somewhat be less competitive due to the rising price of energy to be expected in view of the high energy consumption on a comparatively small unit.

The natural trend in developing countries toward such industrialization as well as the necessity of cooperation to be extended from the developed countries for the industrialization of developing countries both in technical and financial aspects is manifested most plainly in the UNIDO's Lima Declaration and its movement programme adopted in 1975, which includes the form of idea to be aimed at.

Following lines are quoted from the Progress Report of UNIDO's Second Consultation Meeting on Iron and Steel Industry.

> The shift in the pressure for the development of the steel industry in the different parts of the world presents the developing countries with an exceptional opportunity. They are able to pursue their own development schemes, provided they are soundly organized and appropriately related to their own conditions and their local and regional markets, with technical assistance and deliveries of equipment more readily available from developed countries than at any time during the past ten years.

The developing countries would thus be able to make rapid progress with their steel industries, reducing their dependence on imports, improving their balances of payments and creating a sound basis for their engineering industries and further industrialization. If this opportunity is seized during the course of the next few years the industrial momentum created would facilitate the achievement of the Lima targets relating to the share of developing countries in world industrial output. That result would still be eminently practicable even if the measures now under consideration to stimulate economic revival in developed countries show benefits in the near future, because of the great stimulus to world trade generally which that would provide.

In this section, the present iron and steel market conditions on the basis of which the master plan of Pakistan iron and steel industry is to be prepared will be described. The past apparent steel consumption* (ASC) in Pakistan is analyzed to give the basic data for forecasting the future ASC.

The past ASC is analyzed on the basis of the data gathered for 8 years from 1972-73 to 1979-80. In the first place, the domestic steel production of Pakistan is analyzed by product categories**. Then, steel imports are analyzed in the same manner. Furthermore, as for the steel consumption, the present situation of industrial sector as an end-user as well as the relation of steel consumption with GNP are studied. In addition, the present level of steel consumption in Pakistan is compared with the international level.

Note:

* ASC = domestic steel production + steel imports - steel exports

Since steel exports of Pakistan are found too small to be negligible after various investigations, no particular mention will be made on them hereinafter.

** Steel product categories shall be as defined in Appendix to 3-2.

3.2 Present Domestic Steel Production

3.2.1 General

The existing steel industry in Pakistan is composed of semi-integrated plants with melting and rolling facilities, and plants with rolling facilities only. The former are producing steel ingots or steel billets by melting domestic and imported scrap in a small-sized electric furnace and, in their rolling mills, they are mainly producing bars and sections. The latter are producing bars and sections by rerolling the billets and rerollable scrap imported as well as domestic rerollable scrap from shipbreaking, etc. and domestic ingots. They are called "re-rollers".

The present annual crude steel production capacity and actual production of semi-integrated mills were examined based on various kinds of information obtained from the Pakistan Steel Melters Association, Pakistan Steel and 11 semi-integrated mills to which visited, and the results obtained are arranged in Table 3.2.1.

The utilisation rate is low in the public sector and high in the private sector. The reason for this is probably to be found in that, while companies in the private sector are rolling the bars and sections which are delivered comparatively steady to the construction industry, most of companies in the public sector are self-supplying some of the materials for manufacturing the machinery of their own make, but the manufacturing of machinery has not as yet been so active.

There are no available data on the production capacity and actual production of re-rollers only. As for the rolled steel products, the present actual production is estimated at 609 thousand tonnes from various information such as volume of imported billets and those data obtained from the Pakistan Shipbreakers Association, Pakistan Steel Re-Rollers' Association and Pakistan Steel. From these estimations and the change in mild steel production formulated by the Statistics Division, the change in steel production based on the domestic finished steel production and crude or liquid steel equivalent (hereinafter called "CSE") is estimated as shown in Table 3.2.2.

Note: The yield of iron and steel production in Pakistan shall be as follows:

CSE/scrap = 0.90

Ingots or Billet/CSE = 0.95

Finished Steel Products/CSE = 0.85

Table 3.2.1 Existing Capacity of Crude Steel Production and Actual Production

(Unit: 1000 tonnes, %)

	Private			Public			Total		
	Capacity	Production	Utilization (%)	Capacity	Production	Utilization (%)	Capacity	Production	Utilization (%)
Steel Casting and Forgings	-	2	-	-	24	-	-	26	-
Steel for Rolled Products	-	336	-	-	26	-	-	362	-
Total	418	338	80.9	188	50	26.6	606	388	64.0

Table 3.2.2 Steel Production (Finished, CSE)

(Unit: 1000 tonnes)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
A. Mild Steel Products (Statistics Division)	183.9	218.1	224.0	230.7	269.6	315.3	362.4	420.4
B. Finished Steel Production	266.4	316.0	324.4	334.2	390.5	428.1	525.0	609.0
C. CSE base	306.8	363.8	373.7	384.8	449.7	526.0	604.5	701.3

3.2.2 Present Steel Production by Categories

As for the Pakistan steel industry, its finished steel production by categories is described here. Finished steel products now being made in Pakistan are limited only to bars, wire rods, wires, sections, pipes and hoops. Of these, pipes and hoops depend completely upon imports for their raw materials.

(1) Bars, wire rods and wires

Wire rods and wires are now produced in Pakistan only in very small quantities. These products are imported for the most part. Metropolitan Steel Corporation is one of a few domestic rollers. About 8 thousand tonnes per year of wire rods 6 to 10 mm in diameter and about 6 thousand tonnes per year of wires less than 5 mm in diameter are produced therein.

Bars are now largest in production among steel products in Pakistan. Round bars, ribbed bars, square bars, flat bars, etc. are now available in Pakistan. Bars of comparatively good quality are, for the most part, rolled from the imported billets of definite quality and are being supplied mainly by the public sector and leading rollers for dam, bridge, cannal and big building construction. According to the information given from the Pakistan Steel Melters Association, Pakistan Steel Re-Rollers' Association and other sources, the total bar production of today in Pakistan is estimated at about 360 thousand tonnes, which account for almost 60% of total finished steel products.

Most part of bars produced in Pakistan is held by round bars. It seems that deformed bars or ribbed bars, square bars or flat bars have a higher market share next to round bars in this order. Part of companies in the public sector is also producing the cold-finished steel bars.

(2) Sections

Although reinforced concrete beams have so far been generally used in even non-residential buildings such as factory buildings, they have recently begun to use sections particularly in factory buildings. Conside-ring that construction by sections is cheaper in building cost than by reinforced concrete, some steel manufacturers have replaced the existing bar mill with a new mill capable of rolling sections such as angles and I-beams and further installed continuous casting facilities with a view to achieving higher productivity. In recent years, this tendency has been spreading rapidly. The section mills to be installed in place of bar mills are capable of producing I-beams with web 6 to 8 inches long. Therefore, the production capacity of these medium-sections will be increased in the future. Although angles now available in Pakistan are on the whole smaller than 3-inch in size, there are some companies, Pakistan Engineering Company for example, which produce angles larger than 3-inch in size in large quantities and deliver them to WAPDA. Among sections, angles, I-beams and channels are now produced at a higher rate in this order. The total production of sections is estimated at about 200 thousand tonnes.

(3) Pipes and hoops

Almost all pipes available in Pakistan are welded pipes and are now produced in a quantity of about 20 thousand tonnes (For more details, refer to Sub-sec. 3.4.3(3) "Metal processing industries"). Total production of hoops is estimated at about 15 thousand tonnes.

(4) The domestic steel production by categories arranged according to the foregoing is as follows:

(Unit: 1,000 tonnes)

Products	Domestic Production
Bars	360
Wire Rods	8
Wires	6
Sections	200
Hoops	15
Welded Pipes	20
Total	609

3.2.3 Present Special Steel Production

In Pakistan, special steel products have so far been produced by Special Steel of Pakistan Ltd. (SSP). However, since SSP was closed down on December, 1979 due to the technical and financial problems and domestic market problems, almost no special steel products are now produced in Pakistan. SSP's production results since its start-up (July, 1975) are given in Table 3.2.3.

Table 3.2.3 Special Steel Production by SSP

(Unit: 1000 tonnes)

	1975-76	1976-77	1977-78	1978-79	1979-80
Billets	5.3	4.0	3.7	3.5	4.0
Bars and Rods	0.0	-	0.2	0.1	0.1
Plates and Sheets	0.4	0.4	0.2	0.4	0.1
Total	5.7	4.4	4.1	4.0	4.2

Source: SSP

We expect that, through the detailed market research and acquisition of control and production techniques, this special steel producer will be reconstructed in near future as a supplier of basic materials supporting the development of heavy & chemical industries and mechanical industry in Pa stan.

3.2.4 Present Domestic Production of Iron Foundries

It is estimated that the present domestic production of iron foundries is approximately 93,000 tonnes per year (by molten metal basis).

Major manufacturers of the public sector are Pakistan Railways, Heavy Foundry and Forge, Karachi Shipyard and Engineering Works, Pakistan Engineering Co, Northern Foundry and Engineering Works. All manufacturers of iron foundries together with some of the private sector, have their supply capacity of approximately 250 thousand tonnes, with its utilisation ratio of approximately 37%.

3.3 Present Steel Imports

In Pakistan, as for the development of steel products by categories, only steel imports can be statistically grasped in detail.
There is no reasonable statistics of production available in Pakistan, not to speek of the statistics of shipment. Here, the development of steel products by categories will be followed up in detailed.

3.3.1 Development of Steel Imports

According to the "Foreign Trade Statistics of Pakistan" published by the Statistical Division, Government of Pakistan, imports of semi-finished and finished steel products by Pakistan have increased from 347.7 thousand tonnes in 1972-73 to 659.2 thousand tonnes in 1979-80, as is shown on Table 3.3.1.
An average annual growth rate during this period was 9.6%.

With these steel products classified into low carbon steel products (LCS) and high carbon steel (HCS) & alloy steel (AS) products, the former has increased rapidly from 212.6 thousand tonnes in 1972-73 to 633.4 thousand tonnes in 1979-80 at an annual rate of 16.9%, but the latter has shown a marked decline from 135.1 thousand tonnes in 1972-73 to 25.8 thousand tonnes in 1979-80. The share of LCS products in 1979-80 is 96.1%.

SECTION 1

Table 3.3.1 Imports of Steel Products

Code	Steel Product Categories	SITC Code 67-	Grade	1972-73	1973-74	1974-75	197[illegible]
A	Ingots, Billets Blooms and Slabs	2303, 2509, 2519, 2529, 2539, 2549	LCS	33.8	35.1	72.8	[illegible]
		2301, 2302, 2501, 2502, 2511, 2512, 2521, 2522, 2541, 2542	HCS+AS	80.8	46.8	44.6	[illegible]
			Sub-Total	114.6	81.9	117.4	[illegible]
B	Bars and Wire Rods	3109, 3209, 3219, 3229	LCS	11.9	6.1	26.1	[illegible]
		3101, 3102, 3201, 3202, 3211, 3212, 3222	HCS+AS	10.1	7.2	7.6	[illegible]
			Sub-Total	22.0	13.3	33.7	[illegible]
C	Sections	3409, 3509	LCS	1.8	3.0	6.2	[illegible]
		3401, 3402, 3501, 3502	HCS+AS	0.1	0.3	0.2	[illegible]
			Sub-Total	1.9	3.3	6.4	[illegible]
D	Rails	6101, 6102, 6201, 6202, 6209	*LCS	2.7	0.5	1.2	[illegible]
E	Wire	7003, 7004, 7005, 7006, 7009,	*LCS	5.7	17.0	5.4	[illegible]
		7001, 7002, 7008	HCS+AS	1.0	1.8	1.6	[illegible]
			Sub-Total	6.7	18.8	7.0	[illegible]
F	Plates	4109, 4209	LCS	7.2	9.3	9.3	[illegible]
		4101, 4102, 4201, 4202, 4203	HCS+AS	11.3	8.4	8.9	[illegible]
			Sub-Total	18.5	17.7	18.2	[illegible]
G	Sheets, Hoops and Strips	4119, 4219, 4309, 5009	LCS	69.3	157.8	106.8	[illegible]
		4111, 4112, 4211, 4212, 4216, 4301, 5001, 5002	HCS+AS	25.3	15.4	18.0	[illegible]
			Sub-Total	94.6	173.2	124.8	[illegible]
H	Rerollable Coils	2709	LCS	0.6	4.8	6.5	[illegible]
		2701, 2702	HCS+AS	1.5	30.7	0.3	[illegible]
			Sub-Total	2.1	35.5	6.8	[illegible]
I	Galvanized Sheets	4113, 4114, 4115, 4116	*LCS	34.5	37.1	20.8	[illegible]
J	Tinned Plates and Sheets	4701, 4702, 4709, 4711	*LCS	31.3	33.6	44.0	[illegible]
K	Others Coated Sheets	4809, 4213, 4214	*LCS	0.1	0.5	0.0	[illegible]
		4801	A	-	0.1	2.0	[illegible]
			Sub-Total	0.1	0.6	2.0	[illegible]
L	Tubes and Pipes	8200	Seamless	5.0	1.6	4.9	[illegible]
		2900, 8300, 8400, 8500	Welded and Others	13.7	14.8	26.0	[illegible]
			Sub-Total	18.7	16.4	30.9	[illegible]
	Total		LCS	212.6	319.6	325.1	[illegible]
			HCS+AS	135.1	112.3	88.1	[illegible]
			Total	347.7	431.9	413.2	[illegible]

Note: LCS: Low Carbon Steel HCS: High Carbon Steel AS: Alloy Steel
*: Seamless Tubes & Pipes are assumed as HCS+AS and Welded and Others are assumed as LCS.

SECTION 2

3.1 Imports of Steel Products

(Unit: 1,000 tonnes)

	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate 1979-80/1972-73
2549	LCS	33.8	35.1	72.8	29.6	99.3	116.9	114.1	100.3	16.8
2512,	HCS+AS	80.8	46.8	44.6	6.4	13.4	19.2	9.3	4.9	-33.0
	Sub-Total	114.6	81.9	117.4	36.0	112.7	136.1	123.4	105.2	-1.2
	LCS	11.9	6.1	26.1	26.3	18.2	30.5	20.7	30.2	14.2
3212,	HCS+AS	10.1	7.2	7.6	5.6	2.6	3.4	1.3	1.7	-22.5
	Sub-Total	22.0	13.3	33.7	31.9	20.8	33.9	22.0	31.9	5.5
	LCS	1.8	3.0	6.2	17.4	22.0	12.8	13.4	5.9	18.5
	HCS+AS	0.1	0.3	0.2	2.2	0.4	7.3	8.0	0.1	0.0
	Sub-Total	1.9	3.3	6.4	19.6	22.4	20.1	21.4	6,0	17.9
	*LCS	2.7	0.5	1.2	24.4	18.6	7.6	25.4	39.0	46.4
	*LCS	5.7	17.0	5.4	5.6	9.4	13.1	14.7	13.0	12.5
	HCS+AS	1.0	1.8	1.6	1.8	1.5	1.5	0.5	1.1	1.4
	Sub-Total	6.7	18.8	7.0	7.4	10.9	14.6	15.2	14.1	11.2
	LCS	7.2	9.3	9.3	19.2	14.3	9.6	7.5	16.0	12.1
	HCS+AS	11.3	8.4	8.9	3.9	0.9	1.5	0.6	5.3	-10.3
	Sub-Total	18.5	17.7	18.2	23.1	15.2	11.1	8.1	21.3	2.0
	LCS	69.3	157.8	106.8	111.9	180.5	170.3	172.3	257.8	20.6
4301,	HCS+AS	25.3	15.4	18.0	6.1	7.6	6.3	8.5	10.9	-11.3
	Sub-Total	94.6	173.2	124.8	118.0	188.1	176.6	180.8	268.7	16.1
	LCS	0.6	4.8	6.5	8.6	1.1	0.5	43.4	11.5	52.5
	HCS+AS	1.5	30.7	0.3	-	0.0	6.4	0.1	-	-
	Sub-Total	2.1	35.5	6.8	8.6	1.1	6.9	43.5	11.5	27.5
	*LCS	34.5	37.1	20.8	30.6	33.3	39.2	51.5	51.6	5.9
	*LCS	31.3	33.6	44.0	19.5	37.4	38.9	56.6	77.1	13.7
	*LCS	0.1	0.5	0.0	-	0.1	0.0	-	-	-
	A	-	0.1	2.0	0.0	-	0.0	0.1	0.0	-
	Sub-Total	0.1	0.6	2.0	-	0.1	0.0	0.1	-	-
	Seamless	5.0	1.6	4.9	5.7	6.3	4.5	0.8	1.8	-13.6
	Welded and Others	13.7	14.8	26.0	53.7	93.1	16.6	30.3	31.0	12.4
	Sub-Total	18.7	16.4	30.9	59.4	99.4	21.1	31.1	32.8	8.4
	LCS	212.6	319.6	325.1	346.8	527.3	456.0	549.9	633.4	16.9
	HCS+AS	135.1	112.3	88.1	31.7	32.7	50.1	29.2	25.8	-21.1
	Total	347.7	431.9	413.2	378.5	560.0	506.1	579.1	659.2	9.5

·eel AS: Alloy Steel

-AS and Welded and Others are assumed as LCS.

Source: "Foreign Trade Statistics of Pakistan"

Imports of steel products in 1979-80 are shown on Table 3.3.2 with the steel proudcts divided into four groups.

Table 3.3.2 Imports of Steel Products by Groups in 1979-80

Group No.	Group Category	Code	Imported Quantity in 1979-80 (1000 tonnes)	(%)
I	Bars, Wire Rods, Wire and Seemless tubes	B, C, E Part of L	47.8	7.2
II	Sections and Rails	C, D	45.0	6.8
III	Plates, Sheets, Rerollable Coils and Welded Pipes	F,G,H,I, J,K, Part of L	461.2	70.0
IV	Ingots, Billets, Blooms and Slabs	A	105.2	16.0
	Total	-	659.2	100.0

Note: Prepared according to Table 3.3.1

Group I covers light sections, Group II heavy sections, Group III flat products (provided that welded pipes are also included in this Group in view of their materials) and Group IV semi-steel products. Their shares in total steel imports in 1979-80 are 7.2%, 6.8%, 70.0% and 16.0%, respectively. Group I and Group II cover non-flat steel products. Imports of these products are on the low level because they are produced in Pakistan in considerably large quantities.

The main supplying countries by categories of steel products in 1979-80 are shown in Table 3.3.3. Of total steel imports by Pakistan, the import from Japan accounts for 27%, followed by that from USA (22%), Australia (7%) and Federal Republic of Germany (7%).

Japan is the main supplying country for almost all kinds of steel products while USA and Australia are supplying countries mainly of flat products.

Table 3.3.3 Steel Imports by Main Supply Countries in 1979-80

(Unit: 1000 tonnes, %)

Code	Steel Product Category	Supplying Countries No. 1	No. 2	No. 3	No. 4	Total
A	Ingots, Billets, Blooms, and Slabs	Japan 32.0 (30.4)	China 31.6 (30.0)	Argentina 24.0 (22.8)	Netherlands 10.5 (10.0)	105.2 (100.0)
B	Bars and Wire Rods	Japan 23.0 (72.1)	Czechoslovakia 4.0 (12.5)	Federal Republic of Germany 1.3 (4.1)	France 1.2 (3.8)	31.9 (100.0)
C	Sections	Japan 3.0 (50.0)	United Kingdom 1.0 (16.7)	Federal Republic of Germany 0.8 (13.3)	China 0.4 (6.7)	6.0 (100.0)
D	Rails	United Kingdom 22.1 (56.7)	Canada 13.4 (34.4)	Japan 3.2 (8.2)	Portugal 0.3 (0.8)	39.0 (100.0)
E	Wires	China 3.7 (26.2)	Japan 3.4 (24.1)	Poland 1.4 (9.9)	Romania 1.2 (8.5)	14.1 (100.0)
F	Plates	Japan 6.7 (31.5)	Sri Lanka 4.9 (23.0)	United Kingdom 2.1 (10.0)	Belgium 2.0 (9.4)	21.3 (100.0)
G	Sheets, Hoop and Strips	95.1 (35.4)	Japan 58.2 (21.7)	Federal Republic of Germany 32.3 (12.0)	Belgium 19.1 (7.1)	268.7 (100.0)
H	Rerollable Coils	Japan 7.5 (65.2)	U.S.A. 2.3 (20.0)	Belgium 0.9 (7.8)	South Korea 0.5 (4.4)	11.5 (100.0)
I	Galvanized Sheets	Japan 25.2 (48.8)	U.S.A. 16.5 (32.0)	Belgium 4.9 (9.5)	Australia 1.3 (2.5)	51.6 (100.0)
J	Tinned Plates & Sheets	U.S.A. 24.9 (32.3)	Australia 22.8 (29.6)	United Kingdom 6.2 (8.0)	Japan 4.7 (6.1)	77.1 (100.0)
L	Tubes & Pipes	Japan 12.4 (37.8)	Federal Republic of Germany 6.1 (18.6)	U.S.A. 4.9 (14.9)	Italy 3.3 (10.1)	32.8 (100.0)
	Total	Japan 179.3 (27.2)	U. S. A. 145.0 (22.0)	Australia 45.9 (7.0)	Fedral Republic of Germany 43.7 (6.6)	659.2 (100.0)

Note: The figures inside ( ) show the percentage of each supplying country to the total.

Source: Same as Table 3.3.1

(1) Development of main steel products imports by Groups

(a) Non-flat steel porudcts (Groups I & II)

The term "Non-flat steel products" corresponds in the sense of classification to the term "Flat steel products". Steel proudcts covered by Group I and/or Group II such as bars, wire rods, wires, seamless tubes, sections and rails fall under this category.

(i) Bars, wire rods and seamless tubes (Group I)

The change of imports of these steel products is shown in Table 3.3.4. The import of low carbon steel products has shown a steady increase and amounted to 43.2 thousand tonnes in 1979-80 while the import of high carbon and alloy steel products has declined almost for the whole of bars, wire rods, wires and seamless tubes to the level of only 4.6 thousand tonnes in total in 1979-80. Even for the low carbon steel products, those products considerably high in grade and not available in Pakistan are imported. It should be noted that the import of these proudcts has shown a steady and stable increase, though it is very small in quantity.

Table 3.3.4 Imports of Bars, Wire Rods, Wires and Seamless Tubes (Group I)

(Unit: 1000 tonnes, %)

Product Category	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Bars & Rods	LCS	6.9	5.4	13.8	9.8	8.3	18.0	4.7	20.4	16.7
	HCS+AS	3.3	3.3	3.8	2.2	1.6	0.9	0.9	0.9	-16.9
Wire Rods	LCS	5.0	0.7	12.3	16.6	9.9	12.5	16.0	9.8	10.1
	HCS+AS	6.7	3.0	3.7	3.4	0.9	2.6	0.4	0.8	-26.2
Wire										
Galvanized	LCS	1.5	1.8	1.6	1.2	3.6	2.0	3.7	3.5	12.9
Nail	LCS	1.7	2.7	0.8	0.0	0.9	5.0	5.5	2.6	6.3
Spring	HCS	0.2	0.7	0.7	0.7	1.0	0.6	0.2	0.9	24.0
Other	LCS	2.5	12.5	3.0	4.4	4.9	6.1	5.5	6.9	15.6
Other	HCS+AS	0.8	1.1	0.9	1.1	0.5	0.9	0.3	0.2	-18.0
Seamless Tubes	HCS+AS*	5.0	1.6	4.9	5.7	6.3	4.5	0.8	1.8	-13.6
	LCS	17.6	23.1	31.5	32.0	27.6	43.6	35.4	43.[illegible]	13.7
Total	HCS+AS	16.0	9.7	14.0	13.1	10.3	9.5	2.6	4.6	-16.3
	Total	33.6	32.8	45.5	45.1	37.9	53.1	38.0	47.8	5.2

Source: Same as Table 3.3.1

Note: *Seamless tubes are estimated as HCS & AS

(ii) Sections and rails (Group II)

As is shown in Table 3.3.5, the import of low carbon steel products of Group II, i.e., sections and rails has increased mainly due to the expansion of rails since 1975-76 and amounted to 44.9 thousand tonnes in 1979-80. Sections imported are, for the most part, angles. Since light sections have so far been partly supplied from the domestic steel producers, medium and heavy sections more than 80mm in size are mainly imported. It is estimated that high carbon steel and alloy steel sections are now imported for the engineering industries, but their imports are not large in quantity.

Table 3.3.5 Imports of Section and Rails

(Unit: 1,000 tonnes, %)

	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Medium and Heavy	LCS	1.2	0.7	2.4	10.2	15.3	8.6	9.8	4.7	21.5
Sections (Larger than 80mm)	HCS+AS	0.1	0.1	0.1	1.4	0.1	7.2	7.5	0.1	0.0
Light Sections	LCS	0.6	2.3	3.8	7.2	6.7	4.2	3.6	1.2	10.4
(Smaller than 80mm)	HCS+AS	0.1	0.2	-	0.8	0.3	-	0.5	-	-
Rails	*LCS	2.7	0.5	1.2	24.4	18.6	7.6	25.4	39.0	46.4
Total	LCS	4.5	3.5	7.4	41.8	40.6	20.4	38.8	44.9	38.9
	HCS+AS	0.2	0.3	0.1	2.2	0.4	7.2	8.0	0.1	-9.4
	Total	4.7	3.8	7.5	44.0	41.0	27.6	46.8	45.0	38.1

Source: Sames as Table 3.3.1

Note: * Rails are estimated as LCS

(b) Flat steel products (Group III)

Flat steel products are largely classified into: uncoated plates; uncoated sheets, hoops and strips; coated plates and sheets; rerollable coils used mainly as raw materials for welded pipes; and welded pipes (Welded pipes are included in this category because their materials are plates and/or sheets.).

The development of imports of flat steel products based on this classification system is shown in Table 3.3.6. As for the uncoated plates, though low carbon steel products have increased, high carbon steel and alloy steel products have shown a declining tendency. Therefore, there is no marked increase in the total imports of uncoated plates. Also as for the uncoated sheets, hoops and strips, high carbon steel and alloy steel products have shown a tendency similar to that of uncoated plates. However, since low carbon steel products have shown a marked increase at an annual growth rate of as high as 21% in the past seven years, total imports of uncoated sheets, hoops and strips have also increased sharply.

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Table 3.3.6 Imports of Flat Steel Products

(Unit: 1000 tonnes %)

	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Uncoated Plates	LCS	7.2	9.3	9.3	19.2	14.3	9.6	7.5	16.0	12.1
	HCS+AS	11.3	8.4	8.9	3.9	0.9	1.5	0.6	5.3	-10.3
Uncoated Sheets, Hoops, and Strips	LCS	69.3	157.8	106.8	111.9	180.5	170.3	172.3	257.8	20.6
	HCS+AS	25.3	15.4	18.0	6.1	7.6	6.3	8.5	10.9	-11.3
Sheets		80.2	124.4	85.4	107.8	184.1	172.0	175.5	263.6	18.5
Hoops & Strips		14.4	48.8	39.4	10.2	4.0	4.6	5.3	5.1	-13.8
Rerollable Coils	LCS	0.6	4.8	6.5	8.6	1.1	0.5	43.4	11.5	52.5
	HCS+AS	1.5	30.7	0.3	-	-	6.4	0.1	-	-
Uncoated Plate & Sheets Sub-Total	LCS	77.1	171.9	122.6	139.7	195.9	180.4	223.2	285.3	20.6
	HCS+AS	38.1	54.5	27.2	10.0	8.5	14.2	9.2	16.2	-11.5
Coated Plate & Sheet	*LCS	65.9	71.3	66.8	50.1	70.8	78.1	108.2	128.7	10.0
Galvanized	*LCS	34.5	37.1	20.8	30.6	33.3	39.2	51.5	51.6	5.9
Tinned	*LCS	31.3	33.6	44.0	19.5	37.4	38.9	56.6	77.1	13.7
Other	**LCS	0.1	0.6	2.0	-	0.1	-	0.1	-	-
Welded Pipes	*LCS	13.7	14.8	26.0	53.7	93.1	16.1	30.3	31.0	12.4
Total	LCS	156.7	258.0	215.4	243.5	359.8	274.6	361.7	445.0	16.1
	HCS+AS	38.1	54.5	27.2	10.0	8.5	14.2	9.2	16.2	-11.5
	Total	194.8	312.5	242.6	253.5	468.3	288.8	370.9	461.2	13.1

Note: * Estimated as LCS ** Although small quantity of Alloy Steel is included, all are assumed as LCS.

Source: Same as Table 3.3.1

The total imports of uncoated plates and sheets calculated by adding rerollable coils to these products have nearly trebled in seven years from 116.2 thousand tonnes in 1972-73 to 301.5 thousand tonnes in 1979-80.

The total imports of coated plates & sheets with galvanized plates & sheets, tinned plates & sheets and other coated sheets added have doubled in seven years from the level of 1972-73 to 128.7 thousand tonnes in 1979-80 at an annual growth rate of 10%, backed up by the steady increase in the imports of tinned plates & sheets.

The import of welded pipes has also shown a comparatively favorable growth and reached 31 thousand tonnes in 1979-80.

The imports of these flat steel products in total have increased markedly from 195.8 thousand tonnes in 1972-73 to 461.2 thousand tonnes in 1979-80 at an average annual growth rate of 13%.

By the way, the data having been described hereinabove are based on the "Foreign Trade Statistics of Pakistan" published by the Statistical Division, Government of Pakistan, this data does not indicate the imports of uncoated sheets, hoops and stripes classified into hot rolled products and cold rolled products. Therefore, we will clarify this point here according to the IISI's (International Iron and Steel Institute) "World Steel Exports". This data was obtained from the statistics of major steel exporting countries of the western world. The results obtained are given in Table 3.3.7. According to this table, the imports of uncoated sheets, hoops and strips amount to 268.7 thousand tonnes in 1979-80, 95% of which is held by the cold rolled products. However, the coverage by IISI being about 50%, the breakdown of remaining about 50% of imports mainly from East European countries is unknown. Since the assumption that hot rolled products hold the majority in these about 50% unknown imports is undeniable, figures as given in Table 3.3.7 are only for reference.

Table 3.3.7 Imports of Hot Rolled Products and Cold Rolled Products in Uncoated Sheets, Hoops, and Strips

(Unit: 1000 tonnes, %)

	1976-77	1977-78	1978-79	1979-80
Hot Rolled	53.1 (28.2)	28.4 (16.1)	13.7 (7.6)	13.0 (4.8)
Cold Rolled	135.0 (71.8)	148.2 (83.9)	167.1 (92.4)	255.7 (95.2)
Uncoated Sheets, Hoops and Strips Total	188.1 (100.0)	176.6 (100.0)	180.8 (100.0)	268.7 (100.0)

Source: Table 3.3.7 & IISI.

Notes: 1) Total figures come from Table 3.3.6. The percentage of each products to the total comes from IISI.

2) Export statistics of IISI sum statistic of the 13 main western countries.

Table 3.3.8 Imports of Ingots, Billets etc.

(Unit: 1000 tonnes)

	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Billets	LCS	33.6	35.0	72.5	27.5	90.2	111.0	112.9	99.5	16.8
	HCS+AS	80.6	46.7	44.5	6.0	13.4	19.1	9.0	4.9	-33.0
	Sub-Total	114.2	81.7	117.0	33.5	103.6	130.1	121.9	104.4	-1.3
Ingots, Sheet Bars etc.	LCS	0.2	0.1	0.3	2.1	9.1	5.9	1.2	0.8	21.9
	HCS+AS	0.2	0.1	0.1	0.4	0.0	0.1	0.3	0.0	-
	Sub-Total	0.4	0.2	0.4	2.5	9.1	6.0	1.5	0.8	10.4
Total	LCS	33.8	35.1	72.8	29.6	99.3	116.9	114.1	100.3	16.8
	HCS+AS	80.8	46.8	44.6	6.4	13.4	19.2	9.3	4.9	-33.0
	Total	114.6	81.9	117.4	36.0	112.7	136.1	123.4	105.2	-1.2

Source: Same as Table 3.3.1

(c) Ingots, billets, etc. (Group IV)

As already mentioned in Subsec. 2.3.1, in Pakistan domestic rerollers are producing bars and sections using the imported billets, etc. Billets are under the import control by Trading Corporation of Pakistan (TCP) together with pig iron, etc. The change of imports of ingots, billets, etc. in the past is shown in Table 3.3.8. Likewise the case of other steel products, decrease of high carbon steel and alloy steel products and increase of low carbon steel products are clearly indicated in this table.

(2) Development of imports of other iron and steel products

Other iron and steel proudcts such as iron castings, steel castings, tubes and pipes of cast iron are also imported, though small in quantity. The change of their imports is shown in Table 3.3.9. In 1979-80, their imports are very small in quantity as much as 6.4 thousand tonnes in total in which tubes and pipes of cast iron are predominant. In the average year, tubes and pipes of cast iron are imported in the quantity of about 1.5 to 2.0 thousand tonnes nearly same as that of iron castings and steel castings.

Table 3.3.9 Imports of Tubes & Pipes of Cast Iron, Iron Castings, Steel Castings and Iron & Steel Forgings

(Unit: 1000 tonnes, %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Tubes & Pipes of Cast Iron	0.9	0.8	0.4	0.3	1.8	1.1	0.1	5.0	28.1
Iron Castings	0.1	0.4	1.1	0.6	1.5	0.8	1.1	1.1	40.9
Steel Castings	-	0.1	0.5	2.5	1.5	2.0	0.9	0.4	-
Iron & Steel Forgings	0.1	0.2	-	-	-	0.1	-	-	-
Total	1.1	1.5	2.0	3.4	4.8	4.0	2.1	6.5	28.9

Source: Same as Table 3.3.1

Table 3.3.10 Imports of Scrap, Pig Iron and Ships for Breaking up

(Unit: 1000 tonnes, Rs million, %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Scrap	50.1 (85.7)	48.2 (53.4)	131.9 (202.7)	136.2 (190.1)	123.8 (145.6)	210.6 (246.3)	113.6 (118.0)	213.2 (271.3)	23.0 (17.9)
Pig Iron	43.3	17.9	117.7	27.7	11.7	8.5	38.5	47.2	1.2
Pig Iron, etc.	49.2 (68.1)	21.8 (37.1)	125.3 (280.4)	31.4 (64.1)	16.3 (38.9)	15.5 (46.8)	44.4 (96.3)	67.9 (146.1)	4.7 (11.5)
Ships for Breaking up	(8.4)	(4.6)	(11.9)	(22.8)	(122.7)	(293.2)	(170.8)	(31.9)	(21.0)
Total	(162.2)	(95.1)	(495.0)	(277.0)	(307.2)	(586.3)	(385.1)	(449.3)	(15.7)

Source: Same as Table 3.3.1

Note: The figures inside ( ) show the value.

3.3.2 Development of Imports of Scrap, Pig Iron and Ships for Breaking Up

The change of imports of scrap, pig iron and ships for breaking up is shown in Table 3,3.10. Pig iron is supplied to number of domestic engineering industries where it is made into various kinds of mechanical parts as iron castings. Its import is under the control of TCP together with billets. Although the import of pig iron amounts to 47.2 thousand tonnes in 1979-80, it has so far been subject to sharp fluctuations.

Scrap is supplied to domestic steel melters as one of steelmaking raw materials and to re-rollers of bars and sections as rerollable scrap. Because of its changeable price, scrap is subject to heavy fluctuations also in volume of imports. However, its import has generally been moving with the change in import of billets so as to be complementary to each other in quantity. Since construction activities have [illegible]cent been comparatively brisk, its import in 1979-80 reached the recordbreaking level of 213.2 thousand tonnes.

Although ships for breaking up as one of iron sources in Pakistan have been playing a great role in steel-making as meltable scrap and rerollable scrap, their weight can not be determined from customs statistics. According to the Pakistan Shipbreakers Association, the import of ships for breaking up on a scrap basis amounted to 450 thousand tonnes in 1978-79 and 100 thousand tonnes in 1979-80. In 1980-81, it does again show a sharp increase to the level of 35 thousand tonnes on a monthly basis, that is, 420 thousand tonnes on a yearly basis. This is due to the reason that import duties and sales tax on them were reduced from the former rates of 62% to 30% on July, 1980, while the demand for them was, of course, brisk. In the customs statistics, the sum of ships for breaking up imported is given. From this, it can be clearly understood that the import of such ships increased rapidly from 1976-77 towards the peak of 1977-79 and then declined sharply up to 1979-80.

The main supplying countries of these items in 1979-80 are as follows. The main supplying countreis of pig iron are Brazil, United Kingdom, China and Poland. They supplied 10 to 12 thousand tonnes, respectively. In the past, pig iron was supplied also from Japan, USSR, etc. As for scrap, nearly 70% of the total is supplied from Middle East centering around UAE (Dubai), Kuwait, Bahrain, etc. As for ships for breaking up, they are supplied from Lebanon, Liberia, UAE (Dubai), France, etc. In the peak year of 1977-78 in the past, the main supplying countreis of them were United Kingdom, Federal Republic of Germany, Greece and Singapore. These countries vary markedly with year.

3.3.3 Development of Expenditure for Iron and Steel Products and Scrap Imports

The change of expenditure for iron and steel products and scrap imports and total imports is shown in Table 3.3.11. In 1979-80, the expenditure of Pakistan for iron & steel products and scrap imports including ships for breaking up totals to Rs 3,094.1 million. While the expenditure for total exports in this year amounts to Rs 46,929.1 million, the former accounts for 6.6% of the latter. Although this ratio was held at 9 to 10% from 1972-73 to 1976-77, it has recently been somewhat lowered.

Table 3.3.11 Expenditure for Iron & Steel and Scrap Imports and Total Imports

(Unit: Rs million , %)

		1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
A.	Iron & Steel Products	737.8	1,002.3	1,983.1	1,514.0	1,717.0	1,522.2	2,085.5	2,790.9	20.9
	Pig Iron, etc.	68.1	37.0	280.4	64.1	38.9	46.8	96.3	146.1	11.5
	Steel Products	665.0	958.1	1,682.8	1,400.0	1,653.1	1,452.2	1,974.6	2,598.8	21.5
	Iron & Steel Casting & Forging	4.7	7.2	19.9	49.9	25.0	27.2	14.6	46.0	38.5
B.	Iron & Steel Scrap	85.7	53.4	202.7	180.1	145.6	246.3	118.0	271.3	17.9
C.	Ships for Breaking up	8.4	4.6	11.9	22.8	122.7	293.2	170.8	31.9	21.0
	A + B + C	831.9	1,060.3	2,197.7	1,726.9	1,985.3	2,061.7	2,374.3	3,094.1	20.6
D.	Total Import	8,398.3	13,479.2	20,925.5	20,465.3	23,012.2	27,814.7	36,388.1	46,929.1	27.9
	(A + B + C) / D (%)	9.9	7.9	10.5	8.4	8.6	7.4	6.5	6.6	-
E.	Foreign Trade Deficit	-152.9	3,318.0	10,638.7	9,212.4	11,718.3	14,834.3	19,463.1	23,519.0	-

Source: Same as Trable 3.3.1

3.4 Analysis of Pakistan's Steel Consumption

In this section, Pakistan's steel consumption is analyzed from the following aspects:

- Present apparent steel consumption (ASC)
- Present steel consumption by product categories
- Present steel consumption by industrial sectors
- Present steel consumption by regions

3.4.1 Present apparent steel consumption

The development of Pakistan's ASC viewed from the aspects of imports, domestic production is shown in Table 3.4.1. According to this table, Pakistan's ASC in 1979-80 is estimated at 1,340 thousand tonnes. In these seven years, it has increased at an average annual growth rate as high as 10.1%, though showing heavy fluctuations. Otherwise it must be memorized that the level of steel consumption in 1972-73 was very low because of economical confusion after the war with India in 1971 and recession of the former East Pakistan. ASC per capita also showed an increase from 10kg in 1972-73 to 17kg in 1979-80. Since steel is considered an essential basic material for all industries, steel consumption of a nation is deeply concerned with the general economy in the nation and is generally said to have a high correlationship with GDP. In this connection, the correlation between Pakistan's ASC and GDP was calculated out and shown in Fig. 3.4.1. From this figure, it is obvious that these two are deeply concerned with each other.

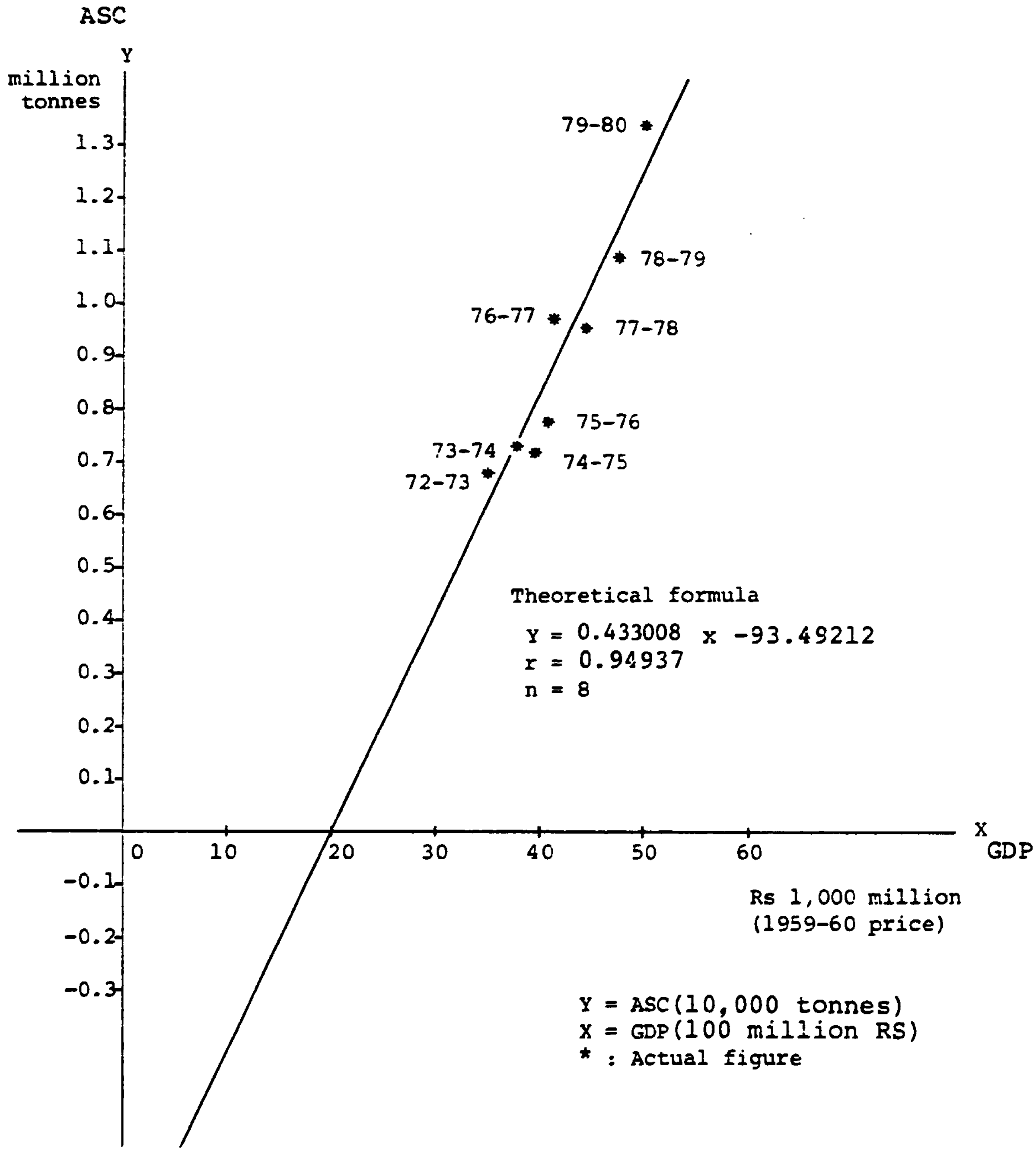


Fig. 3.4.1 Correlation between ASC and GDP in Pakistan

Table 3.4.1 Apparent Steel Consumption

(Unit: 1,000 tonnes, %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
I. Steel Imports	437.7	432.0	413.7	381.0	561.5	508.1	580.1	659.6	9.6
a Semi-finished Products	116.7	117.4	124.2	44.6	113.8	143.0	166.9	116.7	0.0
b Finished Products	321.0	314.5	289.0	333.9	446.2	363.1	412.2	542.5	7.8
c Steel Castings	0.0	0.1	0.5	2.5	1.5	2.0	0.9	0.4	-
II. Steel Import (CSE)	500.4	493.7	471.2	442.3	646.3	579.8	661.5	761.4	6.2
a Semi-finished Products	122.8	123.6	130.7	46.9	119.8	150.5	175.7	122.8	0.0
b Finished Products	377.6	370.0	340.0	392.8	524.9	427.2	484.9	638.2	7.8
c Steel Castings (CSE)	0.0	0.1	0.5	2.6	1.6	2.1	0.9	0.4	-
III. Domestic Steel Production (CSE)	306.8	363.8	373.7	384.8	449.7	526.0	604.5	701.3	12.5
IV. Apparent Steel Consumption III + II b + II c (CSE)	684.4	733.9	714.2	780.2	976.2	955.3	1,090.3	1,339.9	10.1
Growth Rate of ASC (%)	-	7.2	-2.7	9.2	25.1	-2.1	14.1	23.3	-
ASC per Captita (kg/person)	10	11	10	11	13	13	14	17	-

Notes: I a includes ingots, billets and rerollable coils etc.
I a ÷ 0.95 (Yield) = II a
I b ÷ 0.85 (Yield) = II b
I c ÷ 0.95 (Yield) = II c
III shows the same figure of Table 3.2.2
ASC per capita is calculated by deviding by the population of Table 1.2.1

Indirect steel imports are not included in this ASC. Although Pakistan is importing considerably large amount of steel consumed goods such as capital goods and durable consumer goods, it involves much difficulty to totalize these indirect steel imports. The data formulated by IISI (International Iron and Steel Institute) in 1976 is shown in Appendix to 3-2 for reference. According to this data, the volume of indirect steel imports of Pakistan amounts to 97.5 thousand tonnes. Since this IISI's data was formulated on the basis of export statistics of 14 western advanced countries, it is assumed that in Pakistan much more indirect steel imports than this data may be included because not a few capital goods are imported from socialist countries.

3.4.2 Present steel consumption by product categories

Pakistan's steel consumption by product categories in 1979-80 determined from Subsec. 3.2.2 and 3.3.1 is shown in Table 3.4.2.

Table 3.4.2 Steel Consumption by Products Categories

(Unit; 1,000 tonnes, %)

Products Categories	(1,000 tonnes)	(%)
Non-flat Products	666.8	57.9
Bars and Wire Rods	399.9	34.7
Sections	206.0	17.9
Rails	39.0	3.4
Wires	20.1	1.7
Seamless Tubes	1.8	0.2
Flat Products	484.7	42.1
Uncoated	305.0	26.5
Plates	21.3	1.9
Sheets, hoops and strips	283.7	24.6
Coated	128.7	11.2
Galvanized	51.6	4.5
Tinned	77.1	6.7
Welded Pipes	51.0	4.4
Total	1,151.5	100.0

On the other hand, special steel consumption is estimated at 30 thousand tonnes in 1979-80, being very small in quantity as much as 2.7% of total steel consumption. It is estimated that the present consumption of steel forging and foundry is 26 thousand tonnes, and that of iron foundry is 121 thousand tonnes.

3.4.3 Present steel consumption by industrial sectors

Many relevant basic data for the analysis of steel consumption by industrial sectors were widely and eagerly sought for. However, the existing production statistics by industrial sectors in Pakistan are at such a low level as described in Section 1 and thus quite insufficient for our analysis. On the other hand, personal visits to selected enterprises and interviews with the managerial staff were made. Steel consuming enterprises and corporations including those belonging to the tubes and pipes manufacturing industry to which personal visits were made were more than 15 in number. The answers to the questionnaire given from such enterprises and corporations are tabulated in Appendix to 3-4. Frequent visits were also made to the federal and state authorities in charge of control of information as to the steel consuming industries. On the other hand, visits were also made to steel melters and re-rollers to ask them some questions on the customers of their products. As a result, some information about steel consumption was obtained for the following major industrial sectors:

- Construction industries
- Machinery and equipment manufacturing industries
- Metal processing industries
- Automobile industries
- Others

(1) Construction industries

The comprehensive statistics indicating the construction activities in Pakistan is only "Construction" in Gross National Product as given in the National Accounts of Pakistan. As reference statistics, "Gross fixed capital formation" is available. This sector is the largest consumer of non-flat steel products such as bars and sections.

Turning to the present building construction activities*, general housing in the urban areas is built of concrete blocks, and concrete bars are also used in it though small in quantity. However, houses in the local districts are, for the most part, built of brick or clay. Therefore, it is rarely the case that steel bars are used for housing construction in the lcoal districts.

Non-residential buildings found in abundance in the urban areas are, for the most part, built of reinforced concrete, not only for their columns, but also for their beams. Therefore, few cases are known where steel sections are used in such buildings.

Note: * As for the present building construction activities, more detailed mention is made of cost and expenses for materials, labours, etc., invested or used in such activities in Appendix to .

Factory buildings have conventionally been built of reinforced concrete also for their beams. However, such cases where steel sections such as I-beams are used for their beams have often been met with recently. If this tendency on the user side becomes more marked and when the capacity of domestic steel rollers for supplying steel sections is also expanded, there is a very great possibility of steel sections being popularly used also in general buildings as their beams.

In the civil engineering field, steel bars of comparatively high grade manufactured from imported billets of guaranteed quality are used for construction of dams, bridges, canals, harbours, power plants, waterworks and sewerages.

Change of cement production is shown in Table 3.4.3, which will be an indicator for the level of building construction activities and steel bars consumption.

Table 3.4.3 Cement Production

(Unit: 1,000 tonne, %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Growth Rate
Production	2,876	3,145	3,320	3,196	3,071	3,224	3,022	3,343	2.4
Growth Rate %	-	9.4	5.6	-3.7	-3.9	5.0	-6.3	10.6	-

Source: Pakistan Statistic Year Book

In this sector, steel structures such as tanks and transmission line towers (ordered mainly from WAPDA) are also consumed. In the recent Pakistan Steel Project, many steel structures were supplied by

Pakistan Steel Fabricating Company. Large-sized steel structures are supplied mainly by Pakistan Engineering Co. (Lahore), Quality Steel Works Ltd. (Karachi) and Karachi Shipyard & Engineering Works (Karachi) in the public sector as well as Nowshere Engineering Company Ltd. moved from the public sector to private sector in 1978. The supplying capacity of these four companies in total is estimated at 37 thousand tonnes per year. Provided that Karachi Shipyard & Engineering Works is not engaged in manufacture of transmission line towers at present. Small-sized steel structures are manufactured by many companies in the private sector. Minor companies including steel doors and windows manufacturers are scattered in large numbers all over the country. According to the Investment Promotion and Supplies, Government of Pakistan, it is estimated that they have an annual production capacity of as much as 200 thousand tonnes. However, the utilization rate is estimated to be less than 30% as a whole

The import of steel structures suddenly increased to 111 thousand tonnes per year in 1976-77 with the climax of the Pakistan Steel Project, though it was formerly at the level of less than 20 thousand tonnes per year. Then, it declined to 66 thousand tonnes in 1977-78 and 38 thousand tonnes in 1978-79, but increased again in 1979-80 to 142 thousand tonnes.

(2) Machinery and equipment manufacturing industries

As already mentioned in Chapter 1, this sector is still undeveloped in Pakistan. Since a wide variety of products are manufactured in this sector, there are no available dynamic statistics of production covering the whole of this sector. Products of this sector are described here with division of them into electrical machinery and goods, and machinery other than electrical.

(a) Electrical machinery and goods

In this field, the only product which production can be statistically grasped is an electric fan. Its production in 1979-80 amounted to 67 thousand units of pedestal fans, 201 thousand units of ceiling fans and 2.4 thousand units of table fans. In addition, the following products seem to be in domestic production:

- Electric transformers, switchgears, generators, motors and fans
- Industrial and domestic airconditioners and refrigerators
- Electric wires and cables
- Electric meters and other electrical measuring instruments
- Electrical appliances, accessories and fittings
- Accumulators and dry cell batteries

- Welding electrodes, electric lamps and tubes

- Capacitors (condenser)

- Insulators and electrical insulation materials

According to the data obtained from the authorities concerned, in 1976-77 units which are supplying, among products enumerated above, those connected with steel consumption are as follows:

Product Categories	Units
Switchgear	9
Transformer	8
Industrial & domestic airconditioners	1
Electric motors	31
Electric fans	140
Electric appliances, accessories and fitting	52
Dry cell and dry batteries	10
Accumulators	8
Electric lamps and search lights, etc.	5
Electric energy meters	3

The utilization rate seems to fall within the range of 20 to 50% on one-shift basis in most cases, though it is held nearly at 100% in some companies.

The reasons for low utilization are:

i) Shyness in the past on the part of the entrepreneurs to make maximum investment in plant and equipment for the purposes of balancing and modernization.

ii) The industry suffers from lack of adequate Working Capital which has been aggravated further due to the squeeze on bank credit. This reflects itself in low inventories of raw material maintained by the units leading to unnecessarily long delivery period.

iii) Non-availability of raw material at the right time and at reasonable prices.

iv) Fiscal anomalies in the rates of duties and taxes on materials being higher in comparison to those on some imported finished goods.

v) The labour situation also, at time, affects the rate of capacity utilization.

The imports of electrical machinery in 1979-80 are as follows:

Categories	Rs million
Electrical power machinery	314.3
Switchgear	247.1
Domestic electric equipment	112.1
Automotive electric equipment	24.4
Other electrical machinery	162.9
Total	860.8

Source: Foreign Trade Statistics of Pakistan

(b) Machinery other than electrical

This sector covers a very wide range of machinery. Likewise the electrical machinery, a wide variety of products are now being produced in large quantities in Pakistan. However, only the production of sewing machines can be grasped by the dynamic statistics of production. The production of sewing machines in 1979-80 amounts to 67.3 thousand units, being nearly at the same level as in 1972-73. According to the information obtained from the authorities concerned, major items of machinery other than electrical as well as installed capacity and utilization for them were surveyed and reported in 1976-77. The results obtained are given in Table 3.4.4. Although there is a capacity for supplying a very wide variety of machinery, the utilization rate is estimated at as much as 20 to 50%. The reasons for such low utilization rate are:

i) Wide fluctuations in demand of capital goods.

ii) Limited market size denying the benefit of economy of scale in production

iii) Dependence on imported raw materials and spares

iv) Resource constraints

v) Unfair competition with similar imported goods

vi) Fiscal anomalies

vii) Dearth of ancillary industries

Table 3.4.4 Installed Capacity and Utilization of Machinery other than Electrical in 1976-77

Item	Installed Capacity	Utilization (%)
1. Disel engines (Slow speed, medium & high speed, vehicle type)	23,800 units	44
2. Petrol engines	400 "	-
3. Low pressure package boilers	60 "	25
4. Wheat thrashers	4,000 "	25
5. Spraying machines	27,250 "	-
6. Centre lathes	3,400 Nos	17 (items 6–7)
7. Turret lathes	70 "	
8. Milling machines	160 "	60
9. Drilling machines	2,200 "	17 (items 9–13)
10. Shapers and Planers	150 "	
11. Grinding machines and Crankshaft grinders	200 "	
12. Power presses, guillotine shears	150 "	
13. Power Saws	150 "	
14. Power looms	6,000 "	40
15. Ring spindles	120,000 units	-
16. Household sewing machines	150,000 "	50
17. Cone winding machine	50 "	-
18. Printing machinery	350 "	26
19. Flour and rice milling other grain processing plants, oil expellers, cotton ginning plants, etc.	150 million RS	-
20. Road rollers	250 Nos	40
21. Sugar mill machinery		
22. Cement mill machinery	12,000 tonnes	50
23. Chemical, Petro-chemical, Fertilizer mill machinery		
24. Pumps and compressors	23,000 units	-
25. Anti-friction bearings	1.6 million Nos	-

Source: Governmental Information

viii) Shortage of skilled manpower; and its continued migration to oil rich countries

ix) Fast obsolescence of technology

x) Import of plant and machinery which can be produced locally

Against the total domestic demand for machinery other than electrical, the domestic supply rate is said to be 32% in 1972-73 and 25% in 1973-74. The Government expects that this rate will be raised to 40% in the future.

Late visit was made to the representative enterprises in the public sector such as Heavy Mechanical Complex, Pakistan Machine Tool Factory and Pakistan Engineering Co. which were established to be a main force for the development of capital goods manufacturing industry in this country. The utilization rate in these enterprises is generally low as much as 30 to 40%, though it is held nearly at 70% in some companies. On the other hand, the imports of machinery other than electrical have recently shown an increasing tendency, as is indicated in Table 3.4.5.

According to the foregoing, although the domestic supply rate against the total demand for machinery other than electrical can not be grasped accurately, it is impossible to presume that such rate has recently been raised, because the reasons for low utilization as mentioned above do not seem to have recently been eliminated.

3.5.7

Table 3.4.5 Imports of Machinery other than Electrical

(Unit: Rs million, %)

	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
Power Generating Machinery	40	146	377	128	259	204	458	413	39.6
Agricultural Machinery and Implements	73	201	383	534	837	939	1,090	1,480	53.7
Office Machines	20	35	35	50	43	78	108	80	21.9
Metal Working Machine	22	66	25	62	48	65	62	92	22.7
Textile & Leather Machinery	214	243	323	714	581	573	505	635	16.8
Machines for Special Industries	79	122	366	407	547	574	528	540	31.6
Machinery and Appliances and Parts	292	293	562	901	996	1,713	1,505	2,349	34.7
A. Total - Machinery other than Electrical	740	1,106	2,071	2,796	3,311	4,146	4,256	5,589	33.5
B. Total - Import of the Country	8,398	13,479	20,925	20,465	23,012	27,815	36,388	46,929	27.9
$\frac{A}{B}$ (%)	8.8	8.2	9.9	13.7	14.4	14.9	11.7	11.9	-

Source: Same as Table 3.3.1

(3) Metal processing industries

As for this sect a) steel pipes, b) steel wire products, c) bolts, nuts and washers, and d) tin cans are described here. At present, there exists neither tinning industry nor steel sheets galvanizing industry in Pakistan, though galvanized pipes are produced partly.

a) Steel pipes

At present, seamless tubes required for oil and gas production and in the process type industries such as chemical fertilizers manufacturing industry are not produced in Pakistan. Pipes now available in Pakistan are welded steel pipes and cast iron pipes. There are two kinds of welded steel pipes, i.e., electric welded pipes and spiral welded pipes, both of which are now in domestic production. Electric welded pipes now available in Pakistan are, for the most part, medium- or small-sized MS pipes ranging from 15 to 150mm in diameter. In the public sector, Karachi Pipe Mills (Karachi), Pakistan Engineering Co. (Lahore) and Pioneer Steel Mills (Lahore) are producing these pipes. These pipes are shipped by such companies after they have been galvanized. The total annual production capacity of these three major manufacturers now exceeds 44 thousand tonnes, but the production results of these companies total to about 13.5 thousand tonnes. Therefore, the utilization rate is now at the level of about 30%. As for the end use of these pipes, the pipes of higher grade are delivered to Sui Northern Gas Pipelines as a gas line pipe conforming to the API (American Petroleum Institute) Standards. Most of other pipes for general use are delivered as materials for lighting tubular poles and electric utility poles. In addition, these pipes are used as scaffolding pipes for construction work and as ones for water supply, but in small quantity. Also in the private sector, there are many electric welded pipe manufacturers mainly in the Lahore District. Only the pipe manufacturers existing in the Lahore District seem to have an annual production capacity of 23.5 thousand tonnes, but their utilization rate is estimated at as much as 20 to 30%.

Spiral welded pipes are produced only by a private manufacturer in Karachi, which has an annual production capacity of about 2,000 tonnes and is producing line pipes of 6 to 8" in diameter conforming to the API Standards to be delivered to Sui Northern Gas Pipelines. Because these pipes are mostly for special purposes requiring severe material quality and are produced in small lots, timely acquisition of their materials is very difficult, thus leading to the low utilization rate.

As for cast iron pipes, the mill having an installed capacity of 4,000 tonnes per year began its commercial operation at Northern Foundry Ltd. in 1975.

In addition, conduit pipes are produced by private manufacturers in the Lahore District having an annual production capacity of less than 2,000 tonnes, but their production results are unknown.

All of these pipe manufacturers depend on strip mills abroad for their raw materials.

b) Steel wire products

As for steel wire products, barbed wires, chain link fencing, hair pins, springs, wire netting, wire ropes, etc. are being produced in Pakistan. These products are supplied by great number of small industries which depend almost on the imports for their materials. These industries seem to have an annual production capacity of 95 thousand tonnes. Judging from the imported materials, the annual production is estimated less than 25 thousand tonnes, and the utilization rate is at about 25%. By the way, turning to the imports of steel wire products in 1979-80, the results are wire ropes 186 tonnes, wire cables 211 tonnes, fencing wires 44 tonnes, wire gauges 19 tonnes, nails 316 tonnes and spikes 4 tonnes.

c) Bolts, nuts and washers

The existing annual production capacity for these products including rivets, not only of steel, but also of copper is estimated to be 11.8 thousand tonnes. These products are also produced by number of small manufacturers in quantity of less than 2,500 tonnes. The imports of these steel products are small in quantity, that is, bolts 64 tonnes, nuts 25 tonnes, rivets 37 tonnes and washers 148 tonnes in 1979-80.

d) Tin cans

The annual production of vegetable ghee in Pakistan can be statistically grasped. It has shown a steady increase from 187 thousand tonnes in 1972-73 to 451 thousand tonnes in 1979-80, a growth by 2.4 times in seven years. 91% of domestic ghee production is supplied by Ghee Corporation in the public sector and remaining 9% is supplied by 6 units in the private sector. At Ghee Corporation, 16kg cans (0.29mm thick), 5kg cans (0.26mm thick) and 2.5kg cans (0.24mm thick) for ghee are all manufactured from tinned sheets. Its current consumption of tinned sheets per year amounts to 38 thousand tonnes. Accordingly, total consumption of these materials with the consumption in the private sector added to this amounts to 41.8 thousand tonnes.

Further, cans for lubricating oil, shoeblack, fruits, etc., are also produced in Pakistan using tinned plates and sheets and other coated sheets as principal materials. These cans are manufactured by Hashimi Can Co., Ltd., the representative manufacturer in the private sector, and others, where 1.6 thousand tonnes of tinned plates and sheets and other coated sheets are now consumed. Supported by the marked increase in demands for such cans, these companies are now proud of the utilization rate as high as 70%.

(4) Automobile industries

Companies belonging to this sector are under the control of Pakistan Automobile Corporation. Its affiliated companies being engaged in manufacture of automobiles and related products are listed as follows:

Company	Products
Awami Autos	Commercial vehicles, Passenger cars, Tractors
Bela Engineering	Diesel engines
Millat Tractors	Tractors
National Motors	Cars, Land cruisers trucks, Buses, Truck/bus bodies
Naya Daur Motors	Jeeps, Passenger cars
Pakistan Tyres	Tyres
Republic Motors	Trucks, Buses
Sind Engineering	Suzuki motorcycles, Pick-ups, Vans
Trailer Development	Bus bodies, Trucks, Trailers

Except a part of motorcycles now in domestic production, all products are manufactured on an assembly basis. The change in production results of these products is shown in Table 3.4.6. With three major projects, i.e., Suzuki Project (four-wheel), Hino Project and Suzuki Motorcycle Project envisaged by it as coming projects, Pakistan Automobile Corporation is eager to attain the goal of "sharp increase in domestic production rate". If these projects progress as scheduled, consumption of steel products is expected to reach 19.6 thousand tonnes three years later.

The number of assembled automobiles imported in 1979-80 given below for reference.

- Large trucks	4,700
- Buses	1,100
- Medium- & small-sized trucks	14,700
- Jeeps	1,600
- Passenger cars	11,200
- Tractors	17,900
- Total	51,200

Source: PACO

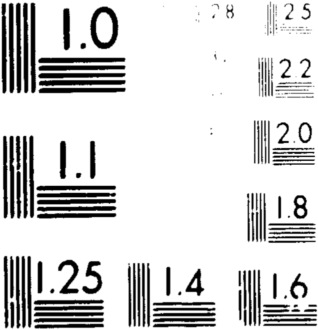
Table 3.4.6 Actual Production of Automobile Industry

(Unit: Numbers, %)

S. No.	Type	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-89	1979-80	Average Annual Growth Rate (%)
1.	Trucks	4,044	5,402	6,324	4,179	3,161	3,148	4,183	5,089	3.3
2.	Buses	464	2,798	2,802	1,983	1,037	520	1,176	1,930	22.6
3.	L. C. V.	1,036	1,603	2,613	2,112	1,927	1,394	8,347	5,963	28.4
4.	4 X 4 Vehicles	720	1,160	2,140	2,366	2,192	1,620	1,219	1,641	12.5
5.	Motorcycles	1,845	4,223	5,343	7,408	5,631	6,015	4,989	8,866	25.1
6.	Engines	-	2,077	6,467	2,839	2,681	1,868	4,769	5,898	-

Source: PACO

Note: All are on y assembly excluding engines and motorcycles.


1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

(5) Others

As one of other steel consuming industries, there is a bicycle industry manufacturing bicycles as a transport equipment other than automobiles. Production of bicycles is statistically grasped. It amounts to 211.7 thousand units in 1972-73, 280.1 thousand units in the peak year of 1978-79 and 279.4 thousand units in 1979-80. The representative bicycle manufacturer is PECO. However, they are also produced by manufacturers in the private sector existing mainly in the Lahore District. The bicycle industry consumes steel products such as sheets, bars and pipes & tubes, consumption of which is estimated at 4 to 5 thousand tonnes per year.

Karachi Shipyard and Engineering Works is the sole shipbuilding company in Pakistan. At the time of our visit, one 4,500-tonne bulk carrier was being built there. Although it has a shipbuilding capacity of 6,000 DWT/year per one shift in 3 berths, its utilization rate is very low as much as less than 20%. The ship repairs division seemed more brisk where two dry docks were all in operation. Although plates and sections are consumed in large quantities in this sector, this sector depends on the imports for all of these materials.

In addition, hand and small tools such as files, shovels, twist drills, hack-saws and blades are produced by number of small manufacturers. Although it is difficult to estimate the annual production capacity for these products, the government authorities estimate that the capacity will be about 15 thousand tonnes while its utilization rate is less than 30%. Furthermore, sporting arms seem to be produced by part of manufacturers existing in the North West Frontier Province and Punjab. However, its details are unknown.

In addition, building hardwares and steel furnitures are produced mainly in Karachi, but there are no detailed data on them.

Turning the eyes to the stainless steel consuming field, in advanced countries, stainless steel is generally used for kitchen utensils such as sinks, cooking tables, pots, frying pans, knives, and tablewares like forks and spoons by making use of its excellent properties in corrosion and heat resistance, durability and external appearance.

High resistant to corrosion and heat, and good in deep drawing works, stainless steel is further widely used in chemical industry, thermal industry and food industry.

Recently it is also used for decorating the exterior and interior of buildings and their doors.

In Pakistan, stainless steel sheets & plates and flat bars have been imported and used as the material for stainless steel tablewares, cutlery and surgical instruments. They have fairly long been processed at several places centering around Gujranwala and Sialkot in the north of Lahore. The processing work is performed by more than 500 small domestic factories which consume about yearly 100 thousand tonnes of stainless steel materials, mainly 18-8 and 13 Cr stainless steels.

Table 3.4.7 Estimate of Present Steel Consumption by Product Categories

(Unit: 1000 tonnes, %)

	Total		Agriculture		Manufacturing		Construction		Electricity, Gas & Water		Transport & Communication	
	1000 tonnes	%	1000 tonnes	%	1000 tonnes	%	1000 tonnes	%	1000 tonnes	%	1000 tonnes	%
Non-flat Products	666.8	100	18.6	2.8	64.4	9.6	428.0	64.2	64.6	9.7	91.2	13.7
Bars, Wire Rods and Wires	420.0	100	8.4	2	42.0	10	294.0	70	33.6	8	42.0	10
Sections	206.0	100	10.2	5	20.6	10	134.0	65	31.0	15	10.2	5
Rails	39.0	100	0.0	0	0.0	0	0.0	0	0.0	0	39.0	100
Seamless Tubes	1.8	100	0.0	0	1.8	100	0.0	0	0.0	0	0.0	0
Flat Products	484.7	100	31.6	6.7	422.9	87.2	26.5	5.4	2.6	0.5	1.1	0.2
Uncoated	305.0	100	29.0	10	258.7	84	16.2	5	0.0	0	1.1	1
Plates	21.3	100	0.6	3	17.5	82	2.1	10	0.0	0	1.1	5
Sheets, Hoops and Strips	283.7	100	28.4	10	241.2	85	14.1	5	0.0	0	0.0	0
Coated	128.7	100	2.6	2	113.2	88	10.3	8	2.6	2	0.0	0
Galvanized	51.6	100	2.6	5	36.1	70	10.3	20	2.6	5	0.0	0
Tinned	77.1	100	0.0	0	77.1	100	0.0	0	0.0	0	0.0	0
Welded Pipes	51.0	100	0.0	0	51.0	100	0.0	0	0.0	0	0.0	0
Total	1,151.5	100	50.2	4.4	487.3	42.3	454.5	39.5	67.2	5.8	92.3	8.0

Notes:
1) Manufacturing means Machinery & Equipment, Metal Processing, Automobile, By-cycle Shipbuilding, Household Applians, etc.
2) Construction means Electricity, Gas & Water and Transport & Communication excluding their facilities.
3) Electricity, Gas & Water means their facilities.
4) Transport & Communication means their facilities.
5) Agriculture means agricultual implements and packing materials for crops.

3.4.4 Present Steel Consumption by Regions

For the present steel consumption by regions, there are no production statistics for the steel consuming industries by regions and indicating the construction activities, now available in Pakistan. Fortunately, a report on the market survey by regions made by Pakistan Steel in 1981 could be got. There also is an estimate prepared by the Pakistan Steel Re-rollers' Association. The present steel consumption by regions arranged on the basis of these data is shown in Table 3.4.8 According to this table, 90% of the present steel consumption is held by the two states, Punjab and Sind. In particular for flat products, Punjab holds the share of more than 60%.

Table 3.4.8 Steel Consumption by Region

(Unit: 1,000 tonnes)

	Punjab	(%)	Sind	(%)	N.W.F.P.	(%)	Baluchistan	(%)	Total	(%)
Non-flat Production	306.0	(45.9)	286.1	(42.9)	58.0	(8.7)	16.7	(2.5)	666.8	(100)
Bars, Wire Rods and Wires	210.0	(50.0)	147.0	(35.0)	50.4	(12.0)	12.6	(3.0)	420.0	(100)
Sections	94.6	(38.6)	138.7	(56.6)	7.6	(3.1)	4.1	(1.7)	245.0	(100)
Seamless Pipes	1.4	(80.0)	0.4	(20.0)	0.0	(0.0)	0.0	(0.0)	1.8	(100)
Flat Products	300.0	(61.9)	176.2	(36.4)	7.9	(1.6)	0.6	(0.1)	484.7	(100)
Uncoated Plates and Sheets, etc.	186.1	(61.0)	116.5	(38.2)	2.1	(0.7)	0.3	(0.1)	305.0	(100)
Galvanized Sheets	33.2	(64.4)	15.9	(31.0)	2.4	(4.6)	0.1	(-)	51.6	(100)
Tinned Plates and Sheets	47.6	(61.7)	26.4	(34.3)	3.0	(3.9)	0.1	(0.1)	77.1	(100)
Welded Pipes	33.1	(65.0)	17.4	(34.0)	0.4	(0.8)	0.1	(0.2)	51.0	(100)
Total	606.0	(52.6)	462.3	(40.2)	65.9	(5.7)	17.3	(1.5)	1,151.5	(100)

Note: Section includes rails

3.5 Consideration

The status of production by domestic iron and steel industries, imports and consumption of iron and steel in Pakistan was described in the foregoing chapters. Here, trend in supply and demand of steel. trend in its prices, position of the steel consumption level in international comparison, etc. are given.

3.5.1 Trend in Supply and Demand of Iron and Steel

Table 3.4.1 shows the transition in the apparent steel consumption(ASC). Here, the domestic production ratio, import of steel and the percentage contributing to ASC are shown by Table 3.5.1. According to the Table, the current domestic production ratio against ASC is estimated to have exceeded 50% against 45% for the years 1972 to 1973.

(1978-79, 55%; 1979-80, 52%, provided that the domestic steel production rate is obtained by converting the finished steel products into CSE.)

While the percentage of steel and scrap imports contributing to ASC undergoes transition between 70 and 80%. These imports do not include scrap produced by ship-breaking. Thus, where they are included, the percentage may exceed by 80%.

When seen as above, Pakistan's steel industry is supplying a half of steel consumption of the country. But most of its steel resorces depend upon the imports,

Table 3.5.1 Apparent Steel Consumption and Selfsufficient Rate

(Unit: 1000 tonnes, %)

Items (CSE)	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80	Average Annual Growth Rate (%)
A. Apparent Steel Consumption	684.4	733.9	718.2	780.2	976.2	955.3	1,090.3	1,339.9	10.1
B. Domestic Steel Production	306.8	363.8	373.7	384.8	449.7	526.0	604.5	701.3	12.5
C. Steel Import and Scrap Import	548.5	540.0	597.9	573.1	765.2	782.0	770.6	965.1	8.4
$\frac{B}{A}$ %	44.8	49.6	52.0	49.3	46.1	55.1	55.4	52.3	
$\frac{C}{A}$ %	80.1	73.6	83.2	73.5	78.4	80.2	70.7	72.1	

Source: Table 3.4.1, Table 3.3.10

Note: Based on CSE.

Scrap imports is assumed to include 10% of rerollable scrap, and 90% of melting scrap.

3.5.2 Price Trend of Steel Products

(1) Domestic products

Steel products produced in Pakistan are generally bars and sections. The bars include round and deformed bars, and twisted ribbed bars such as torsteel. Among round bars, there are so-called first grade products rolled of semi-finished steel products such as imported billets guaranteed of their quality, and so-called second-grade products rolled of re-rollable scrap and domestic billets that are less guaranteed of their quality standard.

Therefore, the difference of their market prices is in the range of Rs 500 to Rs 1,000. In application, the first grade products are used for large-scale constructions, such as dams, bridges and high-rise buildings. While the second grade products are used for general constructions other than above.

Deformed bars and torsteels are of so-called first grade products, and they are thought to be of higher grade than the first grade round bars. So their prices are higher by approximately Rs 500 than the first grade round bars.

Sections include angles, channels and I-beams. Those prices fluctuate almost in linkage with the prices for round bars. For instance, angles are sold higher than round bars by Rs 500 to Rs 1,000, and channels and I-beams, by Rs 1,000 to Rs 1,500 in the market price.

Table 3.5.2 shows the present market prices found out at the local survey.

Table 3.5.2 Domestic Market Prices

Steel Products	Prices (Rs/tonnes)
Plain bars, first grade	6,000 to 6,500
Plain bars, second grade	5,000 to 5,500
Deformed bars	6,500 to 7,000
Torsteels	6,500 to 7,000
Angles	5,500 to 7,000
Channels	6,000 to 7,500
I-beams	6,500 to 7,500

Note: Checked by Local Survey

The prices of these domestic products are strongly subjected to the price fluctuation in the import scrap and the resultant fluctuation in the prices of semi-finished steel products. At the same time, they are greatly affected by the prevailing trend in steel demand represented by activities of the construction industry together with the trend in steel production by suppliers represented by melters, re-rollers and shipbreakers.

Thus, the prices of these products, mainly bars, fluctuate to a great extent in the international market, concurrently, their prices vary in a wide range in the domestic market in Pakistan due to the above-mentioned causes.

As shown in Table 3.5.3, after recording the steep rise in prices some period of time after the first

Oil Crisis, the prices had shown a relatively stable level thereafter.

However, the second Oil Crisis has had a big influence, and the domestic prices have started to rise greatly since the second half of 1979, and maintained the high level of prices until the first half of 1980. After the mid-80, the prices have been settled to some extent, as indicated by the market trend.

in turn, Pakistan is dependent upon the overseas for its steel consumption by 80% or greater.

Table 3.5.3 Wholesale Prices

(Unit: Rs /tonne)

	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Wholesale Prices (Karachi)						
MS Bar 1/2"	3,859	3,553	4,011	4,126	4,027	*5,264
3/8"	4,089	3,586	4,153	4,228	4,003	*5,910
1/4"	4,041	3,697	4,351	4,408	4,214	*5,940
MS Angle 2" x 2" x 1/4"	4,596	4,041	4,322	4,386	4,366	*6,191

Source: Statistics Division

Note:* Average from Jan. to Sept.

(2) Imports

The imported steel products are mainly billets as semi-finished steel products and flat products. The import prices for principal products including them are given on Table 3.5.4.

For comparison, Fig. 3.5.1 shows the trend in international market prices given by "Metal Bulletin".

Those steel products such as bars and angles are used to be imported relatively in a small lot and usually subject to special specifications. So that these imported prices do not reflect the international market prices. Where the comparison is limited to flat products, the Pakistan's import prices are found out to be matched to the trend of international market prices.

On the other hand, in comparison to the import prices, the domestic market prices can be thought to be kept at a considerably high level. Its may be caused mainly by import duty, physical distribution costs and intermediary margins to be incurred. As for import duties firstly, Pakistan's import tariff rates applied to semi-finished steel products is at 50% on the CIF price, and finished products, at 70%.

These rates are found out to be significantly higher than the level regulated by other

3-75

Table 3.5.4 Unit Prices of Main Steel Products Imported

(Unit: Rs/tonne)

Steel Product Category	SITC Code 67 -	Grade	1972-73	1973-74	1974-75	1975-76	1976-77	1977-78	1978-79	1979-80
Billets	2501	AS	1,395	1,846	3,213	2,819	2,849	2,823	2,115	2,772
Billets	2509	LCS	1,259	1,903	3,217	3,038	2,003	1,962	2,488	2,780
Wire Rods	3109	LCS	1,748	2,733	2,997	2,564	2,578	2,521	3,214	3,844
Bars	3209	LCS	3,194	4,231	4,600	3,803	3,839	2,990	5,880	4,650
Angles over 80mm	3409	LCS	2,549	3,278	4,835	2,930	3,250	3,467	4,672	5,044
Angles below 80mm	3509	LCS	2,298	3,348	4,250	2,691	3,274	1,377	4,020	5,786
Plates Heavy	4109	LCS	1,812	2,861	4,289	2,550	2,877	2,692	3,771	3,569
Sheets Heavy G.I.	4113	LCS	1,662	2,498	3,075	2,863	2,980	3,088	3,658	3,907
Sheets Heavy	4119	LCS	1,720	2,401	3,175	2,572	2,535	2,454	3,025	3,156
Sheets Med	4216	Stainless	10,574	11,542	12,518	10,399	10,406	13,516	13,095	12,579
Tinned Plates	4701	LCS	2,256	2,514	5,389	3,087	3,103	3,273	4,122	4,544
Hoops & Strips	5009	LCS	3,124	840	3,802	3,454	4,[illegible]	4,739	5,525	5,764
Wire	7009	LCS	3,454	5,073	8,850	9,578	5,463	4,527	7,586	6,850
Tubes & Pipes Seamless	8200		3,080	4,445	7,529	8,265	4,844	4,593	8,108	7,914
Tubes & Pipes Welded	8300		2,655	4,029	6,793	6,677	3,529	5,359	6,528	7,071

Source: Statistic Division

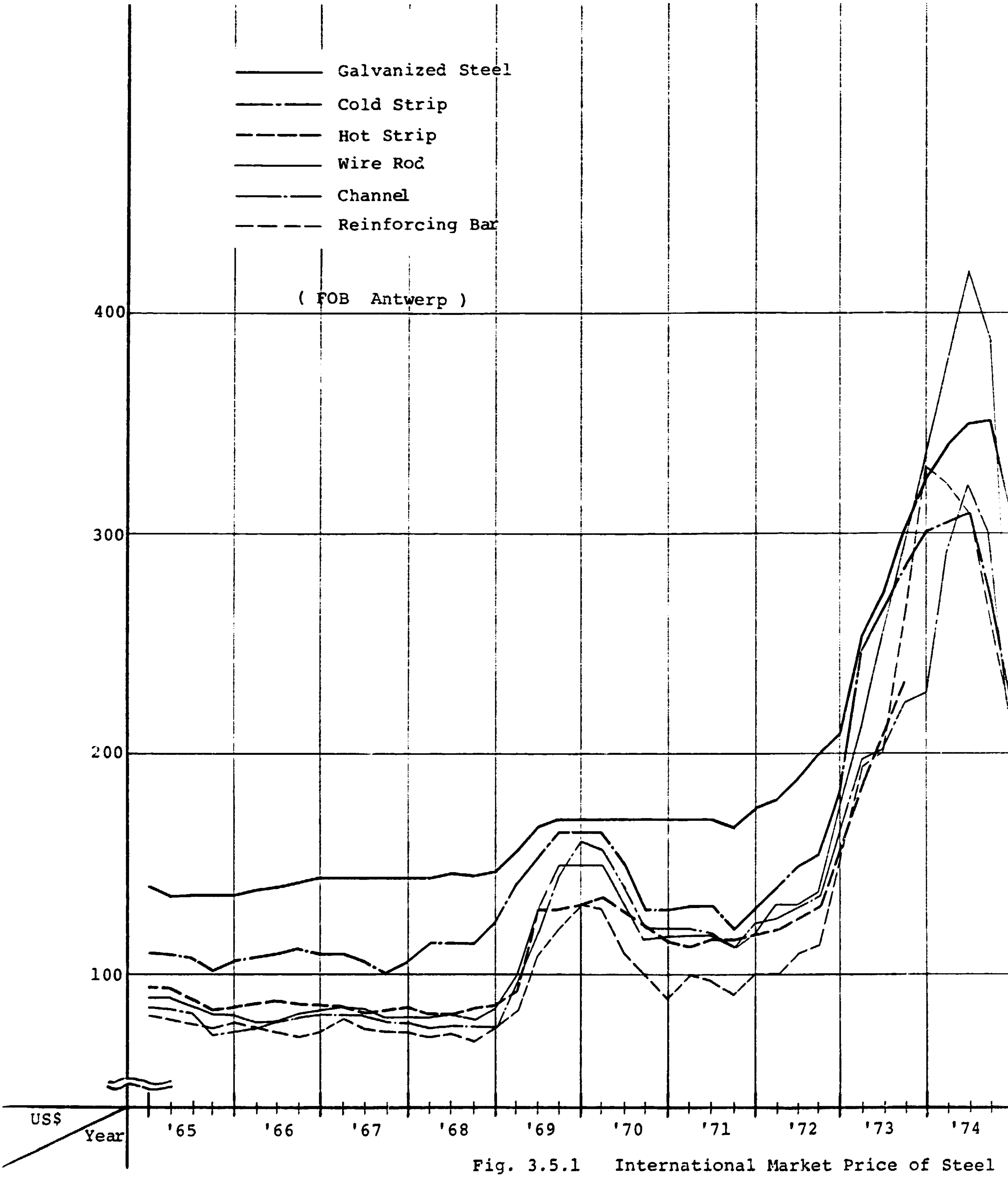
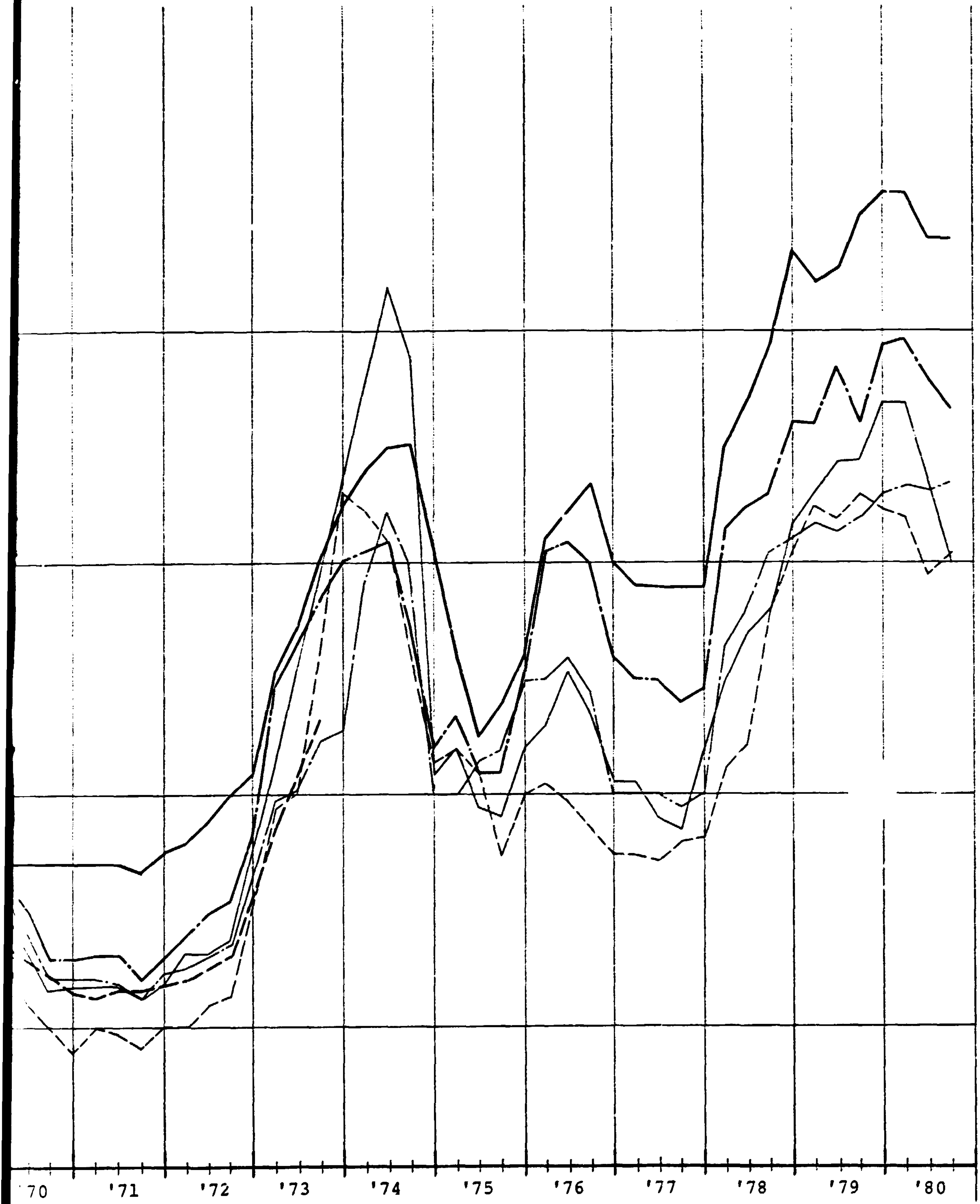


Fig. 3.5.1 International Market Price of Steel

SECTION 1



International Market Price of Steel Products

Source: Metal Bulletin
First issue of
Each Quarter

SECTION 2

developing countries as shown in Table 3.5.5. In addition, the suppliers have to pay 10% of the sales tax on the final selling prices.

Ther, the physical distrubution costs must be considered. The influence of such costs are relatively little within Sind district, centered by Karachi, but the central part of Punjab where both population and steel consumption share a majority is located at the distance exceeding 1,000km away from the coast line. So that the physical distribution costs must not be neglected.

Moreover, a complicated distrubiton system results in the greater intermediary margin. Thus the resultant domestic distribution cost for import products has reached two times the CIF price, sometimes three times in a case of certain products, as the reality reveals.

Steels constitute one of the major key materials. Therefore, machinery manufacturing and other industries may be greatly influenced by the price level of steel materials. Some people sometimes point out that the high-levelled steel prices may act as one of the obstacles toward the further development of Pakistan's industries as a whole.

Table 3.5.5 Import Tariffs of Asian Countries

(As of 1980)

	S. Korea	Taiwan	Thailand	Singapore	Malaysia	Philippines	Indonesia	India	Pakistan
Wire Rod	(Low) 15% (High) 10%	(Low) 20% (High) 15%	20% 0.60BAHT/kg	Free	<6mm 100M$/MT ≥6mm Free	10 - 30%	30%	(Low) 35% (165RS/MT) (High)40% (165RS/MT)	70%
Deformed Bar	15%	10% - 25%	20% 0.60BAHT/kg	"	Actually prohibited	50%	30%	35% (165RS/MT)	70%
H Section	20%	26%	0.30BAHT/kg	"	Free	Rolled Section 30% Formed Section 70%	5%	35% (165RS/MT)	70%
Middle Section	20%	26%	0.30BAHT/kg	"	<80mm 100M$/MT ≥80mm Free		5%	35% (165RS/MT)	70%
Hot Coil	15% (5%)	26%	0.20BAHT/kg	"	Free	10%	5%	35% (225RS/MT)	70%
Plate	20%	20%	0.20BAHT/kg	"	Free	10%	5%	35% (175RS/MT)	70%
Hoop	15%	25%	0.30BAHT/kg	"	Free	10%	5%	35% (225RS/MT)	70%
Cold	20%	20%	0.20BAHT/kg	"	Free	30%	5%	35% (325RS/MT)	70%
Galvanized Iron Sheet	20%	39%	0.75BAHT/kg	"	0.03M$/SQFT	50%	20%	35% (425RS/MT)	70%
Tin Plate	20% (10%)	30%	15% 1.50BAHT/kg	"	Free	50%	Nil	45% (520RS/MT)	70%
Seamless Pipe and Tube	25% (15%)	20%	30% 1.00BAHT/kg	"	125M$/MT or CIF x 25%	10%		75% (450RS/MT)	80%
Welded Pipe and Tube	25%	33 - 39%	30% 1.00BAHT/kg	"		50%		75% (450RS/MT)	80%
Others	Stainless Hot Coil 10% (5%)		Wire (Tin/GI) 30% 1.25BAHT/kg						Rail 50%

Source: JISF

3.5.3 Positioning of Steel Consumption in Pakistan in International Comparison

Pakistan's steel consumption in 1979-80 recorded 1,340 thousand tonnes. At what level the consumption is positioned internationally? Table 3.5.6 shows the ASC and ASC per capita of main advanced countries and developing countries in 1979. According to the Table, the countries with their ASC of 1,000 to 1,500 thousand tonnes per annum are Philippines (1,540), Egypt (1,400), Pakistan (1,340), Singapore (1,290), Malaysia (1,050), Nigeria (1,025) and Syria (1,019), and the countries with their ASC per capita having less than 20 kg are India (19), Pakistan (17), Nigeria (14), Indonesia (14) and Bangladesh (2) . Generally, when the leve of steel consumption is compared internationally, the ASC per capita is used. That of advanced countries is 400kg per capita or greater, and that of some developing countries with the relatively higher level shows 100 to 200kg per capita. From this view point, the level of steel consumption in Pakistan is clearly included in the lower-level group of developing countries.

Table 3.5.6 Steel Consumption and Steel Consumption per Capita of Main Advanced Countries and Developing Countries in 1979 (ASC base)

Countries	Steel Consumption (1000 tonnes)	per Capita (kg/person)	Countries	Steel Consumption (1000 tonnes)	per Capita (kg/person)
Main Advanced Countries			Developing Countries		
USSR*	153,451	588	Middle East:		
United States	140,906	639	Saudi Arabia	3,731	676
Japan	72,329	624	Turkey	3,465	78
F.R. of Germany	36,912	602	Iran	3,080	83
Italy	23,630	415	Iraq	2,730	214
United Kingdom	20,537	368	Syria	1,019	122
France	20,530	384	Kuwait	506	398
Developing Countries					
			Africa:		
Latin America:			South Africa	6,300	221
Brazil	12,760	108	Algeria	2,095	78
Mexico	8,840	127	Egypt	1,400	34
Argentina	3,600	188	Nigeria	1,025	14
Venezuela	2,833	210	Libya	841	294
Columbia	720	27	Morocco	700	36
Chile	700	64			
Peru	550	32	Pakistan	1,340	17
Asia:					
China*	42,706	45			
India	12,050	19			
Republic of Korea	6,947	185			
Taiwan*	4,747	278			
Indonesia	2,005	14			
Thailand	1,900	41			
Hong Kong	1,888	410			
Philippines	1,540	32			
Singapore	1,290	547			
Malaysia	1,050	79			
Bangladesh	130	2			

Source: Steel Consumption comes from IISI, Population comes IFS (International Financial Statistic) by IMF. Exceptionally the population of USSR, China, Hong Kong, Taiwan come from The World Bank.

Note: Figures marked* shows production in 1978.

3.5.4 Consideration for Current Steel Market

The steel consumption in Pakistan has shown relatively high growth rate by 10% per annum (1972-73 to 1979-80), and its domestic steel production has likewise highly increased by 12.5% per annum. But the analysis made hitherto has revealed that these growth rates are obtained from 1972-73 when steel consumption and production were in low level and that Pakistan in the present steel consumption is in the lower-level group of developing countries. In addition, it is also made clear that the steel consumption of Pakistan is dependent upon overseas steel resources by 80% or higher.

In general, in the developing countries, there is a tendency that the prices for capital goods are relatively higher than those for consumer goods that work direct impact on people's living, contrary to the advanced countries.

It may be right to assert that the most important problem for any developing country exerting its every effort to achieve its industrialization is to steadily supply capital goods at reasonably low prices. It is widely accepted and convinced that the basic materials such as steels that are indispensable to such capital goods as machinery do well serve to the problem of industrialization required by the nation.

However, as described in 3.5.2 "Price Trend of Steel Products", the steel products imported by Pakistan do turn out to be very costly at the stage of domestic consumption in terms of the international standards. This fact may account for one of cost-up factors for steel consuming industries, and thereby interfere with the enlargement of domestic market for steel products. As a result, it works favorably to the increase of imports of machinery etc. It can not be but said that the problem in the aspect of these prices for the development of Pakistan's steel industry is very significant as well as the modernization of production and technology.

Another basic and essential problem is the urgent and effective setup of a public agency to provide ready and accurate statistical informations on the trend in Pakistan's steel industry and its pertinent industries.

As of present, in Pakistan, these detailed dynamic statistical data are not available.

In the industrialized countries, the system of these statistics is well established and these are regularly made public.

And, in fact, individual manufacturers use these informations to the full to facilitate their market research so that they can be assured and justified of their proposed equipment investments and increase of production level.

3.6 Outlook for Steel Demand in Pakistan

3.6.1 Methods of Steel Demand Forecast

In making a master plan for the steel industry in Pakistan, it is very important and also quite difficult to forecast the trend of steel demand in this country during the coming 20 to 30 years. Before forecasting demand for steel, general methods of steel demand forecast will be introduced below: As generally used methods of forecast, there are macroforecasting methods, such as the GDP correlation analysis method, which attempts to make an analysis in relation to Gross Domestic Product (GDP) and the Steel-Intensity (SI) analysis method, which utilize macro-economic indicators, and micro-forecasting method which attemts to totalize demands for steel in individual sectors. Here, an objective is to forecast demand for steel during 2000 to 2010, 20 to 30 years later from now, and micro-forecasting mechod is not appropriate in making long term forecasts. Because a forecast of demand for steel in individual steel consuming industries involves a lot of uncertain factors, and thus these method is usually used for short and medium term forecasting.

The GDP correlation analysis is often applied to make a long term forecast of demand for steel as it is relatively easy to obtain GDP, its explaining variable, in a long term.

A typical macro-method is the SI analysis method which has been developed by the International Iron and Steel Institute (IISI). This uses GNP and population as explaining variables. It considers that SI, i.e., steel consumption per $ 1 of GNP changes according to the stage of economic development (in terms of GNP per capita). Steel Intensity is indicated on the vertical axis and GNP per capita on the horizontal axis. An enormous amount of data from countries are shown in the form of a certain curve on this graph. This is also often used in making a long term forecast of demand for steel as it uses GNP and population, which are the economic fundamental indicators of a country, as variables. In 1972, IISI introduced "Projection '85" which used this SI analysis method to forecast the world demand for steel. However, the oil crisis immediately after that caused the forecast to differ considerably from what has happened as steel demand in the industrialized countries has fallen back considerably. Since then, this method has been criticized by various quarters. Yet, this still can be used as a method to forecast a long term demand for steel.

(Although IISI admits the limitation of this method, it does not deny its usefulness.)

To forecast a steel demand in Pakistan, the GDP correlation analysis method (A) and the SI analysis method (B) and also the Trend Line method (C) will be used.

3.6.2 Economic Outlook in Pakistan

(1) Pakistan is now in the course of carrying out the Fifth Five-Year Plan (1978-79 to 1982-83) which was established in 1978. The plan was outlined in Section 1.1. Table 3.6.1 below shows the average annual growth rate of GDP by sector and that of population.

Table 3.6.1 Annual Growth Rate of Gross Domestic Product and Population in the Fifth Five-Year Plan (unit: %)

Sectors	Annual Growth Rate
GDP, Sectors	
1. Agriculture:	6.0
(a) Major Crops	7.0
(b) Minor Crops	6.8
(c) Others	3.7
2. Manufacturing:	10.0
(a) Large Scale	12.0
(b) Small Scale	3.0
3. Construction	8.4
4. Trade and Transport	7.7
5. Others	4.9
GDP	7.0
Population	2.8

Note: GDP at Constant Factor Cost

Source: "The Fifth Five-Year Plan, 1978"

Taking into consideration changes in economic conditions since then, the Planning Commission now foresees the average annual growth of GDP and population for the coming three years as follows:

Table 3.6.2 Prospects of GDP and Population from 1979-80 to 1982-83 (unit: %)

Sectors	Annual Growth Rate
GDP, Sectors	
1. Agriculture:	6.6
(a) Major Crops	5.6
(b) Minor Crops	3.7
(c) Others	3.9
2. Manufacturing:	9.4
(a) Large Scale	10.3
(b) Small Scale	7.3
3. Construction	7.1
4. Trade and Transport	6.4
5. Others	4.6
GDP	6.0
Population	2.9

Note: Annual Growth Rate at Constant Factor Cost
Source: Planning Commission, Government of Pakistan

As shown above, the average annual growth rate has been lowered by 1% down to 6% as to GDP and raised by 0.1% up to 2.9% as to population from the respective rates forecasted in the Fifth Five-Year Plan.

(2) Economic forecast during 2000 to 2010

Pakistan experienced an average annual growth rate of 5.5 % in terms of real GDP during the past seven years. It is very difficult to foresee the GDP trend during the coming 20 to 30 years. In the following section, future GDP trend will be examined by referring to the forecast made in Pakistan and also to "World Development Report, 1980" prepared by the World Bank.

According to the World Bank, since the oil price rise of 1979, the world economy has experienced unbalanced international payment, slow down in the economic growth of the advanced industrialized countries, reduced world trade, reduced export from oil importing developing countries, lower economic growth in oil importing countries, etc. These phenomena are similar to those occurred immediately after the 1973 oil crisis, although they differ in degree. After 1980, all oil importing countries, including both developed and developing countries, have been placed in a position to adapt themselves to high oil price and stagnated world trade while maintaining loss in low economic growth to the minimum in individual countries.

The World Bank assumed two different cases according to the level of adaptation, which these countries could make to meet economic difficulties during 1980 to 1985, and predicted GNP growth rates up to the year 2000. In the low adaptation level case, although present unbalance in international payment will be improved during the period, economic growth will remain suppressed, and bases for economic recovery will remain unsatisfactory after 1985. In the high adaptation level case, however, the economic growth will not be reduced so much during 1980 to 1985, and will be accelerated after then. Under these assumptions, oil importing developing countries are classified into low income and medium income countries. Moreover, the low income countries are classified into African and Asian countries to forecast GNP growth rates. Results are shown in Table 3.6.3.

Table 3.6.3 GNP Growth Rate in Low Income Oil Importing Countries in Asia

(Unit: %)

Case \ Period	1980-85	1985-90	1990-2000
Low Adaptation Case	3.4	3.7	3.5
High Adaptation Case	4.3	4.8	4.5

Note: Annual Growth Rate

Source: "World Development Report, 1980" by the World Bank

Pakistan is classified as a low income oil importing country by the World Bank. The World Bank tends to present conservative forecast figures due to the nature of its role.

Therefore, in forecasting the economic growth rate of Pakistan during the coming 20 to 30 years, past achievements, forecasts made within Pakistan and forecast by the World Bank are taken into consideration, and an annual growth rate of 5% is finally adopted. There may be some changes in growth rate during the coming 20 years up to 2000 or 30 years up to 2010, but here it is assumed as indicated by the World Bank that there will not be big fluctuations during the period. Therefore, a single rate of 5% has been adopted.

The population trend in Pakistan was already discussed in Section 1.2.3. The past average increase rate is:

2.5% from 1949-50 to 1959-60

2.9% from 1959-60 to 1969-70

3.0% from 1969-70 to 1979-80

For the future prospect, the United Nations made in 1978 a population forecast for each country. According to the United Nations' forecast, Pakistan will have annual growth rates of population as follows:

Table 3.6.4 Expected Population Growth Rate in Pakistan

(Unit: %)

	1980-1985	1985-1990	1990-2000
Population Growth Rate	3.15	2.99	2.60

Source: "United Nations, 1978"

Although the population growth rate forecast made by the Planning Commission in Pakistan will be taken into consideration, the United Nations' forecast will be eventually adopted in this paper, in view of the past trend.

For the period from 2000 to 2010, an annual growth rate of 2.40% will be used, taking into consideration the past trend.

3.6.3 Steel Demand Outlook in Pakistan

(1) Steel demand outlook by the GDP-correlation analysis method

Steel demand outlook by the GDP-correlation analysis method is shown in Table 3.6.5. The relative coefficiency R is quite large. Steel demand is expected to increase from 1,340,000 tonnes in 1979-80 to 1,861,000 tonnes in 1984-85 to 2,627,000 tonnes in 1989-90 to 4,853,000 tonnes in 1999-2000 and to 8,497,000 tonnes in 2009-2010. The average annual growth rate will be about 6 to 7%, though it will slightly fluctuate from period to period.

Table 3.6.5 Steel Demand Forecast by the GDP-Correlation Analysis Method

Year	GDP (Million RS 1959-60 price)	Steel Consumption (1,000 tonnes)
1972-73	35,179	684.4
1973-74	37,901	733.9
1974-75	39,393	714.2
1975-76	40,699	780.2
1976-77	41,727	976.2
1977-78	44,630	955.3
1978-79	47,262	1,090.3
1979-80	50,189	1,339.9
1984-85	64,055	1,861.0
1989-90	81,753	2,627.0
1999-2000	133,166	4,853.0
2009-2010	216,914	8,497.0

$Y = 0.433008\ X - 93.49212$

Y = Steel Consumption (10,000 tonnes)

X = GDP (100 million RS)

R = 0.94937

Note: Steel Consumptions are on the CSE base.

(2) Steel demand outlook by the Steel-Intensity analysis method

In 1974, IISI generated a steel intensity curve from the data of nine developing countries excluding those oil producing countries where steel consumption was showing a wide fluctuations. The theoretical equation of SI is as follows:

$SI = 0.1585 \times \ln (\text{GNP per capita}) - 0.6911$

(This equation applicable to case (b) in Table 3.6.6)

On the other hand, the theoretical equation of SI based on Pakistani data is as follows:

SI = 0.106656 x In (GNP per capita) - 0.430951

(This equation applicable to Case (a) in Table 3.6.6.)

Steel demand outlook obtained from these two equations is shown in Table 3.6.6. The expected demand for steel in Case (a) will follow a trend similar to that of the expected demand obtained by the GDP correlation analysis method, but in detail they show some difference. Prior to 2003-4, it will be lower and after then, it will be higher, with the forecasted demand of 4,853,000 tonnes in 1999-2000 and 8,497,000 tonnes in 2009-2010.

On the other hand, the expected demand for steel in Case (b) is considerably larger than the figures presented so far. According to this forecast, the demand will be 5,672,000 tonnes in 1999-2000 and 11,290,000 tonnes in 2009-2010. In these equations, GNP per capita data of many of the developing countries with already more than US$200 at 1963 price in 1970 are included. Therefore, these equations are applicable to those countries which are taking off or which has already taken off, but if they are applied to a country like Pakistan whose GNP per capita was only US$149 in 1979-80, they tend to present optimistic demand figures.

Table 3.6.6 Forecast of Steel Demand by Steel-Intensity Analysis Method

	GNP (million US$ 1963)	GNP per capita (US$ 1963)	Population (1,000 person)	SI (Steel intensity tonnes/US$)		Steel Consumption (1,000 tonnes)	
1972-73	7,966	122	65,240	0.0859		684.4	
1973-74	8,580	128	67,200	0.0855		733.9	
1974-75	8,932	129	69,210	0.0800		714.2	
1975-76	9,329	131	71,290	0.0836		780.2	
1976-77	9,692	132	73,430	0.1007		976.2	
1977-78	10,656	141	75,630	0.0896		955.3	
1978-79	11,332	146	77,900	0.0962		1,090.3	
1979-80	11,983	149	80,230	0.1118		1,339.9	
				(a)	(b)	(a)	(b)
1984-85	15,294	163	93,690	0.1119	0.1261	1,711.0	1,929.0
1989-90	19,519	179	108,560	0.1226	0.1419	2,393.0	2,770.0
1999-2000	31,794	227	140,330	0.1471	0.1784	4,677.0	5,672.0
2009-2010	51,790	291	177,890	0.1738	0.2180	9,001.0	11,290.0

Note: (a) The theoretical equation of SI based on the data for Pakistan

$SI = 0.106656 \times \ln(\text{GNP per capita}) - 0.430951$

(b) The theoretical equation of SI based on the data for nine developing countries

$SI = 0.1585 \times \ln(\text{GNP per capita}) - 0.6911 + C$

C = Actual SI values - theoretical SI values = 0.0104 (1978-80)

(3) Steel demand outlook by time trend

Expected steel demand obtained with time (year) as a variable is 1,647,000 tonnes in 1984-85, 2,081,000 tonnes in 1989-90, 2,949,000 tonnes in 1999-2000 and 3,817,000 tonnes in 2009-2010.

Table 3.6.7 Steel Demand Outlook by Time Trend

Year	Steel Consumption (1,000 tonnes)
1972-73	684.4
1973-74	733.9
1974-75	714.2
1975-76	780.2
1976-77	976.2
1977-78	955.3
1978-79	1,090.3
1979-80	1,339.9
1984-85	1,647.0
1989-90	2,081.0
1999-2000	2,949.0
2009-2010	3,817.0

$$Y = 86.797619X + 518.5357$$

Y = Steel Consumption (1,000 tonnes)

X = Year (ex. 1972-73 = 1
1973-74 = 2
1974-75 = 3)

R = 0.93617

(4) Steel demand outlook in Pakistan

In the above, three different steel demand outlooks, each obtained by different methods, were presented. Results are shown in Table 3.6.8 and Fig. 3.6.1.

Table 3.6.8 Forecast of Steel Demand in Pakistan

(Unit: 1000 tonnes, %)

Case		1979-80 1)	1984-85	1989-90 2)	1999-2000 3)	2009-2010 4)	Average annual growth rate 2)/1) %	3)/2) %	4)/3) %
A	GDP-correlation analysis	1,259	1,861	2,627	4,853	8,497	7.6	6.3	5.8
B-(a)	Steel-Intensity analysis	1,226	1,711	2,393	4,677	9,001	6.9	6.9	6.8
B-(b)	"	1,340	1,929	2,770	5,672	11,290	7.5	7.4	7.1
C	Time-trend	1,213	1,647	2,081	2,949	3,817	5.5	3.5	2.6
D	Combination of A and B-(a)	1,340	1,786	2,510	4,765	8,749	6.5	6.6	6.3

Note: As for 1979-80, Cases A, B and C show theoretical values and Case D shows actual values

Case C represents a pessimistic case, annual growth rate gradually decreasing. Cases A and B-(a) demonstrate a similar trend to show an annual growth rate of 6 to 7%. Case B-(b) represents the most optimistic case, showing an annual growth rate of more than 7% during the entire period. It is desirable to eventually adopt Case D which is a combination of Cases A and B-(a). The appropriateness of Case D will be evaluated through the analysis of the 1970-1978 data for developing countries, and Case D will be finally adopted.

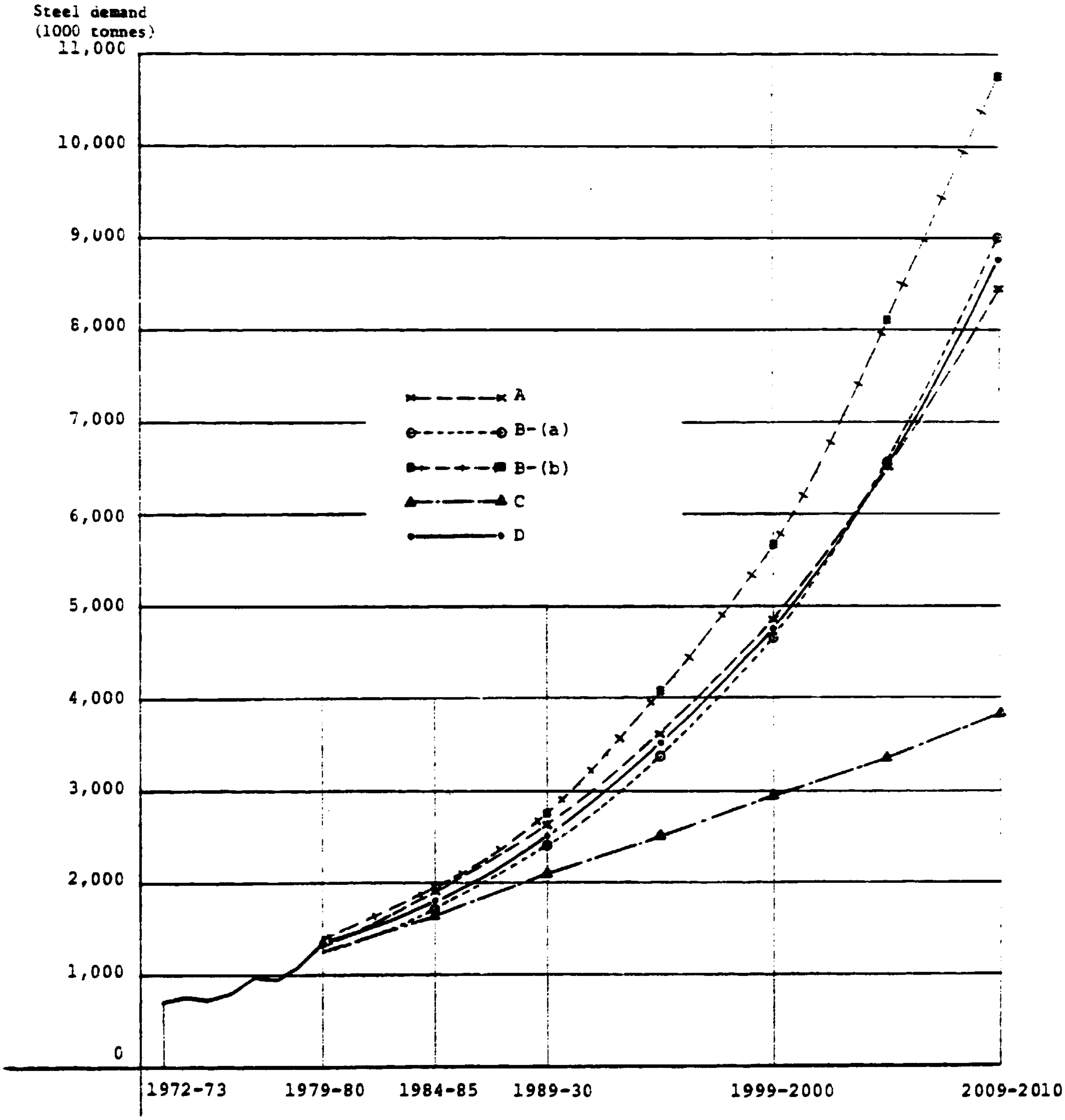


Fig. 3.6.1 Forecast of Steel Demand in Pakistan

According to IISI, developing countries take off at per capita GNP of about US$200 (at 1963 price), showing a rapid increase in the consumption of steel and GNP. For the smooth progress of industrialization, however, the following take-off conditions will have to be satisfied in addition to GNP per capita:

- Investment rate of at least 20% to total GDP
- Share of a manufacturing industry at least 20% of total GDP
- Capital goods manufacturing to account for more than 10% of all manufacturing
- Steel consumption to be more than 700 tonnes per capita formation of US$ one million (at 1963 price).

These requirements have been made into indices by each developing country for 1978, and are shown in Table 3.6.9. (However, "proportion of capital goods manufacturing to the entire manufacturing" is not shown because of lack of data.)

In addition, the data have been classified into groups from the standpoint of steel consumption per capita as shown in Fig. 3.6.2 to 3.6.4. Countries have been grouped into those with steel consumption per capita of less than 100 kg, those with steel consumption per capita of more than 100 kg, and oil producing countries.

Table 3.6.9 Indices of Conditions for "Take-off" in Developing Countries in 1978

Countries	GNP per capita	Gross domestic investment / GDP	Manufactures / GDP	Steel consumption / gross domestic investment	Steel consumption per capita
Low-income countries					
Bangladesh	1) 50	60	40	11	1
India	55	120	85	85	16
Pakistan	2) 75	90	80	76	14
Middle-income countries					
Egypt	3) 111	140	125	57	25
Thailand	116	135	90	98	43
Philippines	123	150	125	63	32
Morocco	153	120	85	65	33
Peru	155	75	*55	92	30
Syria	182	160	105	94	77
Tunisia	223	150	60	70	66
R. Korea	218	160	120	208	203
Turkey	213	105	90	130	81
Taiwan	4) 204	130	190	374	278
Mexico	288	125	140	122	123
Brazil	368	115	140	84	100
Argentina	5) 552	10) 125	10) 185	99	100
Portugal	353	115	180	34	153
Yugoslavia	357	10) 165	12) 180	149	245
Hong Kong	539	10) 125	10) 125	209	410
Greece	642	135	95	69	167
Singapore	6) 882	180	130	121	537
Spain	481	10) 100	10) 150	142	191
Oil producing countries					
Indonesia	6) 49	100	45	105	14
Nigeria	7) 84	10) 140	10) 45	52	17
Malaysia	8) 272	125	85	79	75
Algeria	9) 552	185	60	49	139
Iran	10) 247	10) 165	10) 60	395	196
Iraq	11) 190	135	12) 50	229	96
Source	Statistics of IMF	World Bank	World Bank	IMF, World Bank, IISI	IISI, World Bank
Unit	US$200 (at 1963 prices) = 100	20% = 100	20% = 100	700 tonnes/ US$ million = 100	Kg/person

Note:

1) at 1973 prices
2) at 1978-79 prices
3) 1977 at 1965 prices
4) at 1960 prices
5) 1975
6) at 1965 prices
7) 1977 at 1968 prices
8) at 1970 prices
9) 1977 at 1977 prices
10) 1977
11) 1975 at 1965 prices
12) 1960

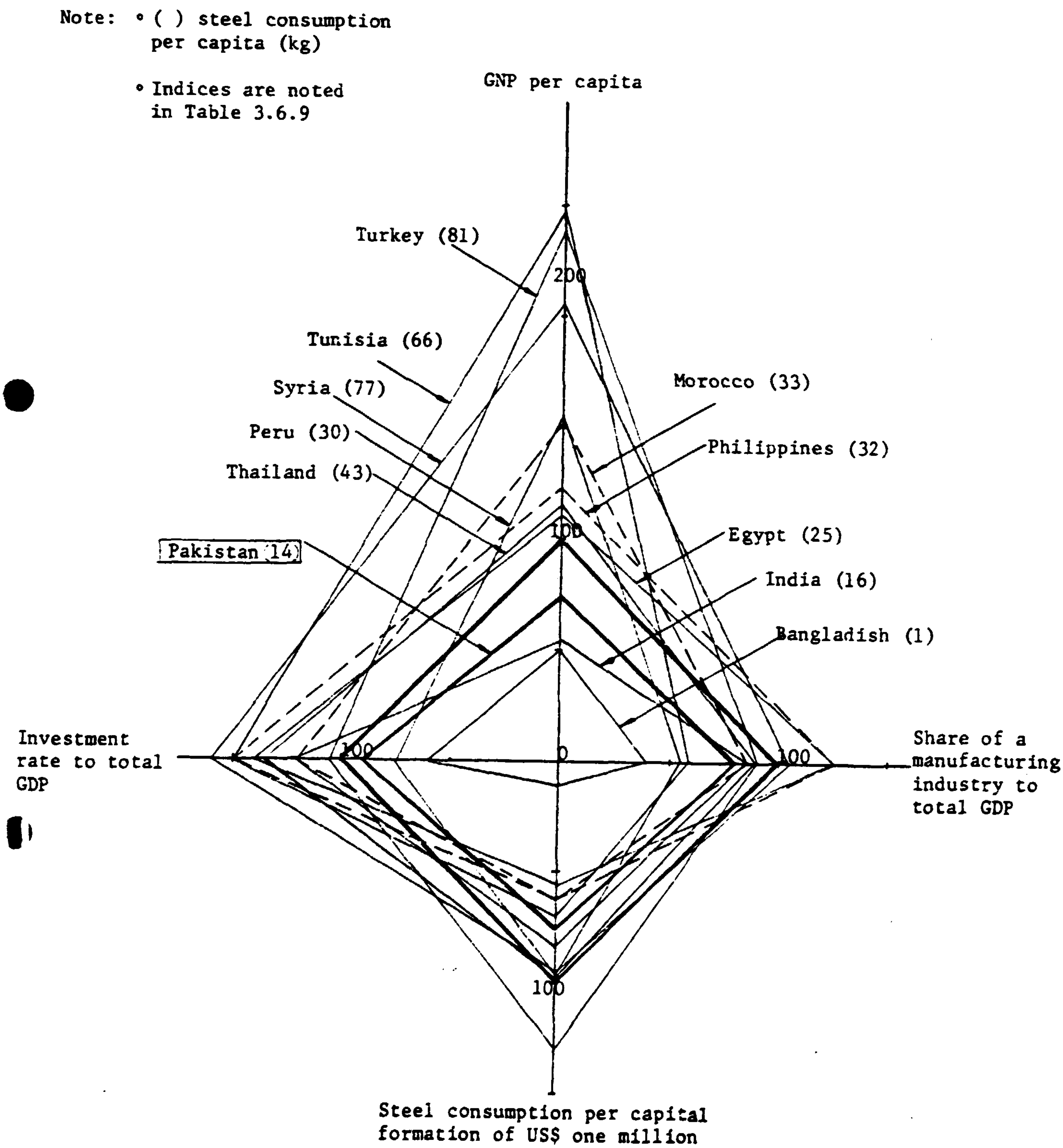


Fig. 3.6.2 Indices of Conditions for "Take-off" in Developing Countries in 1978 (Below 100 kg steel consumption per capita)

Note: * ( ) steel consumption per capita (kg)

* Indices are noted in Table 3.6.9

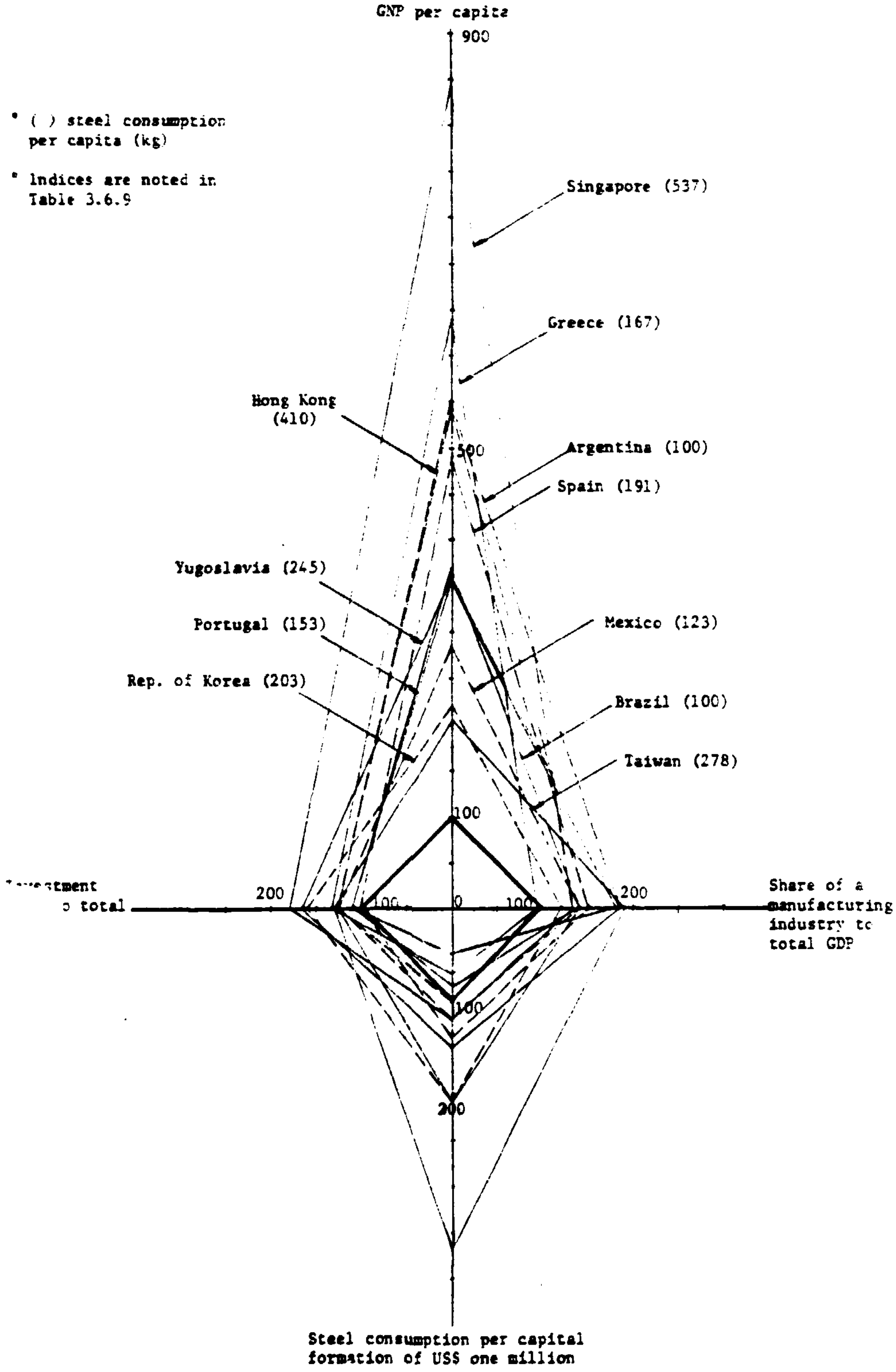


Fig. 3.6.3 Indices of Conditions for "Take-off" in Developing Countries in 1978 (Above 100 kg steel consumption per capita)

Note: . ( ) steel consumption per capita (kg)
. Indices are noted in Table 3.6.9

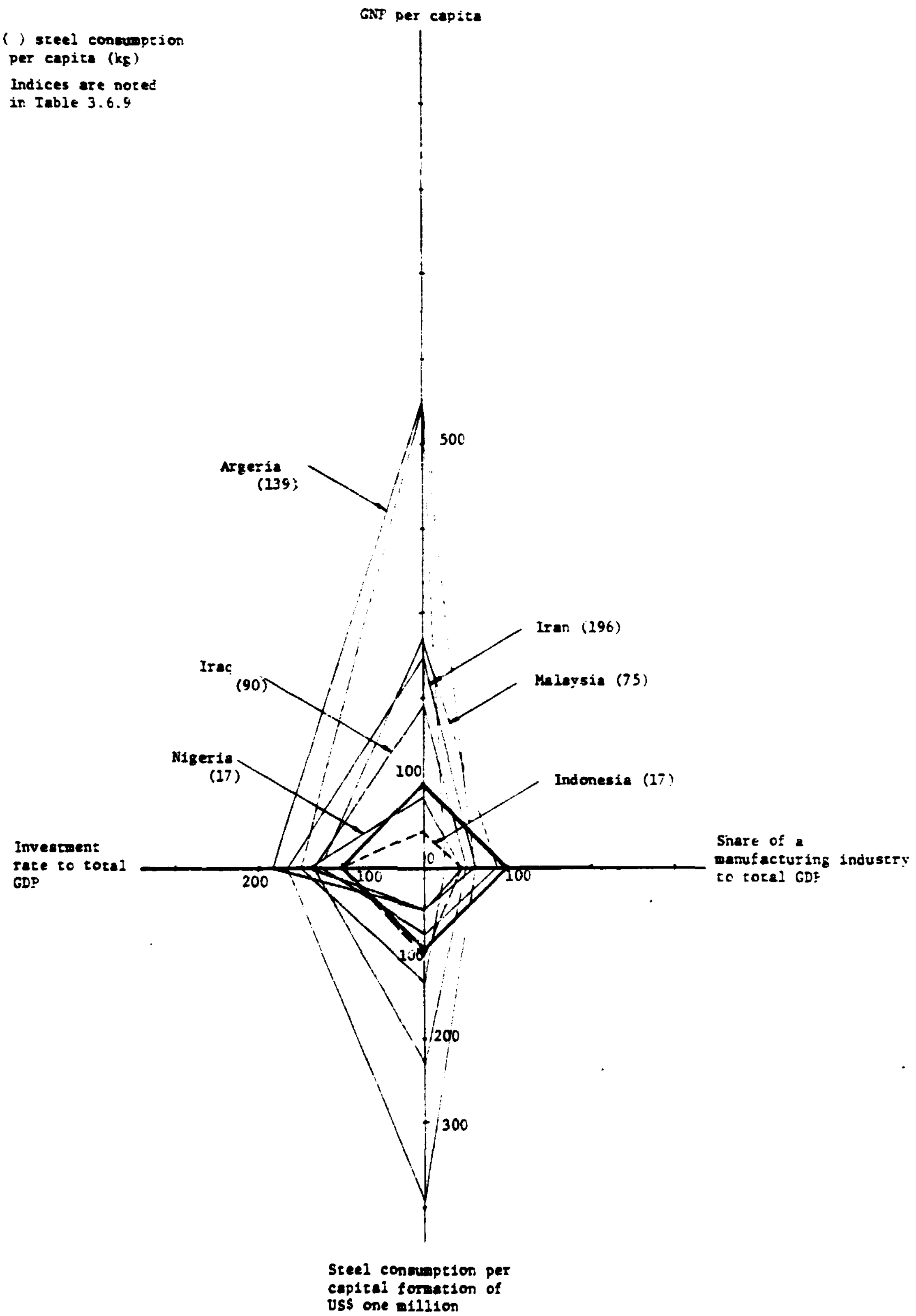


Fig. 3.6.4 Indices of Conditions for "Take-off" in Developing Countries in 1978 (Oil producing developing countries)

Countries with steel consumption per capita of more than 100 kg almost satisfy the take-off requirements, but countries with steel consumption per capita of less than 100 kg often do not satisfy the share of a manufacturing industry to GDP and the rate of steel consumption to gross domestic investment. Bangladesh, India and Pakistan, all of which are classified as low income countries by the World Bank, do not satisfy almost all of the requirements for take-off, except that one indicator for India meet the take-off requirements. It is therefore clear that Pakistan has not reached yet an economic development stage for take-off. All of the oil producing countries do not meet conditions of the share of a manufacturing to GDP, and population-dense Indonesia and Nigeria are both at a low level also in terms of GNP per capita. The oil producing countries generally show wide fluctuations.

Table 3.6.10 shows the GDPs and past average annual growth rates of steel consumption of developing countries which will be referred to in forecasting future steel consumption in Pakistan. Data for oil producing countries and for countries with steel consumption per capita of more than 100 kg cannot be used as reference, and therefore data for countries with a per capita steel consumption of less than 100 kg are shown. From Fig. 3.6.2, Egypt, Peru, the Philippines, Morocco and Thailand have been selected as countries which are at a higher level than current Pakistan in terms of per capita GNP and steel consumption. Data for India and Bangladesh are also shown.

Table 3.6.10 Annual Growth Rate of GDP and Steel Consumption in Developing Countries and Steel Consumption Per Capita in Those Countries

	Annual growth rate of GDP 1970~1978 (%)	Steel consumption			1978 Steel consumption per capita (kg/person)	1978 GNP per capita at 1963 prices (US$)
		1970 (1000 tonnes)	1978 (1000 tonnes)	Annual growth rate (%)		
Egypt	7.8	857	1,132	3.5	25	[1] 222
Peru	3.1	434	549	3.0	30	309
Philippines	6.3	1,157	1,553	3.7	32	245
Morocco	6.4	318	710	10.6	33	305
Thailand	7.6	767	1,719	10.6	43	231
India	2.9	6,714	10,765	6.1	16	109
Bangladesh	2.9	133	103	-3.1	1	[2] 99
Source	World Bank	IISI			IISI, World Bank	IMF
Note		Due to wide fluctuations in the consumption of steel from year to year, 1970 uses an average for 1969 to 1971, and 1978, for 1977 to 1979.				1) 1977 base at 1965 price 2) at 1973 price

In 1978-79, Pakistan had steel consumption per capita of 14 kg and GNP per capita of US$146. For the period 1999-2000, Pakistan is expected to have GNP per capita of US$227 and steel consumption per capita of 34 kg of Case D.

It is seen that the 1978 figures shown in Table 3.6.10, for the five countries of Egypt, the Philippines, Morocco, Peru and Thailand are roughly comparable to the 1999-2000 figures for Pakistan. These countries, except for Peru, show an annual growth rate of 6 to 7% in real GDP for the period from 1970 to 1978. During the same period, steel consumption of these five countries showed an annual growth rate of 6.3% on the average, though there were fluctuations between 3 and 10%. These countries do not necessarily satisfy the take-off requirements currently, and are not generally considered as having taken-off. It is difficult to foresee what proportion domestic investment and manufacturing each will account for in the entire GDP of Pakistan in 1999-2000. In view of the examples of these countries, generally speaking, however, Pakistan will not reach a take-off stage by then. Neither GNP nor steel demand can be expected to make a rapid growth. It may be reasonable, therefore, to foresee an annual growth rate of about 5% for GNP and that of 6.3 to 6.6 (Case D) for demand for steel.

Table 3.6.11 Summary of Steel Demand Outlook in Pakistan

	1979-80	1984-85	1989-90	1999-2000	2009-2010
Steel consumption (1,000 tonnes)	1,340	1,786	2,510	4,765	8,749
Steel consumption per capita (Kg/person)	17	19	23	34	49
GNP per capita (US$ at 1963 prices)	149	163	179	227	291

3.6.4 Outlook for Demand of Steel Product Categories

(1) Changes in the proportion of flat and non-flat products

In general, steel demand for construction has accounted for a higher proportion in developing countries, and in order to meet such demand, a large number of ingot-makers by open hearth and electric furnace and re-rollers have existed in those countries. As developing countries progress towards a take-off stage, the proportion of non-flat products increases for the construction of houses and buildings and for the improvement of infra-structure. After then, as income increases and as durable goods spread, demand for flat products increases. In the case of Pakistan, non-flat products currently account for a large share as mentioned in Section 3.4.2, and is estimated to account for 58%. Future shares of flat and non-flat products could be estimated on the basis of actual changes seen in many developing countries. Table 3.6.12 shows changes in the share of flat and non-flat products in developing countries. The data for these developing countries clearly indicate an increase in the share of flat products and a decrease in the share of non-flat products.

Pakistan is expected to trace the same trend, but as her current per capita steel consumption and GNP are low and are not expected to show a rapid increase, their shares are not expected to change as rapid as witnessed in other developing countries. The production of ghee oil cans, home appliances, motorcycles, light vehicles and various machines will certainly increase gradually, but their increase rate is expected to be relatively small. In the case of Thailand, non-flat and flat products had almost the same share at the time when per capita steel consumption was 48 kg.

In view of the above-mentioned consideration, flat and non-flat products are expected to show changes in share in Pakistan as shown in Table 3.6.13.

Table 3.6.12 Percentage Share of Flat Products and Non-flat Products in Developing Countries

Countries	Year	Apparent Steel Product Consumption			Steel Consumption Per Capita
		Flat (%)	Non-flat (%)	Total (%)	(kg/person)
Thailand	1966	35.2	64.8	100.0	21
	1970	41.3	58.7	100.0	29
	1973	45.3	54.7	100.0	40
	1977	49.0	51.0	100.0	48
Mexico	1968	50.3	49.7	100.0	77
	1974	52.9	47.1	100.0	105
	1979	55.6	44.4	100.0	123
Brazil	1968	48.9	51.1	100.0	56
	1970	49.3	50.7	100.0	66
	1973	52.3	47.7	100.0	95
	1975	52.2	47.8	100.0	106
Venezuela	1975	51.6	48.4	100.0	196
Argentina	1967	54.3	45.7	100.0	88
	1971	53.1	46.9	100.0	157
	1975	56.4	43.6	100.0	172
Spain	1977	58.5	41.5	100.0	249

Source: IISI and others

Table 3.6.13 Expected Changes in the Share of Flat Products and Non-Flat Products and Their Expected Quantities in Pakistan

(unit: %, 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000	2009-2010
Changes in share					
Flat-products	42.1	44.0	46.0	48.0	50.0
Non-flat products	57.9	56.0	54.0	52.0	50.0
Total	100.0	100.0	100.0	100.0	100.0
Quantity (rolled steel products)					
Flat-products	485	701	1,041	2,086	4,032
Non-flat products	667	892	1,223	2,260	4,032
Total	1,152	1,593	2,264	4,346	8,064

Note: Rolled steel products are calculated by applying a yield rate of 91% for 1984-85, 92% for 1989-90, 93% for 1999-2000 and 94% for 2009-2010 to steel ingots for rolling to be obtained by excluding cast iron from CSE base in Table 3.6.11.

(2) Breakdown of non-flat products by categories

As it is very difficult to forecast demand for individual rolled steel products, changes in percentage share are estimated from general examples of other countries. Under the circumstance of non-flat products losing their shares, sections are expected to show a relatively smaller proportional decrease than bars, as already seen in some quarters. This is because a gradual increase of factory buildings and office buildings with large spans is expected to lead to an increased use of sections. A decrease in the demand for wire rods and wires is expected to be relatively small as they will be used in extensive home appliances, as wires, nails, etc. Rails will show a considerably large loss in their share as they will be used mainly in repairment and as there are no large-scale plans to construct new railways. Seamless pipes have an extremely limited demand, but the demand for them is expected to increase considerably as they will be used in machine industries and oil and gas development. A large expansion cannot be expected, however, in view of the past maximum records of about 6,000 tonnes a year.

Table 3.6.14 Expected Changes in the Share of Non-flat Products and Their

	1979-80	1984-85	1989-90	1999-2000	2009-2010
Share (%)					
Non-flat products total	57.9	56.0	54.0	52.0	50.0
Bars wire rods & wires	36.4	35.0	33.6	32.3	30.8
Bars	33.1	31.7	30.4	29.1	27.6
Wire rods & wires	3.3	3.3	3.2	3.2	3.2
Sections	21.3	20.8	20.1	19.3	18.8
Angle, I beams Channels etc.	17.9	17.6	17.1	16.5	16.3
Rails	3.4	3.2	3.0	2.8	2.5
Seamless pipes	0.2	0.2	0.3	0.4	0.4
Quantity (1,000 tonnes)					
Non-flat products total	666.8	892.0	1,223.0	2,260.0	4,032.0
Bars, wire rods & wires	420.0	558.0	761.0	1,404.0	2,484.0
Bars	381.4	505.0	688.0	1,265.0	2,226.0
Wires rods & wires	38.6	53.0	73.0	139.0	258.0
Sections	245.0	331.0	455.0	839.0	1,516.0
Angle, I beams Channels etc.	206.0	280.0	387.0	717.0	1,315.0
Rails	39.0	51.0	68.0	122.0	201.0
Seamless pipes	1.8	3.0	7.0	17.0	32.0

Note: Percentage share is expressed with the total of rolled products

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in the Share of Non-flat Products and Their Quantities

4-85	1989-90	1999-2000	2009-2010	2009-2010 / 1979-80 Annual growth rate
6.0	54.0	52.0	50.0	-
5.0	33.6	32.3	30.8	-
1.7	30.4	29.1	27.6	-
3.3	3.2	3.2	3.2	-
0.8	20.1	19.3	18.8	-
7.6	17.1	16.5	16.3	-
3.2	3.0	2.8	2.5	-
0.2	0.3	0.4	0.4	-
				(%)
2.0	1,223.0	2,260.0	4,032.0	6.2
8.0	761.0	1,404.0	2,484.0	6.1
5.0	688.0	1,265.0	2,226.0	6.0
3.0	73.0	139.0	258.0	6.5
1.0	455.0	839.0	1,516.0	6.3
0.0	387.0	717.0	1,315.0	6.4
1.0	68.0	122.0	201.0	5.6
3.0	7.0	17.0	32.0	10.1

expressed with the total of rolled products as 100%

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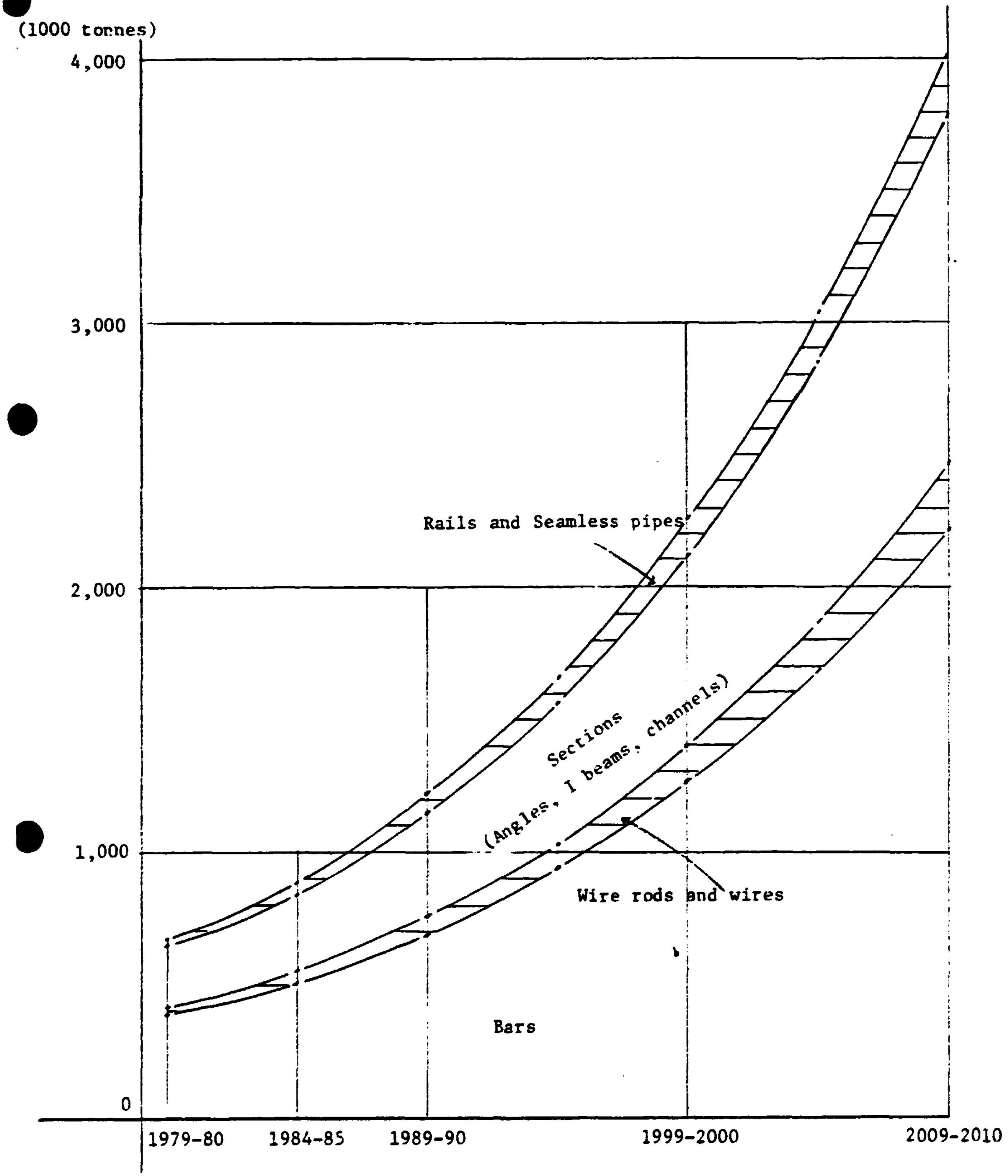

Fig. 3.6.5 Forecast of Non-flat Products

(3) Breakdown of flat products by categories

As in the case of non-flat products, changes in percentage share will be first estimated and then real quantities will be forecasted for flat products. Currently plates account for a very small share (1.8%) in Pakistan although she has both ship-building and machine engineering industries. A gradual increase in the number of projects involging large structures including bridges of long span, power plants, will greatly push up the share of plates in the future. Yet, their share will be still about 3% in around the year 2000. Even though Thailand has a different industrial structure compared with Pakistan, its plates account for 3% of the market today. Thus, 3% share of plates cannot be said high.

Uncoated hot rolled sheets are used for automobiles, motorcycles, panels, home appliances, drums, etc. Uncoated cold rolled sheets enjoy extensive applications including automobiles, motorcycles, rotating appliances, hoe appliances, food cans, home appliances, etc. Of the two, cold rolled sheets seem to have a somewhat higher share.

Table 3.6.15 Expected Changes in the Share of Flat Products and Their

	1979-80	1984-85	1989-90	1999-2000	2009-2010	20 19 Annua
Share (%)						
Flat-products total	42.1	44.0	46.0	48.0	50.0	
Plates	1.8	2.0	2.5	3.0	3.5	
Sheets	40.3	42.0	43.5	45.0	46.5	
Uncoated sheets	24.6	25.2	25.6	26.0	26.5	
Hot	13.2	13.4	13.5	13.6	13.8	
Cold	11.4	11.8	12.1	12.4	12.7	
Coated sheets	11.2	12.2	13.2	14.0	14.7	
GI	4.5	4.8	5.1	5.3	5.5	
Tinned	6.7	7.3	8.0	8.5	8.9	
Others	-	0.1	0.1	0.2	0.3	
Welded pipes	4.5	4.6	4.7	5.0	5.3	
Quantity (1,000 tonnes)						
Flat-products total	484.7	701.0	1,041.0	2,086.0	4,032.0	
Plates	21.3	32.0	56.0	130.0	282.0	
Sheets	463.4	669.0	985.0	1,956.0	3,750.0	
Uncoated sheets	283.7	402.0	580.0	1,130.0	2,137.0	
Hot	152.9	214.0	306.0	591.0	1,113.0	
Cold	130.8	188.0	274.0	539.0	1,024.0	
Coated sheets	128.7	194.0	299.0	609.0	1,186.0	
GI	51.6	76.0	116.0	230.0	444.0	
Tinned	77.1	116.0	181.0	370.0	718.0	
Others	-	2.0	2.0	9.0	24.0	
Welded pipes	51.0	73.0	106.0	217.0	427.0	

Notes: Percentage share is expressed with the total of rolled products as 1(

SECTION 1

...cted Changes in the Share of Flat Products and Their Quantities

...84-85	1989-90	1999-2000	2009-2010	2009-2010 / 1979-80 Annual Growth Rate
44.0	46.0	48.0	50.0	-
2.0	2.5	3.0	3.5	-
42.0	43.5	45.0	46.5	-
25.2	25.6	26.0	26.5	-
13.4	13.5	13.6	13.8	-
11.8	12.1	12.4	12.7	-
12.2	13.2	14.0	14.7	-
4.8	5.1	5.3	5.5	-
7.3	8.0	8.5	8.9	-
0.1	0.1	0.2	0.3	-
4.6	4.7	5.0	5.3	-
				(%)
701.0	1,041.0	2,086.0	4,032.0	7.3
32.0	56.0	130.0	282.0	9.0
669.0	985.0	1,956.0	3,750.0	7.2
402.0	580.0	1,130.0	2,137.0	7.0
214.0	306.0	591.0	1,113.0	6.8
188.0	274.0	539.0	1,024.0	7.1
194.0	299.0	609.0	1,186.0	7.7
76.0	116.0	230.0	444.0	7.4
116.0	181.0	370.0	718.0	7.7
2.0	2.0	9.0	24.0	-
73.0	106.0	217.0	427.0	7.3

...s expressed with the total of rolled products as 100%.

SECTION 2

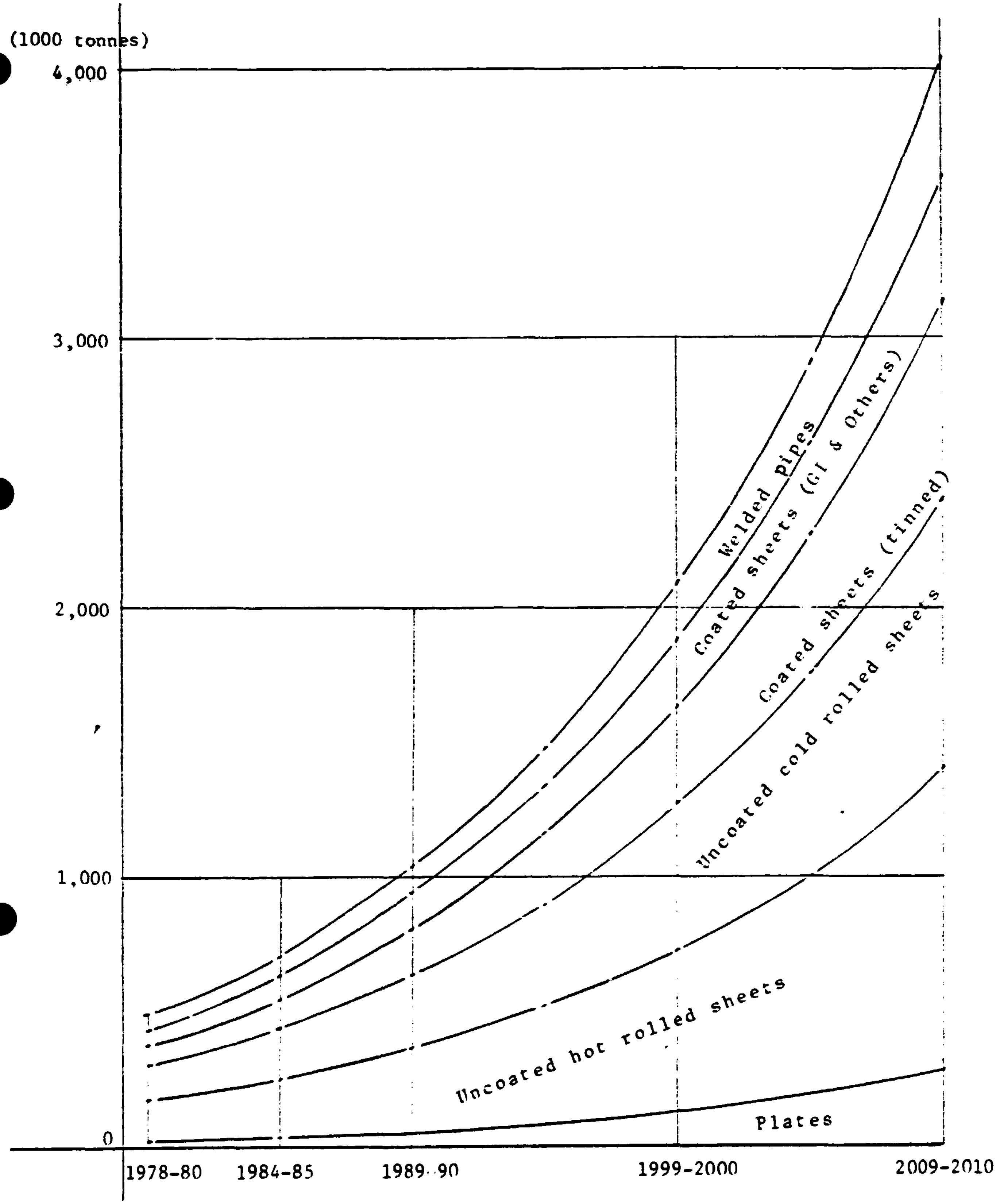

Fig. 3.6.6 Forecast of Flat Products

As coated sheets, there are galvanized, tinned and other coated sheets. Galvanized sheets generally enjoy a large share in developing countries, but as they are not used as roofing materials in Pakistan, their share is quite small there, being only 4.5%. (In Thailand, the share is about 10%.)
As galvanized sheets are used in such applications as various home and electrical appliances, however, they are expected to show an average annual growth rate comparable to that of flat products. Tin-plates are being used for ghee oil cans, food cans, lubricant cans, shoe polish cans, etc., and have been enjoying a high growth rate. From now on, too, they are likely to maintain a high growth rate. Other coated sheets are not being used today, but are expected to find applications in such field as automobile, electric machinery, home equipment, etc.
Welded pipes are used for pipelines for water, gas or oil and also for electric light poles and illumination poles, and are expected to show the same level of growth as flat products.

3.7 Outlook for Steel Demand and Supply in Pakistan

3.7.1 Introduction

In this section, future production will be forecasted separately for non-flat and flat products on the basis of Pakistani current production capacity and additional capacity to be completed soon, taking into consideration the outlook for steel demand discussed in the preceding section. Then, demand for and supply of steel products in Pakistan up to 1999-2000 will be studied briefly. Demand and supply outlook will be studied in detail in Chapter 6, "Prospective Project Study". There, existing mills, mills to be constructed and new projects will be examined.

3.7.2 Demand-Supply Projection of Non-Flat Products

Current supply of non-flat products is as discussed in Chapter 2. A large number of small scale companies are estimated to have produced 574,000 tonnes of products during 1979-80. The existing steel mills are expected to maintain as a whole their current production capacity, and future production may be predicted, taking into consideration only technological improvements and some minor capital investment leading to capacity expansion. Pakistan Steel plans to start the production of billets in 1982.

The above discussion may be summarized as in Table 3.7.1.

Table 3.7.1 Demand-Supply Projection of Non-flat Products

(Unit: 1,000 tonnes)

Year	1979-80	1984-85	1989-90	1999-2000
Demand	667	892	1,223	2,260
Production Capacity:				
Pakistan Steel	-	120	120	120
Existing steel mills	820	861	902	919
Total	820	981	1,022	1,039
Supply:				
Pakistan Steel	-	100	120	120
Existing steel mills	574	668	902	919
Total	574	768	1,022	1,039
Self-sufficiency rate (%)	(86)	(86)	(84)	(46)
Balance	93	124	201	1,221

Note: The 1984-85 demand includes those products which cannot be produced with the existing mills (such as rails, seamless pipes), and therefore the rate of operation is set at a low level.

The deficit of non-flat products shown in Balance column in Table 3.7.1 will not increase so much up to 1989-90 owing to the commencement of operation at Pakistan Steel and increased rate of operation at the existing mills, and the self-sufficiency rate (Supply/Demand) is expected to be maintained at the current level (over 80%). Thereafter, there will be no additional production capacity, however, demand is expected to increase. Therefore, deficit is expected to reach 1,221,000 tonnes by 1999-2000, and then self-sufficiency rate will be greatly reduced down to 46%.

3.7.3 Demand-Supply Projection of Flat Products

As for flat products, Pakistan is currently producing only 15,000 tonnes of hoops. Pakistan Steel is constructing a hot strip mill with an annual production capacity of 1.8 million tonnes to complete it by the middle of 1983. Problems related to the operation of this mill will be discussed in detail in Chapter 6. Here it is assumed that Pakistan Steel will take about 20 months from the starting of operation to the full production, that the effective production capacity (realistic maximum production capacity taking into consideration balance in facilities, operation capacity, etc.) will be 95.5% of the nominal capacity (95.5% in Japan) and that the production of flat products will be 623 tonnes in view of the balance between billet and slab. Then, Table 3.7.2 will be obtained.

Table 3.7.2 Demand-Supply Projection of Flat Products

(Unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	485	701	1,041	2,086
Supply:				
Pakistan Steel	-	470	623	623
Existing steel mills	15	15	15	15
Total	15	485	638	638
Self-sufficiency rate (%)	(3)	(69)	(62)	(31)
Balance	470	216	403	1,448

Note: Demand included coils for welded pipes.

Deficit will decrease from today's 470,000 tonnes to 216,000 tonnes by 1984-85, the first production year of the hot strip mill, and self-sufficiency rate will be raised considerably from 3 to 69%. However, this high level of that rate will be maintained only up to 1989-1990. The hot strip mill will reach its maximum production at 638,000 tonnes due to the limitation of pig iron and slab. Thereafter, deficit will rapidly increase and self-sufficient rate will start to decline to reach 1,448,000 tonnes and 31%, respectively, by the year 1999-2000.

3.8 Foreign Market

3.8.1 Introduction

So far, Pakistan's domestic market has been studied. In this section, world steel demand and supply outlook, steel markets in the surrounding countries and present conditions of steel industries in those countries will be briefly studied. Also, their future will be discussed.

Outlook for world demand for steel was briefly discussed in Section 3.1. In this section, production outlook will be added to the discussion to forecast world demand for and supply of steel.

As countries surrounding Pakistan, Saudi Arabia, Iran, Iraq and Kuwait from the Middle East and India, Bangladesh, Thailand, Malaysia and Indonesia from Asia, a total of nine countries, have been studied.

3.8.2 Outlook for World Steel Demand and Supply

First, world steel production will be forecasted. This process has many difficulties. Of the available data, relatively new data are shown in Table 3.8.1. The data are for the Western World only up to 1985.

Table 3.8.1 Outlook for Steel Production in the Western World

(Unit: million tonnes)

		Advanced industrialized countries	Developing countries	Western world total
UNIDO (Oct. 1979)	1977		62.7	
	1985	-	118.6	-
*	Annual growth rate 85/77		8.3	
CIA	1978		64.0	
(Aug. 1979)	1985	-	112.0	-
**	Annual growth rate 85/78		8.3	
IISI	1980	513.9	84.5	598.4
(Mar. 1980)	1985	522.7	127.3	650.0
*	Annual growth rate 85/80	0.3	8.5	1.7

Note: As for regional grouping, CIA figures include West European countries other than EC countries and also South Africa. IISI grouping is comparable to UNIDO's grouping.

* Capacity ** Production
° Crude steel base

Here, steel demand and supply in the Western World will be forecasted only up to 1985 due to limitation in data. Most recent data and Table 3.8.1 are used to prepare Table 3.8.2.

During the coming five years, although demand in the developing countries will expand following the past

Table 3.8.2 Steel Demand and Supply Outlook in the Western World

(Unit: million tonnes, %)

	1970	1975	1978	1980	1985	80/70	85/80
Developing countries							
Consumption	58.9	90.9	106.7	114.3	158.3	6.9	6.7
Production	33.9	49.7	66.7	78.0	117.3	8.7	8.5
Production-consumption	-25.0	-41.2	-40.0	-36.3	-41.0		
Developed countries							
Consumption	359.6	321.9	346.1	345.8	380.2	-0.3	1.9
Production	385.2	373.9	402.3	387.1	418.2	0.0	1.6
Production-consumption	25.6	52.0	56.2	41.3	38.0		
Total of the Western World							
Consumption	418.5	412.8	452.8	460.1	538.5	1.0	3.2
Production	419.1	423.6	469.0	465.1	535.5	1.0	1.9
Production-consumption	0.6	10.8	16.2	5.0	-3.0		

Note:

- Production figures are taken from Table 3.8.1, assuming 80% operation rate of capacity presented by IISI.
- Consumption figures are calculated, taking into consideration the growth rate of Nippon Steel Corp. shown in "Steel in the 80's" by OECD and 1981 outlook presented in "Short Range Outlook" (March, 1981) by IISI.
- Crude steel base.

trend, demand in the developed countries will continue to be stagnant, and that in the Western World as a whole will show an annual growth rate of only 3.2%. As for production, the developing countries which account for 17% of the total production in the Western World will maintain the past growth rate as in the case of demand, but the developed countries will show only a slight growth. As a result, the developing countries as a whole will improve their self-sufficient rate to 74% by 1985 from 68% in 1980. Steel demand and supply in 1985 will be more stable than today in the Western World.

3.8.3 Steel Markets in Surrounding Countries

(1) Oil Producing Countries in the Middle East

Saudi Arabia, Iran, Iraq and Kuwait have been selected for analysis. As shown in Table 3.8.3, steel consumption in these countries showed a rapid increase in the past ten years, especially after the first oil crisis. As a result, steel consumption per capita reached a level of more than 200 kg by 1979.

These countries except for Iran are studied as follows:

These countries had almost no infrastructure ten years ago, and have made a great progress in these ten years in their efforts to build it up.

As manufacturing industries have not been developed, demand for steel products has been centred on such applications as bars and sections for construction and pipes and tubes for oil, and demand for flat steel products has been quite limited. Steel production has been almost zero in these countries. Only in recent years, they have started to construct DR integrated mills which will use low cost natural gas as a reducing agent to produce non-flat steel products. Iraq has constructed a DR integrated mill with an annual capacity of 800,000 tonnes to manufacture bars and sections, but its rate of operation is reported to be very low. Saudi Arabia is constructing a DR integrated mill with a capacity of 800,000 to 850,000 tonnes a year.

On the other hand, Iran which has relatively developed industries among the Middle East countries consumes a considerable amount of not only non-flat products and pipes and tubes but also flat steel products. As for the production of steel products, she has currently rolling mills for sections, wire rods, sheets, pipes and rails to produce about 2 million tonnes of crude steel. She also has a BF integrated plant which has been constructed with Russian assistance. In addition to sections and pipes, plates and sheets are being imported into the country.

In these countries, steel consumption per capita has already reached the level of medium developed steel making countries. Unless their manufacturing industry is developed smoothly, in future there is a high probability of steel demand falling into stagnation when the construction of economic foundations passes through the peak level. In a country like Iran where there is relatively a large population and industries have been developed considerably, such probability is not so large, but current political confusion is causing a great reduction in industrial activities, resulting in a reduction in the demand for steel.

Just for reference, Qatar Steel Co., Ltd., remarkable steel manufacturer in Qatar in Middle East is described here, apart from the steel manufacturers in these countries. Qatar Steel Co., Ltd. has DR integrated mill of annual production capacity of 400,000 tonnes, and produces only steel bars.

Unprecedentedly its mill is proud of larger quantity of production than its nominal capacity under technical cooperation with a Japanese enterprise. Bar consumptions in Qatar is very small in quantity, and most of its products are exported by land to neighbouring Saudi Arabia, Iraq and UAE, etc.

Table 3.8.3 Steel Consumption,

		Saudi Arabia	Iran	Iraq
Consumption	1970	430	1,740	449
	71	432	1,728	432
	72	566	1,804	468
	73	810	2,568	771
	74	1,005	2,973	1,864
	75	1,410	5,382	2,010
	76	1,999	4,919	1,082
	77	1,969	5,864	709
	78	2,479	7,000	1,100
	79	3,731	3,080	2,730
Annual growth rate	79/70	27.1	6.6	22.2
Production	1970	-	-	-
	71	-	-	-
	72	-	-	-
	73	-	240	-
	74	-	567	-
	75	-	551	-
	76	-	549	-
	77	-	1,825	-
	78	-	1,300	-
	79	-	1,430	-
[illegible] ch rate	79/70		(79/73) 34.6	
Import	1970	172	947	339
	71	305	1,558	320
	72	403	1,306	349
	73	585	1,924	471
	74	728	2,269	1,425
	75	1,005	3,993	1,485
	76	1,504	3,752	807

Production & Import in Surrounding Countries

(Unit: 1000 tonnes, %)

Kuwait	India	Bangla-desh	Thailand	Malaysia	Indonesia
219	6,432	-	793	606	597
221	7,710	-	795	616	612
188	9,227	79	1,081	701	1,030
139	8,221	187	1,240	1,047	1,442
422	8,551	103	1,234	987	1,280
354	8,500	93	1,108	744	1,448
1,174	8,202	102	1,377	840	1,382
630	10,185	79	1,655	867	1,744
441	10,060	100	1,902	1,000	1,964
506	12,050	130	1,900	1,050	2,005
9.8	7.2	(79/72)7.4	10.2	6.3	14.4
-	6,276	-	153	122	10
-	6,101	-	170	160	10
-	6,856	58	283	187	30
-	6,889	64	324	180	50
-	7,068	82	326	182	80
-	7,991	100	251	183	100
-	9,364	83	281	190	139
-	10,009	113	309	194	250
-	10,099	125	385	203	310
-	10,126	130	400	233	518
	5.5	(79/72)12.2	11.3	7.5	55.1
105	598	-	543	366	388
166	1,217	-	475	398	463
133	1,269	60	604	473	769
142	1,017	127	690	718	1,093
327	1,233	71	675	859	1,068
252	723	72	573	528	963
906	555	82	891	602	1,133

	77	-	1,825	-
	78	-	1,300	-
	79	-	1,430	-
Annual growth rate	79/70	(79/73)	34.6	
Import	1970	172	947	339
	71	305	1,558	320
	72	403	1,306	349
	73	585	1,924	471
	74	728	2,269	1,425
	75	1,005	3,993	1,485
	76	1,504	3,752	807
	77	1,618	3,265	420
	78	1,907	4,564	855
	79	2,870	1,320	2,100
	79/70	36.7	3.8	22.5
Steel Consumption per Capita	1979	460	*197	214
Self-sufficiency rate	(%)			
Production/ Consumption	1970	-	-	-
	71	-	-	-
	72	-	-	-
	73	-	9.3	-
	74	-	19.1	-
	75	-	10.2	-
	76	-	11.2	-
	77	-	31.1	-
	78	-	18.6	-
	79	-	46.4	-

SECTION 2

Note: o*
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[redacted]

-	10,009	113	309	194	250
-	10,099	125	385	203	310
-	10,126	130	400	233	518
	5.5 (79/72)	12.2	11.3	7.5	55.1
105	598	-	543	366	388
166	1,217	-	475	398	463
133	1,269	60	604	473	769
142	1,017	127	690	718	1,093
327	1,233	71	675	859	1,068
252	723	72	573	528	963
906	555	82	891	602	1,133
511	575	89	1,059	568	1,165
339	1,078	109	1,212	700	1,339
389	1,540	178	1,250	750	1,302
15.7	11.1 (79/72)	16.8	9.2	8.3	14.4
398	16	2	41	79	14
	97.6	-	19.3	20.1	1.7
-	79.1	-	21.4	26.0	1.6
-	74.3	73.4	26.2	26.7	2.9
-	83.8	34.2	26.1	17.2	3.5
-	82.7	79.6	26.4	18.4	6.3
-	94.0	107.5	22.7	24.6	6.9
-	114.2	81.4	20.4	22.6	10.1
-	98.3	143.0	18.7	22.4	14.3
-	100.4	125.0	20.2	20.3	15.8
-	84.0	100.0	21.1	22.2	25.8

1978
Crude Base

Source: IISI, Statistics of IMF and other

(2) Asian Countries

India, Bangladesh, Thailand, Malaysia and Indonesia, five countries, main of which are facing the Indian Ocean, have been selected for analysis. Of the five countries, India, Bangladesh and Indonesia have a very low GNP per capita and are therefore classified by the World Bank into the group of low income countries. Steel consumption per capita is still less than 16 kg in these countries. Of the three countries, Indonesia is carrying out relatively positive investment activities as she has a sufficient supply of capital from oil production, and demand for steel is rapidly increasing.

Under the background of relatively stable agricultural production in recent years, Thailand is quite positive in investment activities mainly in light industries, and her demand for steel is showing a stable expansion. Her steel consumption per capita reached the level of 41 kg in 1979.

Malaysia has a relatively high GNP per capita, following Singapore and Hong Kong, the city-states of Southeast Asia. She has rich mineral resources including oil. Her demand for steel has expanded favourably and steel consumption per capita reached a level of 79 kg by 1979.

These countries, except for India, have been producing from old times non-flat steel products with semi-integrated mills and re-rollers, unlike the countries of the Middle East.

India is endowed with rich iron resources and is one of the biggest steel producing countries in Asia. Six biggest blast furnace integrated steel makers produce about 70% of whole crude production of India and produce all kinds of steel products. Basically, India is one of a few Asian countries which are nearly self-sufficient for steel. Yet, she imports flat products, mainly plates and sheets, and its quantity amounts to 600,000 tonnes a year or more. Fundamentally India has no behaviour to export steel products. Although she may sometimes export steel products, their quantity is limited, and she does not produce steel products more than she needs within the country. Except for Bangladesh which has a very small market, Thailand, Malaysia and Indonesia have a steel self-sufficient rate in the order of 20%, and have natural gas resources respectively. Therefore, they have plans to construct DR integrated mills which will use natural gas being produced within the respective country. (Indonesia already has DR integrated mills and Malaysia, small charcoal blast furnaces.)

They have a common characteristic in that all of them import mainly flat steel products including plates and sheets.

In these Asian countries, except for Bangladesh, steel demand is expected to show a growth rate of about 6 to 7% a year as in the past, and they will continue to increase the import of flat steel products for the near future.

(3) Conclusion

The present and future conditions of the steel markets and the steel industries in the four oil producing countries of the Middle East and the five countries of Asia have been briefly studied. Whether Pakistan could expect these countries to become her markets for steel will be briefly examined. Generally speaking, Iran and the Asian countries are the importers of not only non-flat steel products but also a considerable amount of flat steel products. They are expected to continue to import them. Currently they are importing steel products from the world largest steel exporter, Japan, which is exporting 30 million tonnes of steel products a year, and also from EC and Australia, etc. Also, Republic of Korea which has rapidly improved its competitiveness in the export market in recent years is also exporting steel products to these countries. These steel exporting countries have spent many years to establish economical mass production systems and to improve their cost competitiveness. Countries with no iron resource have carried out that by building modern coastal BF integrated plants, and countries with rich iron resources, by using them.

Is it possible for steel industries in Pakistan to enter such world steel market? The answer should be negative for the time being. Domestic steel product prices in Pakistan are almost twice as high as those in other countries. Even when steel prices took a jump with a great demand in the Middle East market immediately after the first oil crisis, Pakistan was not able to export steel products to the Middle East. Pakistan Steel is planning to produce flat products. The first thing they should do is to build up a system for the stable supply of high quality steel products to domestic market. In so doing, they should improve their price competitiveness. It should not be too late to consider to enter the world market after establishing themselves in the domestic market.

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THE MASTER PLAN
FOR
THE IRON AND STEEL INDUSTRY
IN
PAKISTAN

(VOLUME II)

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4. RECENT TREND IN THE IRON- AND STEELMAKING TECHNOLOGY

4.1 Transport and Pretreatment of Raw Materials

Two major factors have contributed to the development of the modern iron and steel industry in the world: a rapid increase in steel demand brought about by the fast growth of the economy, and a large number of improvements made by steel manufacturers. The most important of these improvements has been the development of highly efficient transportation system and pretreatments of raw materials as well as the development of mass-production system based on the blast furnace, converter and continuous casting processes.

4.1.1 Transportation and Receiption of Raw Materials

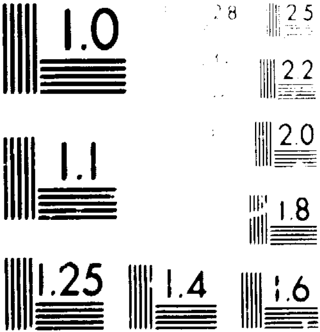
(1) Conditions of location for ironworks and large-sized ships

In Japan and EC countries, modern integrated iron and steel mills were constructed at seashores and have largely depended on the imported main raw materials such as iron ores and coal. For instance, the countries which supply iron ores to Japan are South and North America, Australia, India and Africa that are located over the world. As a result, the average iron ore transport distance on sea in 1980 was about 6,700 sea miles for Japan which was more than twice as 3,000 sea miles for an EC country in the same year. But it was the service of shuttle ships, enlargement of their size and improvement of their operation efficiency that have overcome this disadvantage and reduced the transportation costs. Namely the shuttle ships began to be put in service from 1960's, and in 1970, Japan came to own 44% of the total shuttle ships in the world. Further Japan placed in commission not only the shuttle ships but also the ore-oil combination carriers that transport both oil and ore, and further the ore-oil-bulk carriers that carry oil, ore and coal. As a result, the navigation days without load were shortened, and Japan has succeeded in reducing the sea transportation costs for the materials.

(2) Unloading and storage of raw materials

The ports for loading and unloading the raw materials have been developed in closely related with the construction of large-sized ships, and every newly constructed ironworks can receive these large-sized ships for unloading raw materials.

Although any ironworks needs raw materials with constant quality, the raw materials are not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always constant in properties because they can only intermittently be supplied by ships and further may not be supplied in some seasons. It depends upon the capacity or size of ore storage whether the quality variation of supplied materials can be minimized. For this purpose, the one or one and a half months' supply are generally stored and the yard which is wide enough to receive this quantity of materials is necessary.

4.1.2 Pretreatment of Iron Ores

(1) General

High grade iron ores are shipped from the mines as DSO (direct shipping ore) after undergoing simple crushing and screening processes. They are very limited in quantities. Low grade iron ores or ores containing much impurities are pretreated before shipment for upgrading their quality. This pretreatment process is generally divided into crushing, screening and beneficiation.

The mines have hitherto produced and shipped run of mine ores. These ores were gradually withdrawn from the market at the request of consumers, and today calibrated ore (or lump ore), ore fines and concentrates are the main business commodity.

Iron ores will be screened, or sometimes crushed and screened prior to their charging into the blast furnace, because fine materials, when entered into the blast furnace, may prevent the permeability within the furnace and its smooth operation. This process is called ore sizing or calibrating. Both generated undersize fines from this process and ore fines amount to more than 70% of the total of the iron ores supplied to consumers. These ore fines cannot directly be charged into the blast furnace. They must be agglomerated prior to charge into the furnace. The agglomerated ores are called agglomerates.

The agglomerates must be strong enough not to degrade during transportation and handling, or inside the blast furnace. They must also be easily reducible. Sintering and pelletizing are the typical agglomeration processes. These agglomerates are excellent in the reducibility and the hot properties, and can decrease the consumption of raw flux in the blast furnace through self-fluxed and thereby have much favourable effects on improving the productivity of ironmaking and decreasing in the fuel rates.

The sintering and the pelletizing processes use different materials respectively. Generally, the former uses ore fines with grain size of -5 mm.

The grain size of the latter ranges within 60-80% -44 μm. Therefore the material which is too fine to be used as sintering feed can be used as pelletizing feed. Table 4.1.1 shows the general characteristics of the sintering and pelletizing processes.

Table 4.1.1 Characteristics of Sintering and Pelletizing Processes

Item	Sintering	Pelletizing	
Size range of iron ores	less than 10% +8mm -125 μm the less the better	60-90% −44μm (Specific area: 1000-4000 cm^2/g)	
Chemical composition of products		Self-fluxed pellet	Acid pellet*
T. Fe	55-58%	60-63%	≧64%
SiO_2	5.5-6.5%	3.5-4.5%	≦5.0%
CaO/SiO_2	1.2-2.0	1.2-1.5	—
Al_2O_3	≦ 2.0%	≦ 2.5%	≦3.0%
JIS reducibility	60-75%	60-90%	≧60%
Reduction strength	Low temperature reduction degradation index (DRI)	Reduction under load	average
Size distribution	Wide distribution -5mm grains more as compared with pellets	Narrow distribution -5mm grains fewer	
Location	At consumer side (Ironworks)	At consumer side or supplier side (mine site)	

* On the basis of purchase specification.

Source: ISIJ

(2) Calibrating or sizing

Lump ore is more readily reducible when its top size becomes smaller. But as the charging material, when it contains fine materials, which may prevent the permeability with in the furnace and make the gas distribution uneven causing handing or slip of the furnace and lowering the furnace operation efficiency. Therefore, lump ores must be calibrated by crushing and/or screening to improve its reducibility and the permeability in the furnace. The top size of calibrated ore is about 25-30 mm. Calibrating will make uniform the distribution of reducing gases in the shaft zone of the blast furnace and improve the contact conditions between charging materials and gases. This will promote the heat exchange and lower the fuel rates.

Further, calibrated ore has shortened the time for reduction of ores, imprcved the permeability, sped up the blast furnace operation and greatly contributed to the increase in the output of hot metal.

Hitherto the mines crushed iron ores roughly only for convenience of their transportation. But recently the mines in Australia, Brazil and South Africa which produce high grade ores have come to ship the calibrated ores partly at the request of customers.

The calibration has also a large effect on sinters. Generally, sinters have been crushed to about 50 mm in their top size by the use of the secondary crusher. The sinters being easily degraded during the transportation, the lay-out is often designed where fine materials are removed from ores at the ore bins in front of the blast furnace just before they are charged into the furnace. The more fine materials the charging sinters contain, the worse will be the permeability in the furnace.

(3) Ore bedding

Iron ores are required to be good and constant in quality over a long time. When ores with various brands are used, mixing of some amount of them will average the different characteristics of each brand and also elongate the period of use. If these various brands of ores are mixed with one another by taking them out from hoppers, the same number of hoppers with the number of the brands will become necessary. As the measure against this problem, a bedding method is adopted where various brands of iron ores are thinly spread in layers on the yard and has been producing good results. It has been mainly applied to fines and also partially tried on lump ore.

(4) Sintering process

(a) Enlargement of sintering plant

With the enlargement of blast furnaces, large-sized sintering plants with a sintering area of 300m^2, 500m^2 and 600m^2 have been constructed and have produced good results.

Self-fluxed sinters have proved to have excellent properties as blast furnaces burden from the result of their use in the blast furnace, and thus their burden rate has exceeded 80% in the blast furnace.

New measuring systems have been added in moisture control and bed depth of sinter mixture, and automatic controls of off-gas pressure and temperature.

(b) Sintering operation

The purpose of sintering operation is to minimize the overall costs including the blast furnace operation cost, and to produce the required quality of sinters at a low cost.

More specifically, the sintering operations are intended to maintain the strength and grain size so as to minimize the degradation of sinters and minimize the variation of their chemical composition, thereby lowering the consumption of fuel and electric power and improving the productivity.

Fig. 4.1.1 shows an example of the material balance at the sintering process. The rate of the returned fines is determined by the grain size and sinterability of new materials. Since the unit cost of fuel can be lowered by reducing this rate, how much the rate of returned fines has been reduced under the same material conditions is a barometer of the skillfulness in the sintering operation.

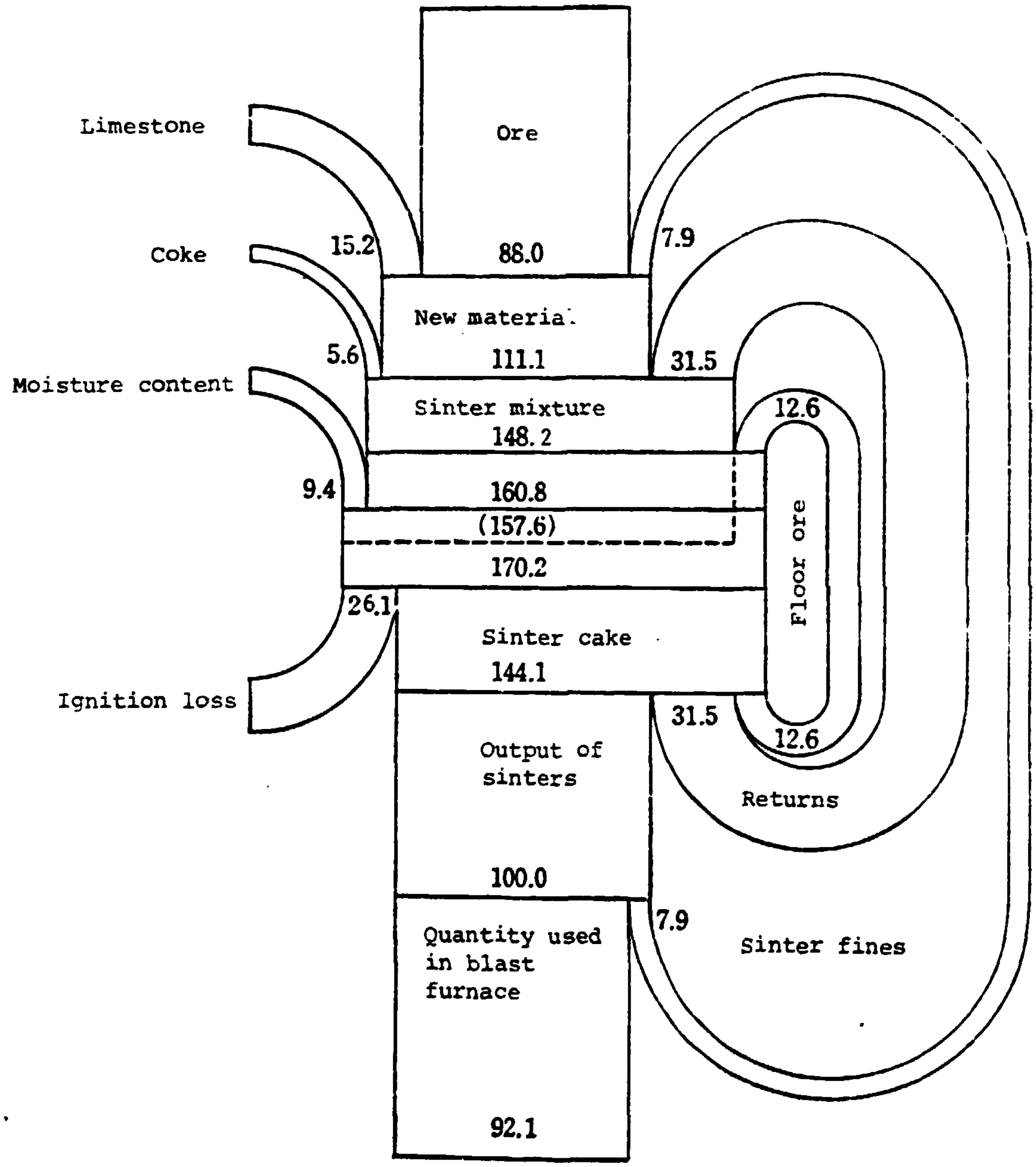


Fig. 4.1.1 An Example of Material Balance in Sintering Plant

Recent studies on quenched blast furnaces providing a clear understanding of the quality of raw materials as well as the process of blast furnace ironmaking, the high temperature properties of sinter in the softening/melting zone have been cleared.

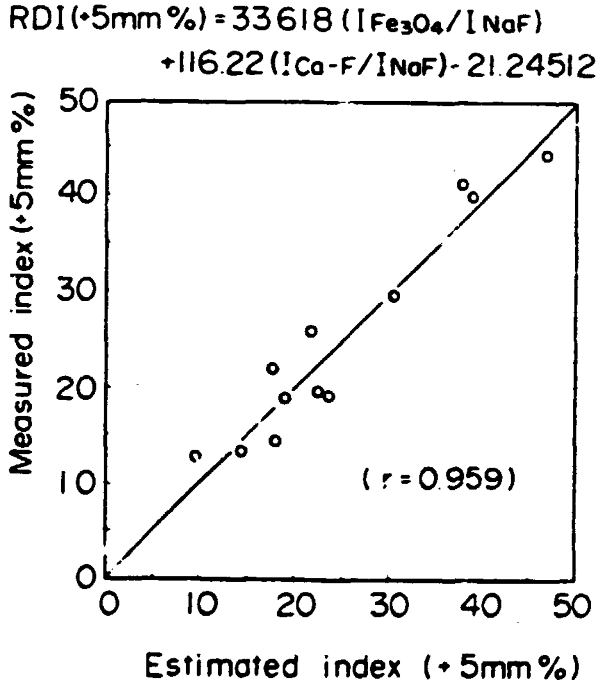
Meanwhile concrete targets have been set for the requirements of raw materials in the blast furnace as follows:

(i) Reduction degradation has been controlled due to the increased use of finer auxiliary raw materials for promoting slagging reaction.

(ii) Some sensors (thermometer,airflow meter, etc.) have provided to control the heat pattern of temperature and airflows within the pallet of a sintering plant, and thus the distribution of temperature within the pallet have been cleared.

(iii) Some targets for sinter texture have been set up between the product qualities (cold strength, reduction degradation index, etc.) and the necessary temperature pattern within the sintering bed in order to obtain more accurate their relationship. However, there are left many unknown points in this field. The sintering mechanism and its reaction speed have been analysed, while a quick analysis method for sintering mechanism has been studied for its practical application. Fig. 4.1.2 shows the relationship between the measured values of RDI and the estimated ones of a quantitative analysis of the sinter texture through X-ray diffraction.

(iv) Efforts have been made to improve the reducibility of sinter through reducing the FeO and SiO_2 contents by above-mentioned techniques, and achieve the blast furnace operations at the low fuel rates.



Source: ISIJ

Fig. 4.1.2 Estimated RDI by X-ray Diffraction

Table 4.1.2 shows the quality control targets for sinters. And Table 4.1.3 shows the parameters for sintering operations.

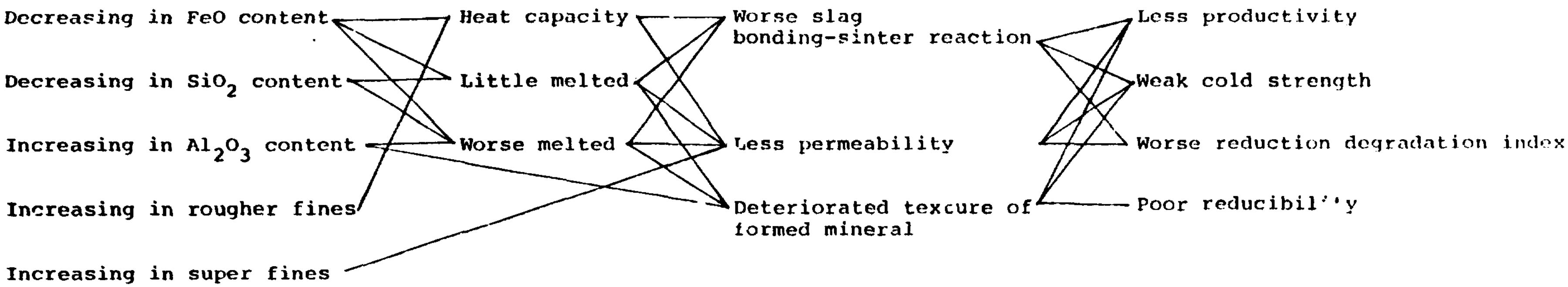
Table 4.1.2 Quality Control Targets for Sinters

Items of quality control for sinters	Target level		Degree of importance
Shatter strength	+10 mm%	≧83-90%	A
Tumbler strength	+10 mm%	≧60-70%	A
RDI index	- 3 mm%	≦35-45%	B
Variations in basicity	CaO/SiO_2	σ≦0.05-0.1	B
Grain size of product (-5 mm)	- 5 mm%	≦5%	B
FeO content of product (%)		≦5%	B
Reducibility (Gaku-Shin Method)	Reduction	60-65%	A

Source: ISIJ

Table 4.1.3 Parameters for Sintering

(Changes in raw material)



(The countermeasures particularly developed during the recent 20 years.)

(i) The optimization of quantity, properties and mineral texture of the formed melted material by slag components (addition of slag forming agent and increase of basicity).

(ii) The optimization of the permeability by improving the size distribution of raw material (adding of binder and crushing of coarse fines).

(iii) Study and countermeasures to reduction degradation mechanism.

(iv) Improvement of the yield rate by increasing the bed depth and the density and reducing the upper fragile portion (tnicker bed depth, high pressure load, after heating furnace, coke sizing, etc.)

(v) Improvement of production efficiency by enlarging the size of machine and improving its operation rate.

(vi) Improvement and stabilization of the control by adoption of automatic control system.

(c) Prospects for sintering

It is expected that the iron ore supply during 1980's will contain a higher percentage of fine ores due to the increase in the supply of finer ores.

The use of finer ores in sintering decreases the permeability and production efficiency. When ore fines are used in large quantities, it is necessary to promote granulation of raw materials and prevent the degranulation and dense bed.

There is the problem of production rate lowering by using sinter with a low silica (SiO_2) content. The SiO_2 content of sinter will affect production rate, strength and reducibility. The manufacture of sinter with 5.5% SiO_2 and 4.0% F_eO (ferrous oxide) contents will be target for the time being.

The desirable properties of sinter is a high reducibility at preheating and indirect zone with low RDI. The control of RDI will also be made in future.

The control of heat pattern will further be discussed through the preparation of mathematic models or corrective works as currently conducted, and will be connected to a continuous on-line system in future.

(5) Pelletizing process

(a) General

The pelletizing process was industrialized to be applied to taconites (low grade iron formation) occurred in U.S.A. in 1943. The full-scale production using this process began in 1954. No large increase in the output of pellets was initially seen, as the production was made in shaft furnaces using magnetite concentrates after beneficiation of taconites at an early stage. The output has considerably increased since 1962 by the invention and use of a grate and a grate kiln which could also be applied to other various types of iron ore as well as magnetite concentrates. The major portion of the pellet output in the world is still now produced in North America. These pellets are said to account for almost a half of the iron source for the production of pig iron in this area. In 1980 the world pelletizing capacity and output are 261 and 206 million tonnes per year respectively as shown in Table 4.1.4.

In it, the total production capacity of the so-called merchant or commercial pellet plants of which products are mainly placed on the market is about 71 million tonnes per year.

Table 4.1.4 World Pelletizing Capacity and Output

(Unit: million tonnes/year)

Area	Capacity	1980 Output
Total	261	206
North America	122	102
Latin America	49	25
Europe (incl USSR)	55	50
Africa	8	6
Asia	15	14
Oceania	12	9

In 1980, pellets for BF grade on the market were approx. 55 million tonnes, and pellets for DR grade approx. 3 million tonnes. There were no troubles happened since the supply capacity of pellets was bigger 13 million tonnes than actual supplied pellets on the market. Pellets on the market will be estimated at approx. 90 million tonnes in 1990.

Most of these commercial pellets had faced the problems of insufficient crushing strength, low reducibility and high swelling at an early stage of production, caused troubles in the blast furnace operations and invited a decrease in the output of pig iron. With this as a momentum, the technical committee was set up by the joint efforts of suppliers and consumers to improve the quality of these pellets. Today most pellets are satisfying the contract specifications. However, charging them in large quantities into a large-sized blast furnace is still avoided (about 20% at maximum), and more efforts are required to improve the quality of pellets in this respect.

On the other hand, the introduction of process control into the pellet manufacturing process has had good effects on the firing control.

Further the cold bond pellets manufacturing method was developed but it has not been industrialized except for North European countries, as addition of about 10% cement in this method causes to lower the iron grade. The process requiring a large consumption of oil energy, the time will be ripe for reconsidering this cold bond method.

It will become important in future to develop the pellets as the material for the direct reduction process which will serve as a measure for ironmaking in developing countries, especially oil or gas producing countries, let alone their charging into blast furnaces.

Three systems are currently operated as pelletizing facilities; shaft furnace, grate and grate-kiln systems.

(b) Pelletizing operation

By comparing between the properties of pellets and sinter, it is found that pellets should be improved in (i) the external shape and (ii) high temperature reduction, softening and melting characteristics.

(i) Pellets which have a smaller angle of repose than that of sinter tend to be segregated in the blast furnace. The ore layer tends to be collapsed at the descending of burden.

(ii) The lime-fluxed pellets begin to soften or melt down at a lower temperature as compared with sinter, which increases the width of cohesive zone and prevents the permeability.

Some recent technical reports for improving these points have discussed about crushed pellets, dolomite-fluxed pellets and porous pellets.

(c) Progress of energy saving techniques

The energy cost accounts for a large portion of the pelletizing cost. A number of pelletizing plants have been shut down because of high fuel costs or insufficient demand. In the factories now in operation, the energy-saving as well as the improvement on pellet quality is strongly called for.

Some concrete measures for energy-saving taken recently are as follows:

(i) Conversion from oil to coal

Coal is pulverized and substituted for the heavy oil. This substitution rate has reached 80% or higher in some pellet plants.

(ii) The use of combustible materials (charcoal, coke breeze, etc.) mixed in iron ores.

(iii) The provision of off-gas recovery equipment (especially the effective use of exhaust gas of cooler).

(6) Preferred ironmaking burden materials

Recent studies have shown that acid pellets develop a dense metallic shell during reduction at temperature in the range 1,000-1,200°C. As a result, reduction shows and the wustite and gangue materials in the core react to form a low melting point slag. Low softening temperatures result which give rise to a broad cohesive zone. Fluxed pellets, however, particularly MgO fluxed pellets, give much higher softening temperatures because of the different phases formed during the high temperature reduction process. Fluxed sinters also result in higher melting point phases. Typical results for the three types of burden materials are given in Table 4.1.5 which show the marked lowering of the softening temperature and the increase in the temperature interval between softening and melting for acid pellets. The degree of reduction is also lower for acid pellets.

The values given imply that higher coke rates would be needed for acid pellet burden when compared with fluxed sinter or fluxed pellets. Actual operating experience has shown that, for each one (1) percent substitution of fluxed sinter, fluxed pellets or acid pellets for lump ore, coke rate saving of 0.8-1.2, 0.5-0.9 and 0.3-0.5 kg/tonne·hot metal respectively can be anticipated.

Table 4.1.5 Softening. Meltdown and Degree of Reduction of Furnace Burden Materials

	Softening Temperature °C	Meltdown Temperature °C	Degree of Reduction %	
			1,000°C	1,200°C
Acid Pellets	1,220	1,490	69	78
Self-fluxed Pellets	1,350	1,460	75	86
Fluxed Sinters	1,310	1,490	84	94

Different burden types may be technically compared if "typical" properties are assumed. These are listed in Table 4.1.6 and ranked as follows:

(a) Fluxed sinter (CaO/SiO_2 1.6-1.8) is the preferred burden because of its high reducibility acceptable RDI, good softening/melting properties, and good blast furnace distributional characteristics.

(b) MgO fluxed pellets have good softening/melting properties, good permiability and high reducibility. However, their spherical shape and high bulk density create distribution control problems in large furnaces.

(c) CaO fluxed pellets have inferior swelling and softening/melting properties to MgO fluxed pellets.

(d) Acid pellets generally have the best stack permiability of acid burden material and do not exhibit adverse RDI. However, they are not superior to good quality lump ore with respect to softening/melting properties and stack distribution control.

(e) Lump ore has better reducibility and furnace permiability than acid sinter. Some of lump ore are equivalent to acid pellets in terms of reducibility.

(f) Acid sinter has the lowest permiability and reducibility and usually exhibits low softening temperatures with adverse effects on the cohesive zone. Normally high blast furnace coke rates are required.

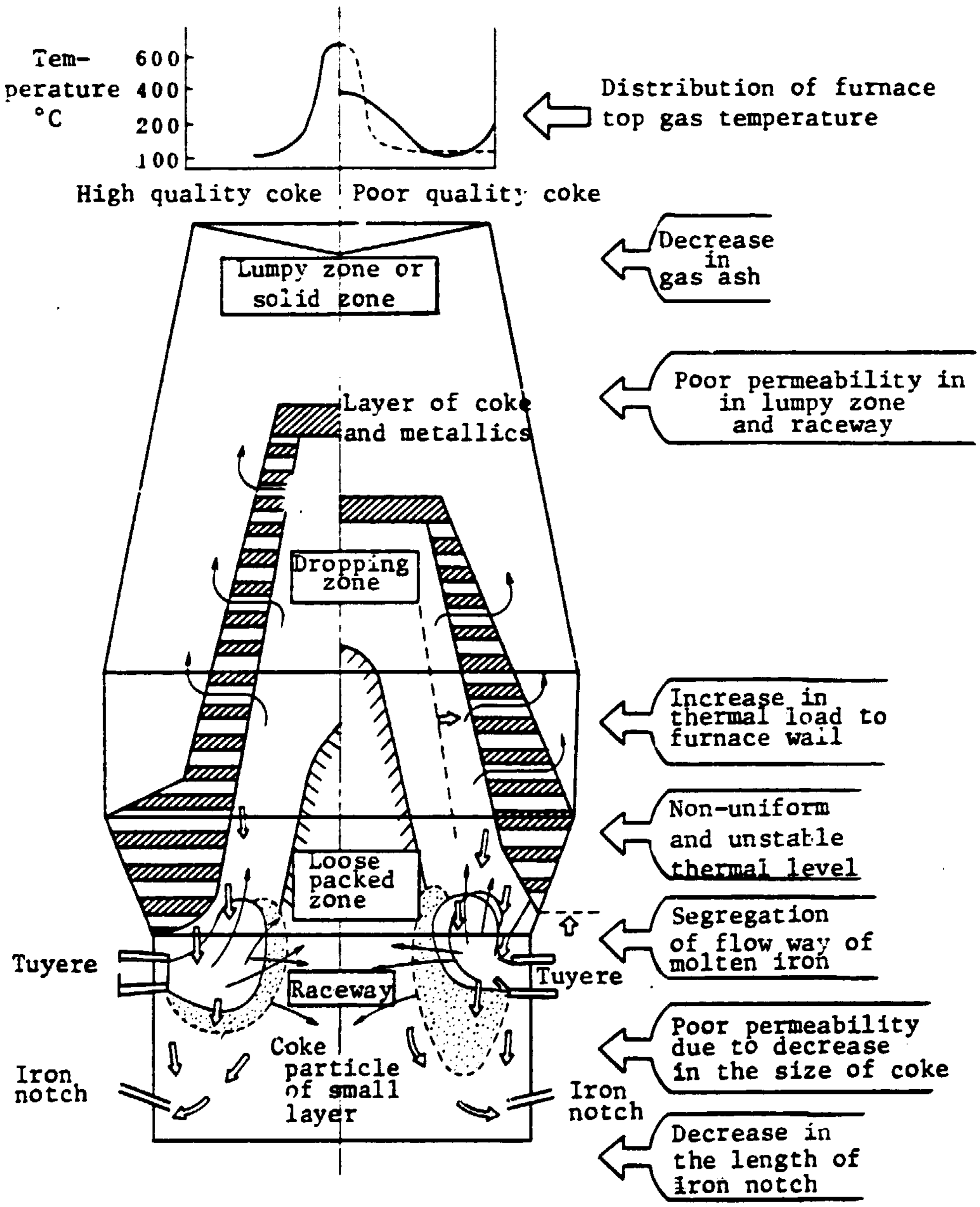
Table 4.1.6 An Indicative Comparison of Sinter, Pellets and Lump Ore Properties

	Sinters (5-50mm)		Pellets (9-16mm)			
	Fluxed	Acid	CaO Fluxed	Partly MgO Fluxed	Acid	Lump (10-30mm)
Reducibility (JIS), % reduction	55-60	45-50	60-70	60-70	50-55	50-55
Softening Temp. (under load) °C	1,150	1,000	1,100	1,150	1,000	1,000
Reduction Degradation Index (RDI) % -3mm	30-40	10-15	5	5	5	5
Thermal Degradation % -10mm	0	0	0	0	0	10
Swelling, %	0	0	12	10	15	0
Abrasion (JIS) % +10mm	65	70	85	85	85	80
Compression Strength kg/pellet	-	-	320	320	250	-
Angle of Repose, Degree	28	28	20	20	20	30

4.1.3 Coal Transformation Technology

(1) General

The progress of coke manufacturing technology has been a history of coal transformation technology. Quality of coke and conditions of a blast furnace are considered to be as shown in Fig. 4.1.3.
As the hot properties of coke within the blast furnace, attention has been paid to control coke strength after reaction in addition to cold drum strength.



Source: ISIJ

Fig. 4.1.3 Diagrammatic Representation of Changes in Softening/Melting Zone and Raceway due to Quality of Coke

With the recent remarkable progress in the blast furnace operation technology and the increase in the output of pig iron due to adoption of large-sized blast furnaces, the construction and operation technologies for large-sized coke ovens have much advanced and greatly contributed towards the development of iron and steel industry.

(2) Equipment of coke oven

(a) Enlargement of coke oven

Since 1961, the coke oven has begun to be enclarged. A consturcted oven has the standard height of 6m. Further an oven with a height of more than 7.5m has appeared. Usual inner volume is now 35-40 m^3. One of the present largest ovens has an inner volume of 48.5 m^3 which is twice or triple larger than that before. In enlargement of the coke oven the most important factor is how to realize uniform heating within each oven chamber both in vertical and horizontal directions within each oven chamber when its height and length get larger. As for uniform heating, which in vertical direction is more important.

(b) Automation, mechanization and energy savings

As coke ovens have become larger, automation, mechanization and energy savings have been taken since 1970's. As a result of such measures, production per oven has increased by three to four times.

Automation has seen a rapid progress during the last ten years. Directions of automation may be classified as follows:

1) Automation of coal blending control,

2) Automation of combustion control, and

3) Automation of the operation of transportation machines moving around coke ovens.

In the near future, a total computer system covering the operation and management of the coal yard and the chemical synthesizing plant will be introduced.

(3) Quality evaluation of coal and coke

As for the quality of coke, many investigations and researches are under way on the relationships among macroscopic strength, grain size, microscopic strength, structure, texture and reactivity, the relations of these factors with manufacturing conditions and blast furnace operations. Particularly noteworthy is that the hot properties, have begun to be regarded as important. This is resulted from the study of the properties of the coke sampled during the blow-down of a blast furnace or at the time of the quenched blast furnace, and the addition of new properties such as coke strength after reaction to the quality characteristics of coke has been promoted.

Another noteworthy matter is that the basic studies have advanced on the coal structure and the mechanism of its conversion into coke and the applications to the estimation of coke strength, the quality evaluation of coal and the analysis of coke texture such as mean reflectance are being promoted especially based on geotexture of coal.

Also, an attempt has been made to widen the range of coal selection and as a most advanced technology, research and development works are being carried out on the briquette charging.

Quality evaluation of coal by means of mean reflectance, maximum fluidity, composition balance index and strength index are shown in Fig. 4.1.4 and 4.1.5 respectively.

Fig. 4.1.6 shows coke strength after reaction (CO_2 gas) by means reflectance and inert quantity.

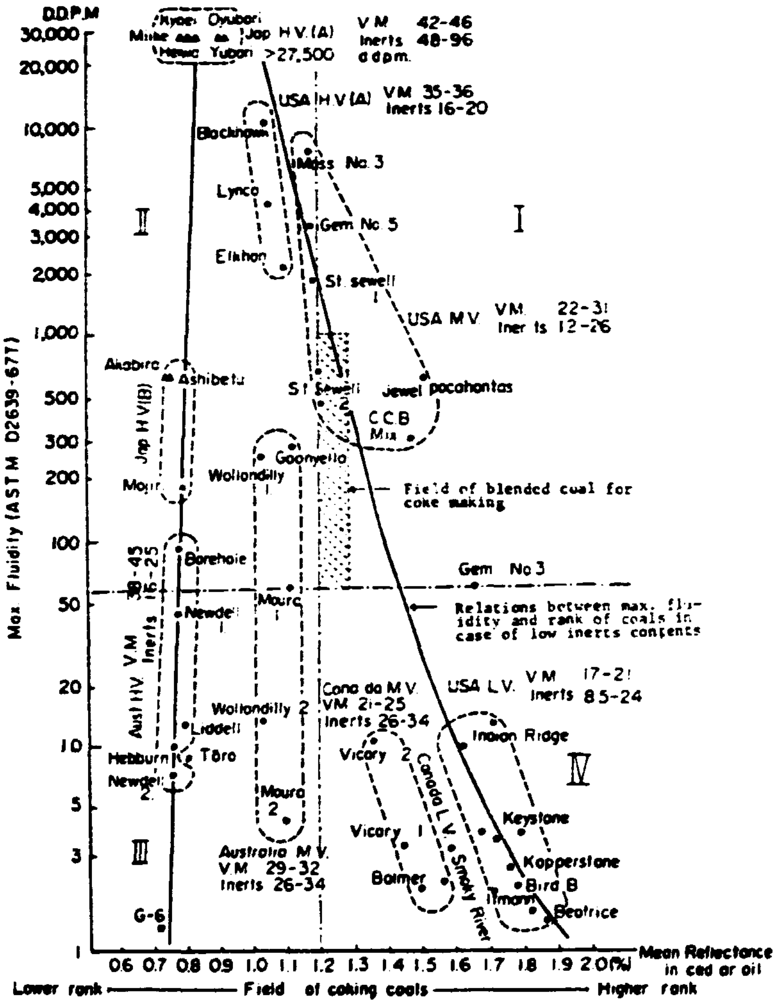


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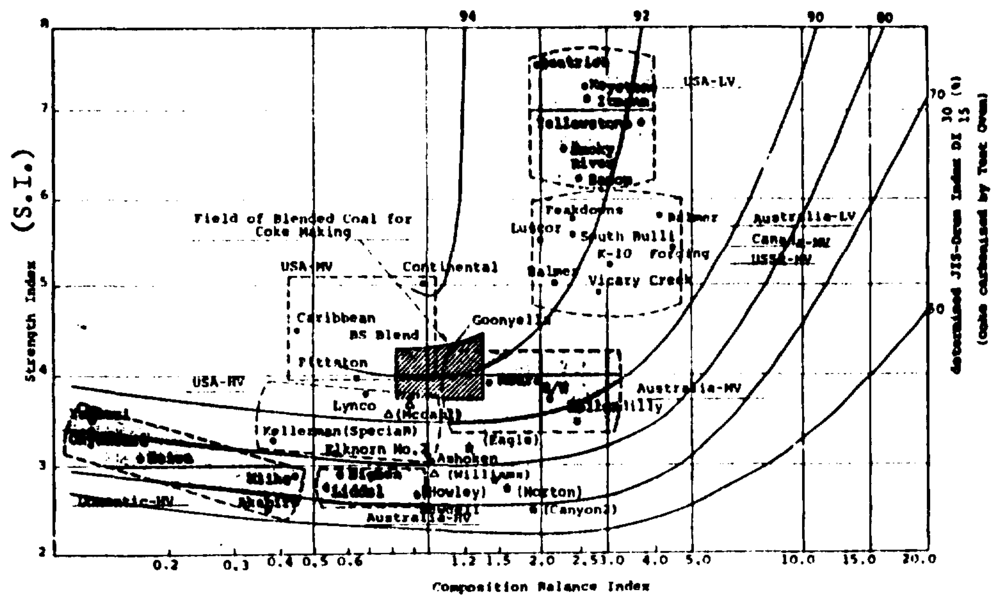
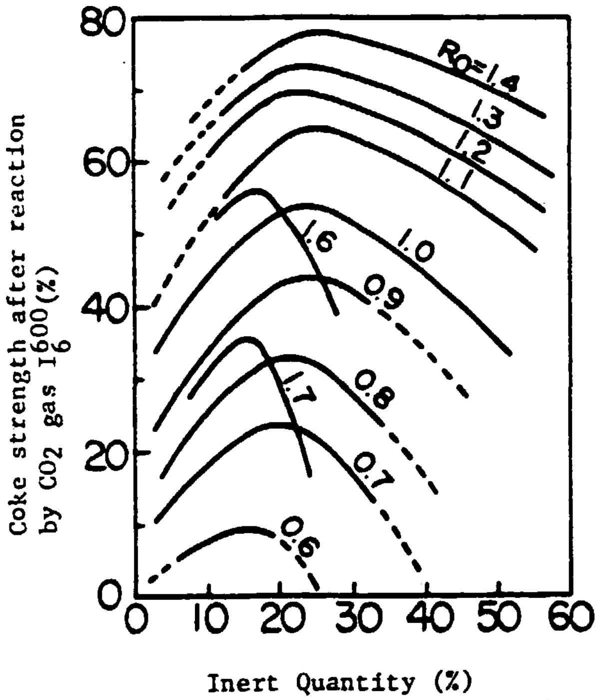
Fig. 4.1.4 Evaluation of Coal by Mean Reflectance and Maximum Fluidity



Source: ISIJ

Fig. 4.1.5 Evaluation of Coal by C.B.I. and S.I.



Source: ISIJ

Fig. 4.1.6 Coke Strength after Reaction (CO_2 Gas) by Mean Reflectance and Inert Quantity

(4) Pretreatment of Coal

As for the pretreatment of coal, there are currently three treatment technologies as follows:

(a) crushing and uniform blending,

(b) dry and preheat of coal prior to charging it in the oven, and

(c) adding caking agents.

These technologies have been combined in existing industrialized processes.

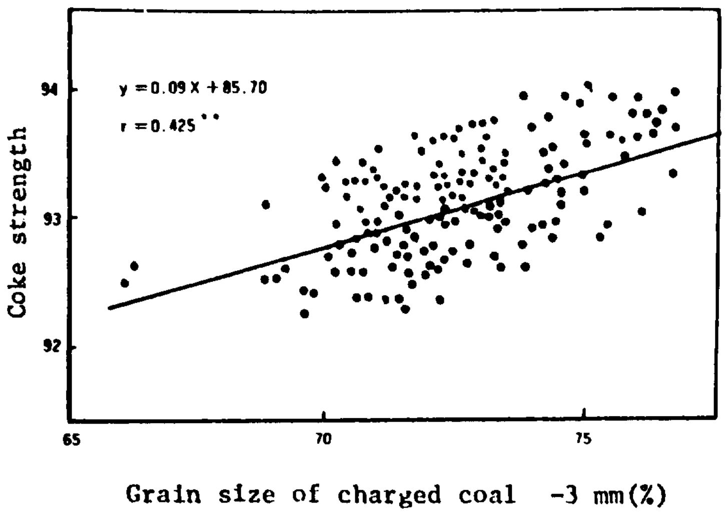
(a) Crushing and blending

Coal is a natural product* and heterogeneous in quality. Various coal pretreatment processes have been developed because the quality of coke is changeable according to the methods of crushing and blending coal.

Fig. 4.1.7 shows relationship between grain size of coal and coke strength, and

Fig. 4.1.8 shows main coal blending and their characteristics.

Note: * Coal is usually shipped after it was washed at mines, and ironworks have no washing facilities.



Volatile matter	30.6%
Soaking time	107°
Coke over temperature	1,238°C
Bulk density	0.743 t/m^3
Moisture	9.19%

Source: ISIJ

Fig. 4.1.7 Relationship between Grain Size of Coal and Coke Strength

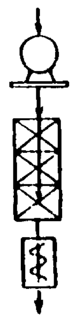
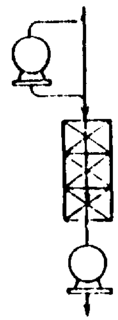
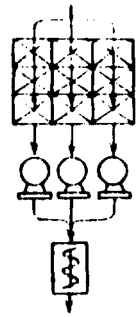
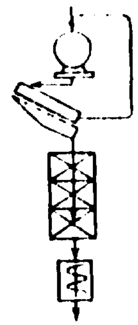
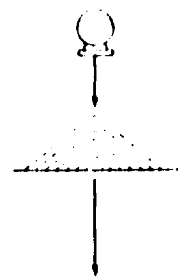
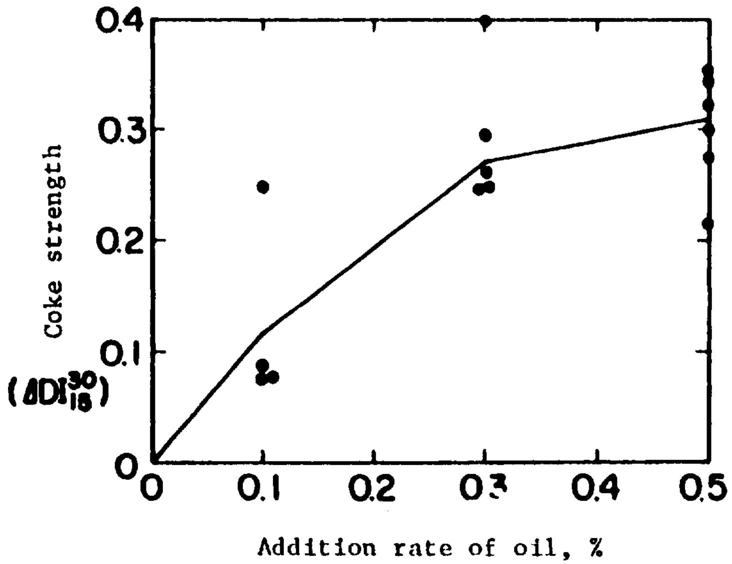
Method	Blending Crushing Method	Crushing Compound Method	Primary and Secondary Crushing Methods	Group Compounding and Crushing Method	Selective Crushing Method	Yard Blending Method
Process Flow						
Characteristics	No coal mixer needed No crushing according to coal characteristics Few dust generation and hanging in the blended bin Countermeasure to large lump coal needed	Crushing according to coal characteristic Consideration needed for dust generation and hanging in the blending bin Coal mixer needed	Crushing according to size and hardness of coal Comperatively few dust generation in the blending bin	Coal with similar characteristics can be grouped, blended and crushed according to each characteristics Few dust generation and hanging in the blended bin Coal mixer needed	Crushing according to the characteristics of coal texture Coal mixer needed	Blending according to the characteristics of coal No blending bin needed Blending of multi-brand coal Difficult blending for short-term

Fig. 4.1.8 Various Coal Pretreatment Processes and Their Characteristics

(b) Dry and preheat of coal prior to charging

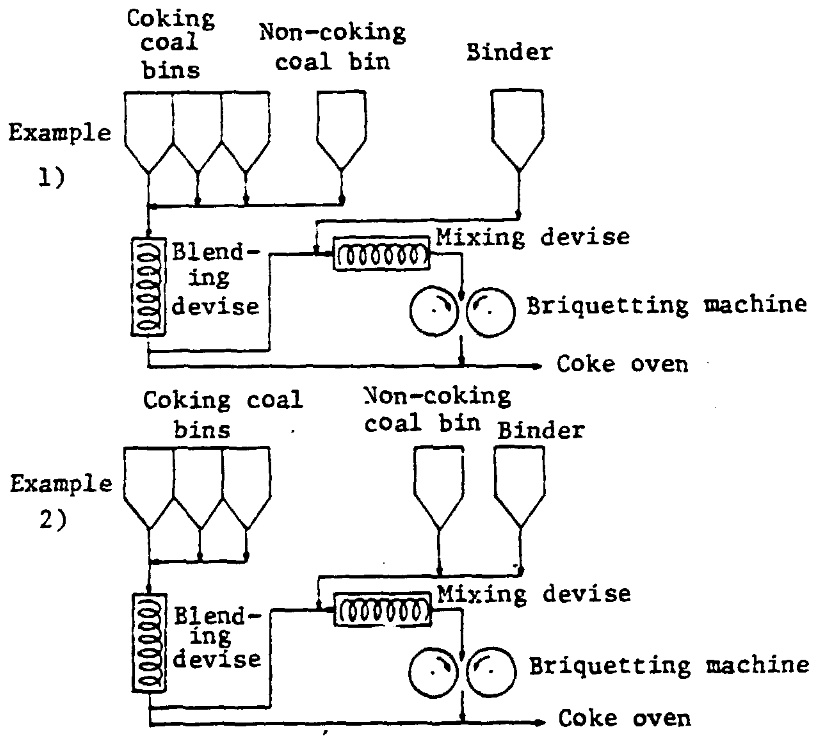
The study of charging coal dried or preheated prior to charging coal in the coke oven is attracting much attention. This will improve the quality of coke, promote the use of low-grade coal and achieve higher productivity through raising the bulk density in the oven chamber and shortening the coking time by drying or preheating coal. Fig. 4.1.9 shows the relationship between addition of oil and coke strength.

Typical processes are shown in Fig. 4.1.10 and 4.1.11.



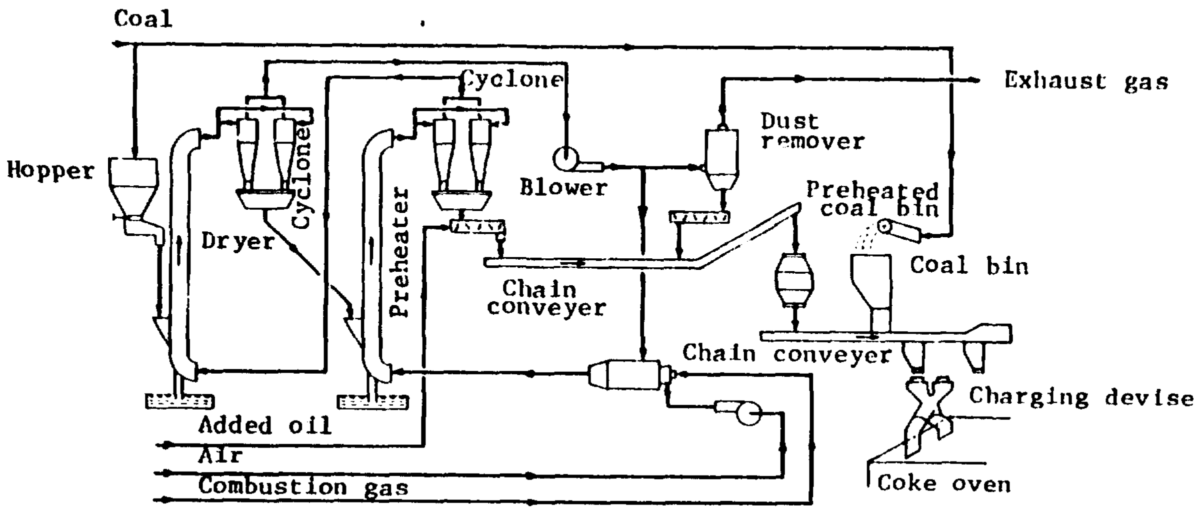
Source: ISIJ

Fig. 4.1.9 Relationship between Addition Rate of Oil and Coke Strength



Source: ISIJ

Fig. 4.1.10 Flow of Coal Briquetting Process



Source: ISIJ

Fig. 4.1.11 An Example of Pre-Carbon Process

(c) Adding of binder

By adding a binder like asphalt pitch to coal, it is possible to improve the softening and melting characteristics of coal at the time of dry distillation and thus to improve coke strength.

A binder is not only useful simply in maintaining and improving the quality of coke but also considered to be a powerful means to develop new coke manufacturing technologies. Studies on the properties of various binders, their effectiveness and their proper use have been just started, and further progress in studies are expected.

Recently, ASP (asphalt pitch) and SRC (solvent refined coal) are being used as a petro-caking agent. As for coal caking agent, crude petroleum origin binders are used.

(5) Energy saving

Ninety percent of energy used by coke ovens is COG or BFG, and efforts are made to save energy for dry distillation.

As a future target, energy saving by means of programmed heating is expected. This programmed heating will use automated combustion control.

The most heat in coke ovens comes from the sensible heat of heated coke, which accounts for 43 % of the total heat. Coke ovens are using the system of collecting the sensible heat by means of CDQ (coke dry quenching).

(6) Considerations

The supply and demand of coal is one of the largest problems for manufacturing coke, and a large factor to regulate the blast furnace ironmaking process.

Accordingly the development of new coke manufacturing technology which can widen the choice by using steam coal of low utility for ironmaking and which can also make it possible to widen the selection of materials from the viewpoint of costs. The coal briquette charging can be a powerful measure in the developments.

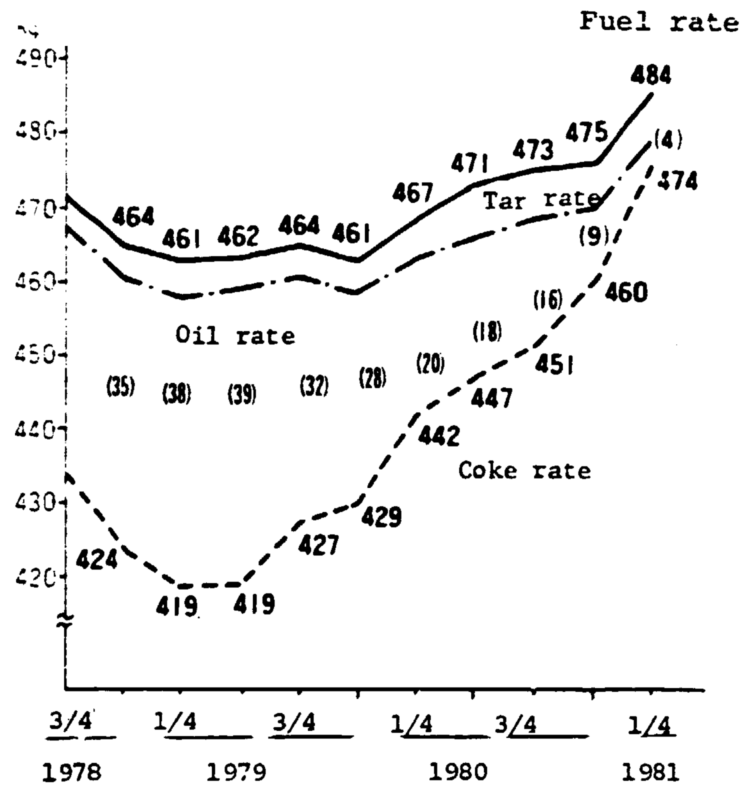
4.2 Ironmaking

4.2.1 Blast Furnace Ironmaking

(1) General

The expansion of iron- and steelmaking has been supported by means of going-large in equipment. The oil crises since 1973 has changed the trend of going-large. Instead of quantitative expansion which was most prevalent during the age of high economic growth, efforts have been concentrated on technologies to reduce operating costs, to save mineral and energy resources and to meet the age of low economic growth which will be expected to last so long. When considering energy saving in the field of ironmaking, an improvement of metallurgical reaction processes cannot be forgotten. Rising price of oil has been so sharp compared with coal price that the blast furnace operation is being made by the so called oilless or all coke operation to the blast furnace in which no oil is injected. All of the existing blast furnaces in Japan have been changed to oilless oepration as of May, 1981. As a result, the apparent fuel rate has been raised, but actual fuel costs have been lowered. The most important task should be in developing technologies to decrease in fuel rates and to realize a stable operation of a blast furnace.

Fig. 4.2.1 shows fuel rates of blast furnace in Japan these three years.



Source: JISF

Fig. 4.2.1 Fuel Rates of Blast Furnace in Japan

(2) Latest improvement in equipment

As the blast furnace has become so large in size, if there are some trouble and defect with the furnace equipment they would deal the operation system a fated blow. Therefore, in order to avoid such a flow the various preventive measures and special considerations have been taken, such as the security of design, selection of construction materials and components, and automation to the newly constructing blast furnace.

In those days the world's largest blast furnace owned by U.S.S.R. had an inner volume of 2,300m^3, and also going larger trend of coke ovens and sintering machines were recognized. Therefore, technological development made in the following twenty years may be considered as the result of the extensive applications of such new technology to the newly established blast furnace and their auxiliaries.

Table 4.2.1 shows the large blast furnaces over 3,000m^3 in the inner volume in the world. Vigorous efforts have been made specially for the saving of the fuel consumption, costs of energy rising the oil and coal since the oil crisis. The large blast furnace, high furnace productivity and

Table 4.2.1 Large Size of Blast Furnaces (Over 1,000 m^3 of Inner Volume)

(As of Dec. 1980)

Country	Name of Steel Works	Furnace	Hearth Diametre (m)	Inner Volume (m3) Working Volume	Total Volume	Kindled Date
Japan	NSC, Ohita	No. 2	14.8		5,070	1976.10
Japan	Sumitomo, Kashima	No. 3	15.0		5,050	1976.9
USSR	Krivoy Roc	No. 9	14.7		5,026	1974.12
Japan	NSC, Kimitsu	No. 4	14.0		4,930	1975.10
Japan	NKK, Fukuyama	No. 5	14.4		4,617	1973.11
W. Germany	ATH, Schwelgerr	No. 1	14.0	4,084		1973.2
UK	BSC, Redcar	No. 3	14.0	3,900	4,573	1979.10
France	Usinor, Dunkirk	No. 4	14.0	3,765	4,526	1973.4
Japan	Kawasaki, Chiba	No. 6	14.1		4,500	1977.6
Japan	Kobe Steel, Kakogawa	No. 3	14.2		4,500	1978.2
U.S.A.	Bethlehem, Sparrows Pt	L	13.6	3,693		1978.11
Netherlands	Hoogovens, Ijmuiden	No. 7	13.0	3,667	4,363	1972.11
Japan	Kawasaki, Olizushima	No. 4	14.4		4,323	1979.6 blew-off
Japan	NKK, Fukuyama	No. 4	14.0		4,288	1978.2
Japan	NSC, Tabata	No. 4	13.8		4,250	1978.7
Japan	NSC, Ohita	No. 1	14.0		4,158	1979.8
Japan	NSC, Tabata	No. 1	13.4		4,140	1975.3
Italy	Italsider, Toronto	No 5	14.0	3,358	4,128	1974.11
Japan	Sumitomo, Kashima	No. 2	13.8		4,080	1979.2
Japan	NSC, Kineitsu	No. 3	13.4		4,063	1971.9
Japan	NKK, Ohgishima	No. 1	13.5		4,052	1976.11
Japan	NKK, Ohgishima	No. 2	13.5		4,052	1979.7
Japan	NSC, Nagoya	No. 1	13.0		3,890	1979.3
Japan	Kobe Steel, Kakogawa	No. 2	13.2		3,850	1978.3 blew-off
Japan	Sumitomo, Kashima	No. 1	13.4		3,680	1979.2
Brazil	CSN, Volta Redonda	No. 3	12.5		3,390	1976.5
Japan	Kawasaki, Mizushima	No. 3	12.4		3,363	1978.6
U.S.A.	US Steel, Gary	No. 13	12.2	2,832		1974.1
W. Germany	Klöckner, Bremen	No. 2	12.0	2,787	3,357	1973.5
Japan	NSC, Nagoya	No. 3	12.5		3,240	1974.12
Japan	NKK, Fukuyama	No. 3	12.4		3,223	1975.1
USSR	Novo Lipetsk	No. 5			3,200	1973.2
USSR	Novo Lipetsk	No. 6			3,200	1978.12
Poland	Katwice	No. 1			3,200	1976.12
Poland	Katwice	No. 2			3,200	1978.1
Japan	Kobe Steel, Kakogawa	No. 1	11.9		3,090	1974.12
USSR	Western Siberia	No. 3			3,000	1971.3
USSR	Kommunarsk				3,000	1977.1
USSR	Western Siberia	No. 1			3,000	1977.3

Source: Kobe Steel

reducing in blast furnace fuel rates may be the outstanding features of the blast furnace process in the past twenty years.

Worthy of special mentioning as the outstanding feature of the large blast furnace may be the various items of equipment to cope with the high top pressure operation. To say nothing of the adoption of blowers with larger capacities and improved refractories for the hot stove, McKee type and bell bulb seal type charging equipment which were mainly used previously have been replaced with the newly devised such as a bell-less type and the movable armour plates have been adopted to enable more precise adjustment of raw material distribution inside of the blast furnace.

The air-tight sealing of the furnace proper and cooling box have been given due consideration, and the stave cooling system has come into wide-spread use.

Prolonged life of a blast furnace will bring about great merits for operation as it will reduce construction cost per unit production and also reduce production loss during repair periods.

Various measures are being taken with respect to facilities, operation, maintenance and management in order to extend the life of a furnace. Such measures have been taken to improve refractory materials, to strengthen cooling system and to install monitoring terminals, to minimize the charging of zinc (Zn) and to reduce thermal load on the furnace wall by means of controlling the distribution of materials charged.

Recently, unit iron production during the life of a furnace has increased from 4,000 t/m^3 to 5,000 t/m^3. Even a furnace with unit production of 7,000 t/m^3 during its life has been introduced.

Improvement has been also made on iron and slag tappings, because a large blast furnace with iron productive capacity of 10,000 tonnes per day is capable of producing molten iron at the rate of more than 7 tonnes per minute. Accordingly, studies have been made on estimation of the amount of molten iron retaining in the hearth, tapping schedules, preparation of casting beds, large iron ladles and mixer cars.

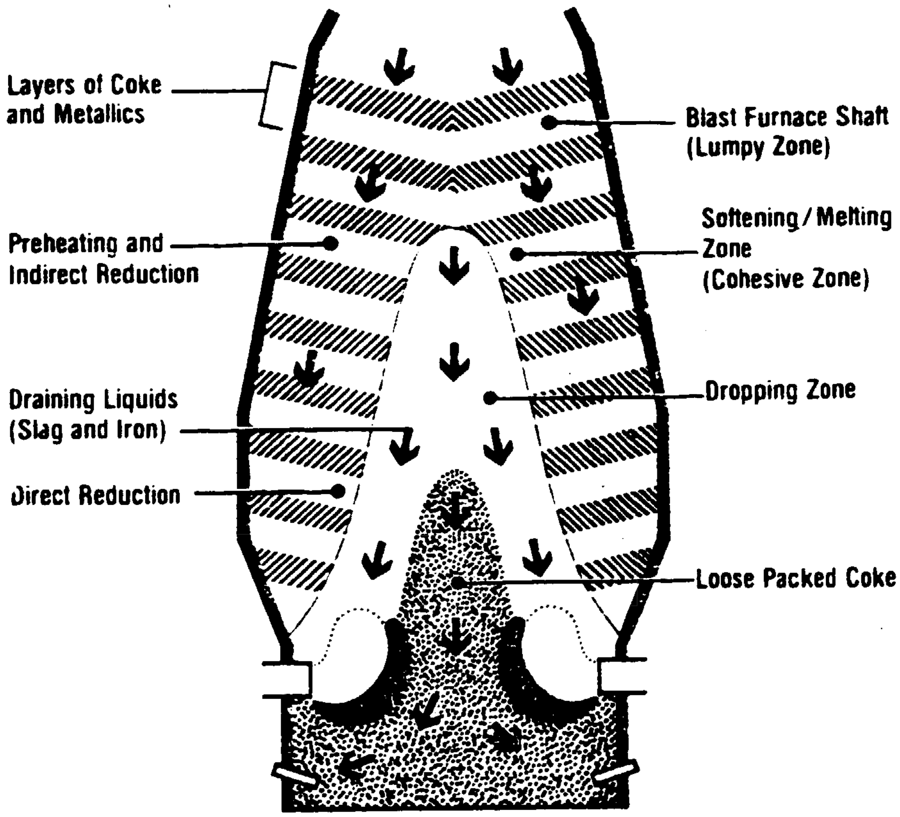
The blast furnace has various auxiliary facilities connected to it, such as the raw material charging equipment to store, convey and charge the raw materials into the furnace, blowers to deliver air into the furnace, hot stove to heat air (1,000 - 1,300°C) prior to its blasting into the furnace, casting bed where the pig iron and slag tapped from notches the furnace are treated, and gas cleaning plant to purify gases discharged from the furnace top.

(3) Technology on blast furnace operation

(a) Chemical and metallurgical reactions in the blast furnace

Recent studies on quenched blast furnaces have provided a clear understanding of the blast furnace process and the relative importance raw material qualities on the efficiency of the process. These studies have shown that the blast furnace can be conveniently divided into a number of reasonably discrete zones, as shown in Fig. 4.2.2 and described as:

1) The solid or lumpy zone
2) The cohesive or softening/melting zone
3) The dropping zone including both the moving loose packed and stagnant loose packed coke zones.
4) The raceway
5) The hearth



Source: ISIJ

Fig. 4.2.2 Diagrammatic Representation of the Blast Furnance Shows Subdivision into Zones and Solids/Liquids Movement.

Strong interrelated effects exist between each of these zones and hence the properties of the ferrous burden can influence conditions in each zone. However, their major direct influence is on the operating performance in the solid and cohesive zones, and thus the explanation will be restricted to consideration of these two zones only.

(i) The solid or lumpy zone

In this region, heat transfer and chemical reactions basically proceed through gas-solid contact. Conditions which promote these mechanisms are necessary for efficient blast furnace operations: high permeability and reduction rate, regular stock descent, and good radial distribution and shape characteristics of the feed are of prime importance in achieving these objectives.

Shape factors influence the flow characteristics of the metallics and affect radial distribution of the burden, which controls radial gas distribution and the shape of the cohesive zone. Pellets show high rolling tendencies and their use in large portions of the burden can cause difficulties in distribution control, primarily in large blast furnaces.

For good aerodynamic conditions in the solid zone, the metallics should be free of fines and have a narrow size distribution, ideally on the order of 15mm when using coke of mean size 45 - 50mm. Sinter, because of its prosity and reducibility, can be, and is, successfully employed at higher mean sizes.

High reducibility of the ferrous burden is required to obtain maximum utilization of the reducing gases in the solid zone and to lessen direct reduction of the metallics by coke in the cohesive zone. Poor reducibility will inevitably lead to higher coke rates and thicker cohesive zones with attendant losses in blast furnace productivity and a trend toward uneven operating conditions.

(ii) The cohesive zone

In this zone, the ferrous burden softens, compresses and melts. Gas flow through

this zone is basically restricted to the coke slits, see as shown in Fig. 4.2.4.
The cohesive zone should be:

1) High to prove sufficient coke slits for goods permiability,
2) narrow to give high gas utilization and hence minimum fuel rates at high ore by coke rate and
3) thin to reduce present drop across the cohesive zone and to minimize gas impingement on the refractory lining.

Further, the cohesive zone should be located well down in the furnace, and this has two major effects:

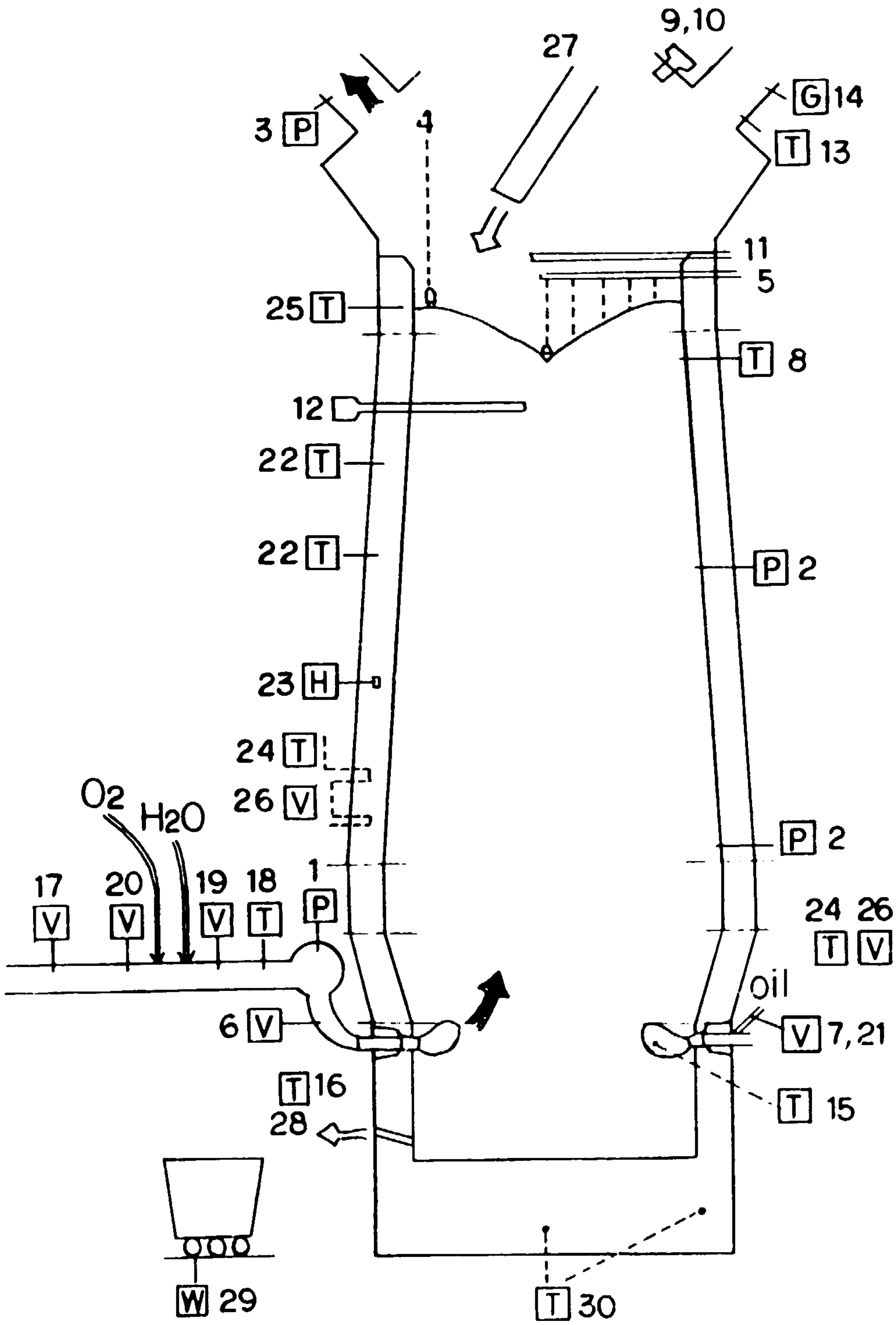
1) Increased contact time between furnace gases and the burden, and also reduction prior to soften ring
2) Silicon and sulphur transfer in the hot metal droplets occurs in the dropping zone.
   The lower the location of the melting front of the cohesive zone in the furnace, the lower will be silicon and sulphur content of the hot metal.

The size, shape and location of the cohesive zone is largely dependent on the properties of the raw materials.

(b) Development of the blast furnace operational technology

All the new technology on the basis of which the blast furnace operation had been developed by around 1960. For example, such technology as calibrating of iron ore, heavy burdening of self-fluxed sinters, burdening of self-fluxed pellets, high top pressure operation and high temperature blast had already been applied to most blast furnaces, and new attempts had been made with regard to the structure of the furnace itself, selection of refractories, automation equipment, and the process control by computers and instrumentations.

Fig. 4.2.3 (1)-(4) show an example of sensing and monitoring systems in blast furnaces operations.



1. Blast press
2. Shaft press
3. Top pressur
4. Stock measu
5. Burden prof
6. Blast flow
7. Oil flow me
8. Thermometer
9. Infra-red c
10. Infra-red c
11. Cross prob
12. Shaft probe
13. Thermometer
14. Sensing poi
15. Thermometer
16. Thermometer
17. Blast flow
18. Thermometer
19. Flow meter
20. Flow meter
21. Flow meter
22. Thermometer
23. Heat flux m
24. Thermometer
25. Thermometer
26. Flow meter
27. Thermomete
28. Thermomete
29. Hot metal v
30. Thermometer

Source: Kobe Steel

Fig. 4.2.3 (1) An Example of Sensing and Monitoring Syst
in Blast Furnace Operation

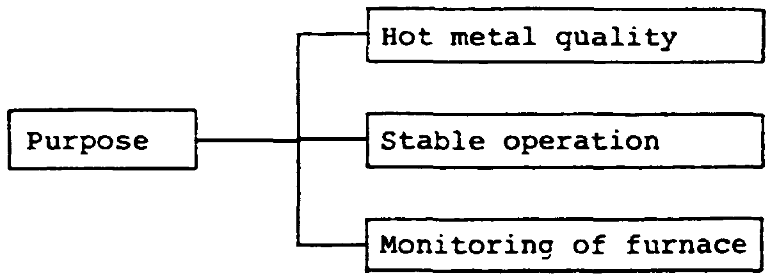
SECTION 1

1. Blast pressure gauge
2. Shaft pressure gauge
3. Top pressure gauge
4. Stock measuring device
5. Burden profile meter
6. Blast flow meter at gooseneck
7. Oil flow meter in total
8. Thermometer for skin flow
9. Infra-red camera
10. Infra-red camera
11. Cross probe
12. Shaft probe
13. Thermometer for top gas temperature
14. Sensing point of gas-chromatography
15. Thermometer for flame temperature
16. Thermometer for hot metal temperature
17. Blast flow meter in total
18. Thermometer for blast temperature
19. Flow meter for steam injection
20. Flow meter for oxgen injection
21. Flow meter for oil injection
22. Thermometer for shell and brick temperature
23. Heat flux meter
24. Thermometer for cooling water temperature
25. Thermometer for wearing plate temperature
26. Flow meter and pressure gauge for cooling water
27. Thermometer, pressure gauge and flow meter for bell-less top
28. Thermometer for shell temperature of runner
29. Hot metal weigher
30. Thermometer for hearth bottom temperature

·el

f Sensing and Monitoring Systems
·nace Operation

SECTION 2


Purpose
Hot metal quality
Stable operation
Monitoring of furnace

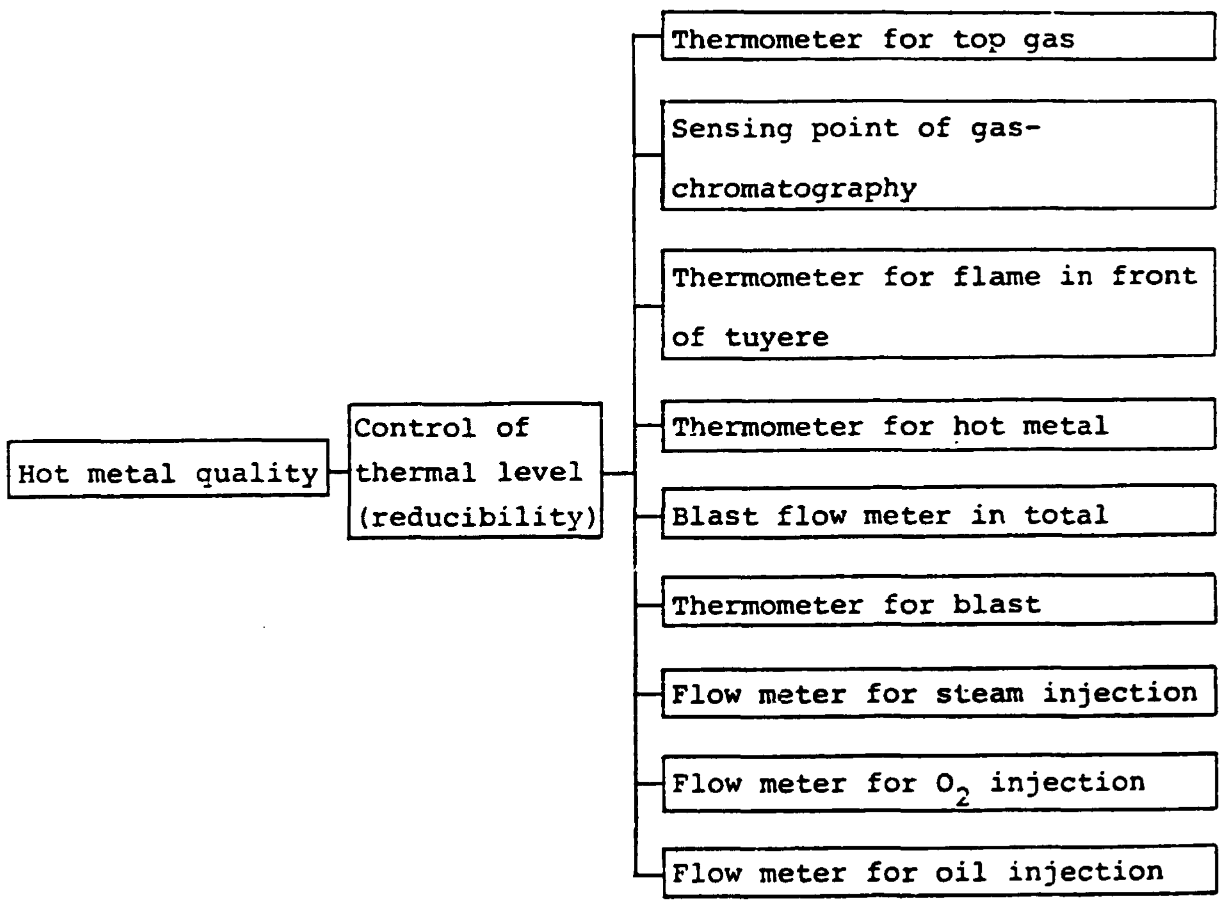

Hot metal quality
Control of thermal level (reducibility)
Thermometer for top gas
Sensing point of gas-chromatography
Thermometer for flame in front of tuyere
Thermometer for hot metal
Blast flow meter in total
Thermometer for blast
Flow meter for steam injection
Flow meter for O_2 injection
Flow meter for oil injection

Fig. 4.2.3 (2)

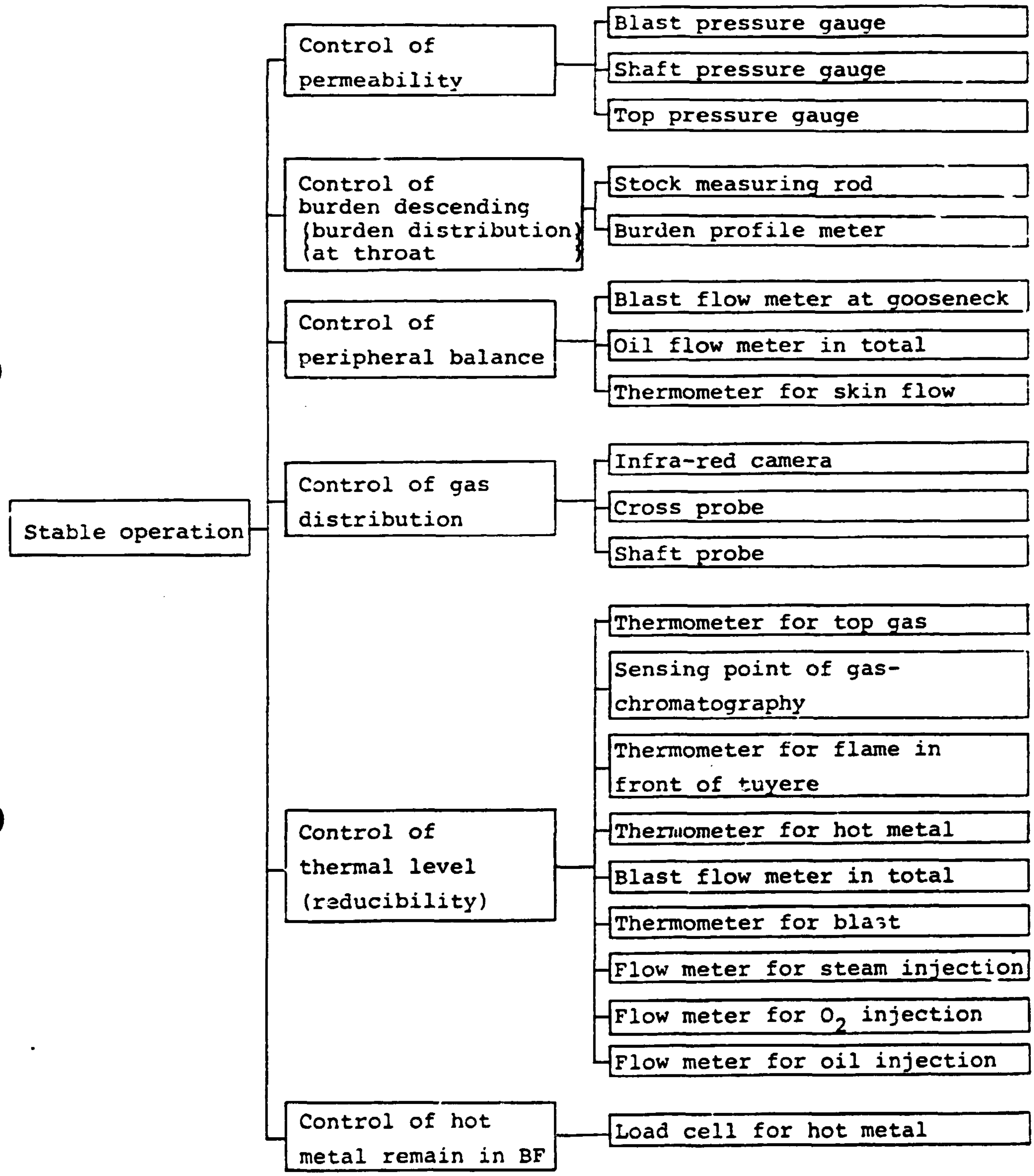
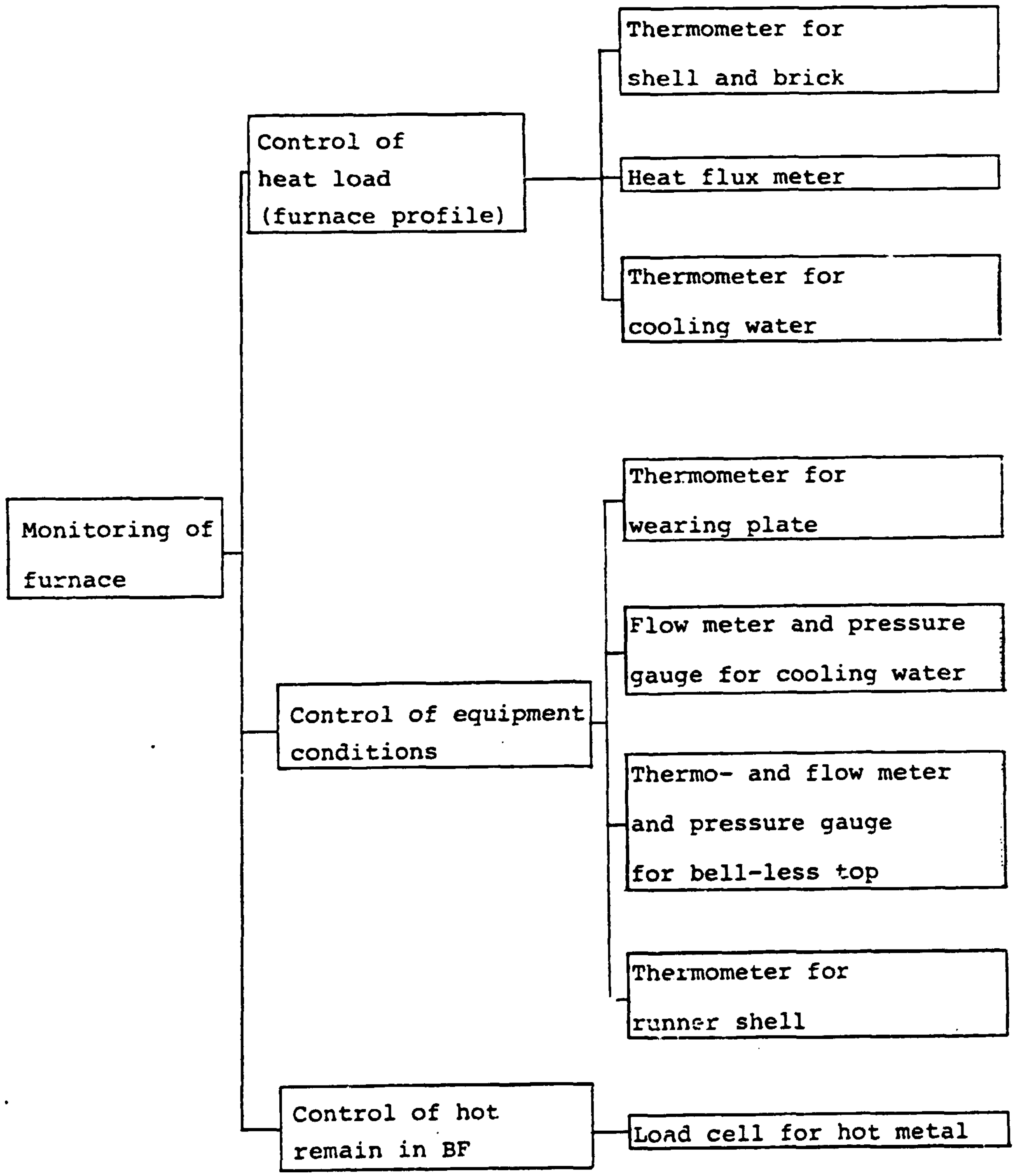

Stable operation
Control of permeability
Blast pressure gauge
Shaft pressure gauge
Top pressure gauge
Control of burden descending (burden distribution at throat)
Stock measuring rod
Burden profile meter
Control of peripheral balance
Blast flow meter at gooseneck
Oil flow meter in total
Thermometer for skin flow
Control of gas distribution
Infra-red camera
Cross probe
Shaft probe
Control of thermal level (reducibility)
Thermometer for top gas
Sensing point of gas-chromatography
Thermometer for flame in front of tuyere
Thermometer for hot metal
Blast flow meter in total
Thermometer for blast
Flow meter for steam injection
Flow meter for O2 injection
Flow meter for oil injection
Control of hot metal remain in BF
Load cell for hot metal

Fig. 4.2.3 (3)



Monitoring of furnace
Control of heat load (furnace profile)
Thermometer for shell and brick
Heat flux meter
Thermometer for cooling water
Control of equipment conditions
Thermometer for wearing plate
Flow meter and pressure gauge for cooling water
Thermo- and flow meter and pressure gauge for bell-less top
Thermometer for runner shell
Control of hot remain in BF
Load cell for hot metal

Fig. 4.2.3 (4)

(c) Other use than heavy oil for blast furnace

As heavy oil replacing technologies for blast furnace, there are (i) all coke operation and (ii) tar blowing-in, both of which are existing, and (iii) COM blowing, (iv) pulvilized coal injection (PCI) and (v) coal and tar mixture (CTM) blowing in which are to be developed.

The pulvelized coal injection (PCI) is expected to be adopted in several blast furnaces during 1982.

This method is useful in terms of both economy and coal saving as it is possible to steam coal with this. Thus, this method is expected to be a main stream in the future.

Individual blast furnaces are expected to select most suitable technologies, emphasizing economy. Of new technologies, PCI will attach great attentions together with CTM and COM.

(d) Energy saving

As for energy consumption, ironmaking consumes about 80% of the total energy consumption at a iron and steel works as shown in Fig. 4.2.4.

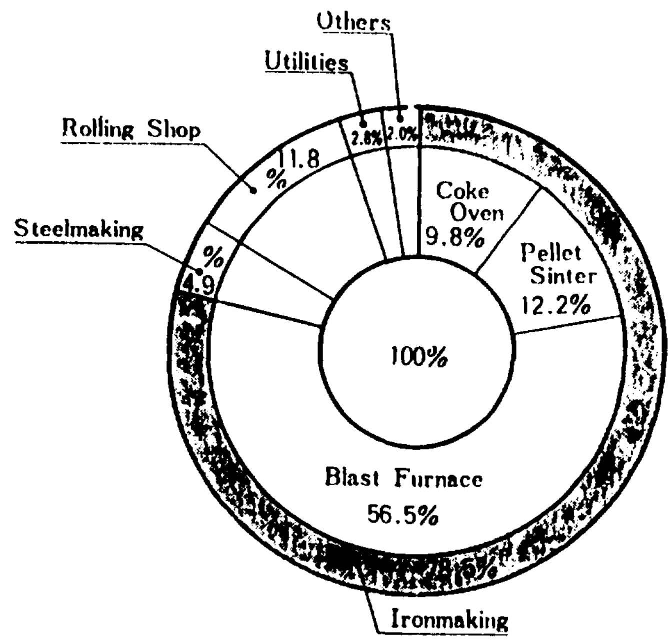


Fig. 4.2.4 Energy Consumption in Each Plant at a Certain Works in Japan (1979)

A blast furnace alone consumes about 50% of the total energy. Of energy consumed in a blast furnace fuel rates account for about 90%. Sine 1965, improvement of raw materials, high pressure and high temperature blast, dehumidifying facilities in hot stoves and gas distribution control have reduced fuel rates.

As for energy saving besides fuel rates, there are furnace top gas recovery and also off-blast recovery facilities.

4.2.2 Direct Reduction Process

(1) General

The direct reduction process refers to the entire process producing reduced iron without going through the molten state or to the process producing liquid iron by melting reduction. The former started commercial operation in 1975 and a total of 63 direction reduction plants were built by 1980, with a total production capacity of 31 million tonnes per year. The latter is still in the stage of bench-scale development. For the near future, it seems to be difficult to commercialize the latter process.

Indirect reduction process the reducing reaction is completed with the iron remaining in the solid state and the gangues still remain in direct reduced iron (DRI).

The degree to which the reduction of iron oxide is achieved is expressed as the reducibility* and/or degree of metallization**. In practice, the reduction is rarely achieved 100 per cent by any direct reduction process. Usually a very

---

* Reducibility: The rate of oxygen removed from into oxide by reducing reaction.

** Degree of metallization: $\frac{\text{Metallic iron in DRI}}{\text{Total iron in DRI}} \times 100$

small amount of oxygen remains in DRI, and this is considered desirable for the steelmaking process to follow.

The iron- and steelmaking process has been nearly completed in the route of large blast furnaces - basic oxygen furnace - continuous casting (BF-BOF-CC) and is likely to continue to be the main iron- and steelmaking process in the future. On the other hand, however, there are growing needs for the direct reduction process in some countries, particularly developing countries, and the introduction of iron- and steelmaking based on the direct reduction process to such steelmaking is better suited to meet the needs of such countries and it is also advantageous from the viewpoint of plant equipment cost and simpler operations as compared with blast furnace's.

These processes may be classified into the gas reduction process, the liquid reduction process and the solid reduction process according to the fuel used. In terms of the shape of reducing furnace, they may be also classified into the shaft furnace process, the static bed process, the fluidized bed process and the rotary kiln process.

These processes vary in applicability according to the reducing agents and raw materials used and geographical conditions.

As for the shaft furnace process, the Midrex process accounts for the largest share with the annual production of 3.75 million tonnes per year among DR processes. This process seems to have reached maturity.

As for the other processes in this category of the shaft furnace a plant adopting the Purofer process has been constructed each in Iran and Brazil. However, both plants have been closed, the former being due to political instability and the latter being due to inability to make profits because of rising oil price. A plant employed the Armco process has been constructed at Huston. This plant also has been closed due to energy problem. The HYL-III process is a converted process from the static bed process to the shaft furnace process. A plant of this process has been operating at Hylsa's own plant in Mexico since May, 1980, but it seems to take some time for this process to be introduced into the world market.

With the static bed process, a number of plants employed the HYL process are producing approx. 2.23 million tonnes per year mainly in Mexico in 1980. This process has a disadvantage of high fuel rate - 3.2 to 3.4 Gcal/tonne even at a most efficient plant, and therefore no plants have been constructed in developed countries where natural gas is costly. In recent years, Hylsa has been changing its own plants into HYL-III process, and its plants of the HYL-I or HYL-II process belonging to the category of the static bed process seems to have finished their role as mass production unit.

As for the static bed process, a plant of the FIOR process and another of the HIB process have been constructed in Venezuela. Both seems to have lots of problems. As a result of repeated modifications both in operation and facilities, continuous production with them seems to have finally become possible. However, it is very unlikely that new plants of this process will be built during the 1980's, at least during the first half of the 1980's. A plant of the rotary kiln process produces considerably less amount as compared with its capacity. As reducing agents, oil, natural gas and/or coal may be used. However, this process has a problem of kiln ring formation, and plants of this process can be operated continuously only for two months.

Table 4.2.2 shows estimated production of DRI in 1980, and typical DR process flows are shown in Fig. 4.2.5 to 4.2.8.

Table 4.2.2 Estimated Production of DRI in 1980

	Estimated production, 1,000 tonnes	Share, %	Operation rate, %
Midrex	396	55.5	74.7
HyL	237	33.2	79.6
Armco	22	3.1	65.2
FIOR	23	3.2	65.7
SL/RN	23	3.2	33.5
Others	13	1.8	-
Total	714	100	

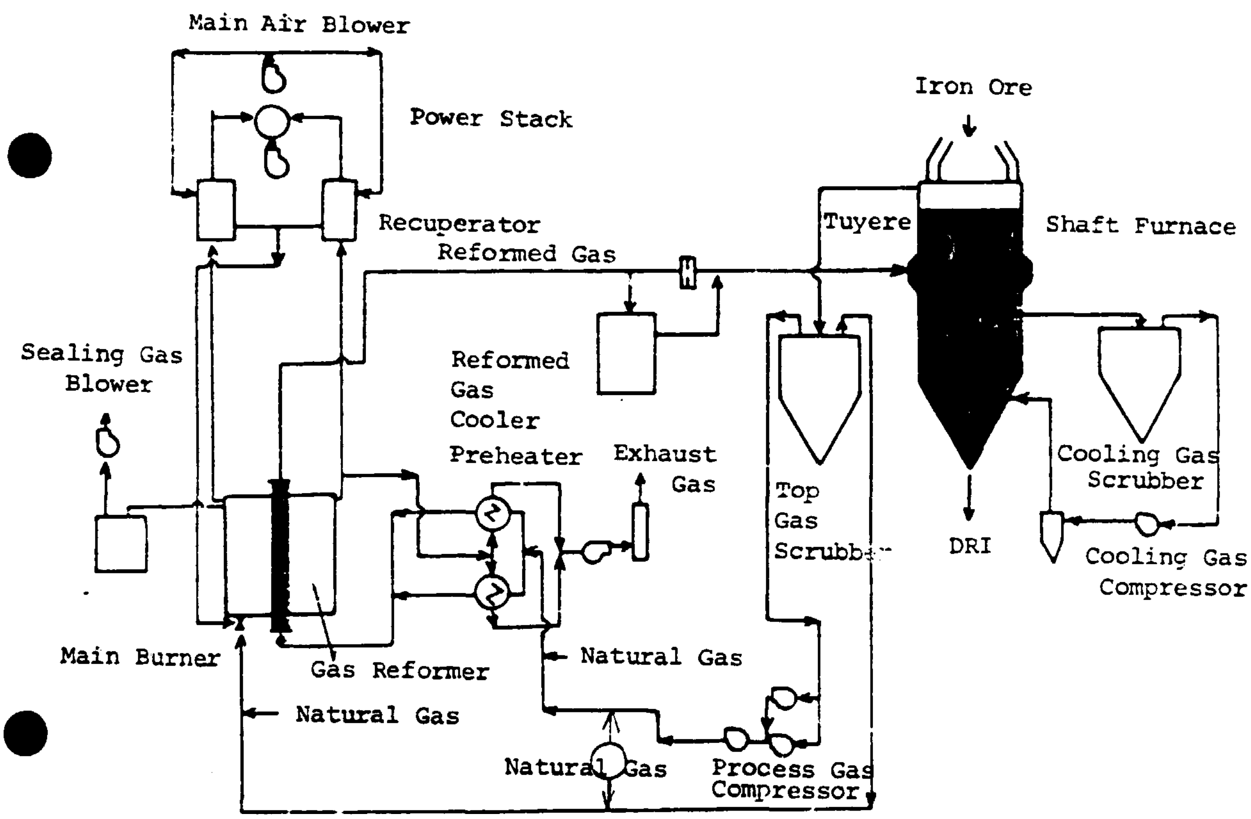
Source: JISF

(2) Future of Direct Reduction Process

As a future DRI production technology, the shaft furnace process is expected to stay in the main stream. Although some shaft furnace processes have reached a level of perfection like the Midrex process, various measures are expected to be attempted to save energy consumption, like the high pressure operation in the HYL-III process, hot briquetting or hot charge into an electric furnace. Approximately two thirds of the DRI capacity in the world is expected to be located in th Middle East for the next two decades. It is anticipated that virtually all of the energy required for the production of DRI in that region will be from natural gas.

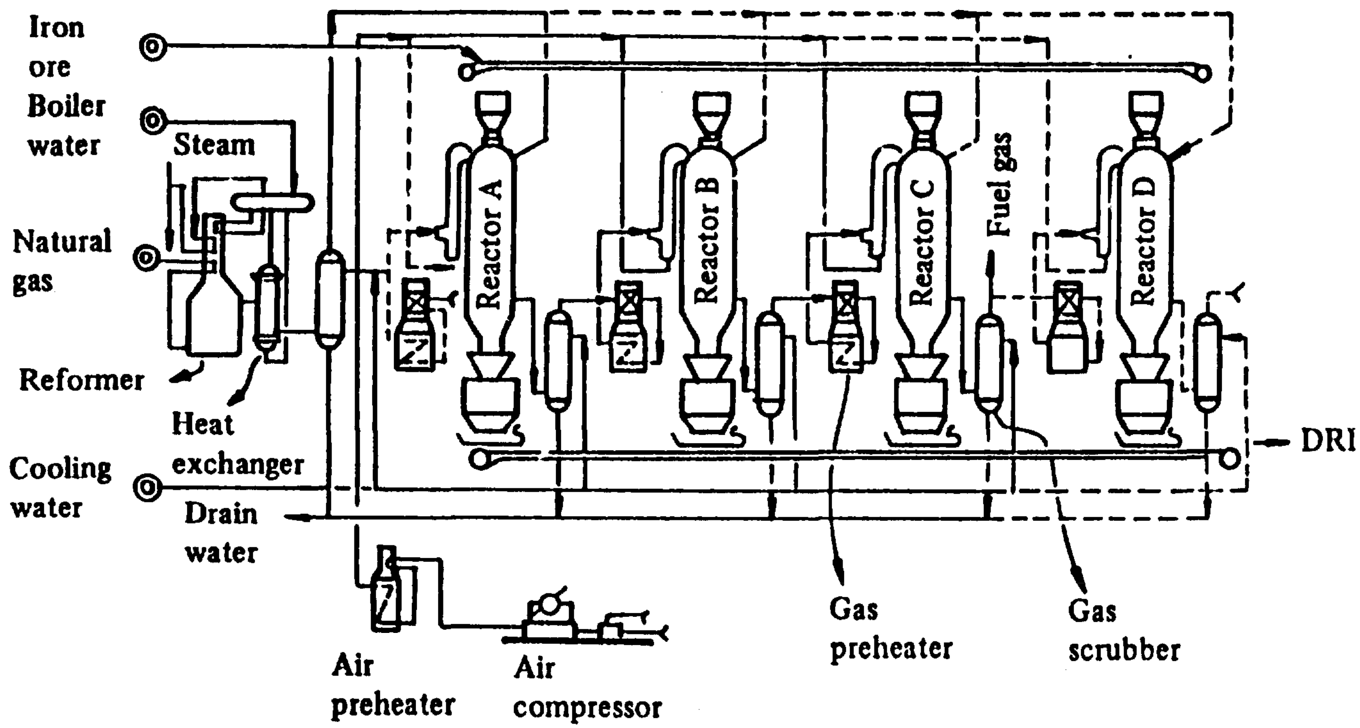
Meanwhile, it is anticipated that coal-based processes for producing DRI will come into more general use in the next two decades. Such processes are most likely to be utilized in industrialised regions where coal is relatively abundant and natural gas is relatively expensive.

Several coal-based processes for producing liquid iron are being developed. An important advantage to some of these processes, such as



Source: Midrex

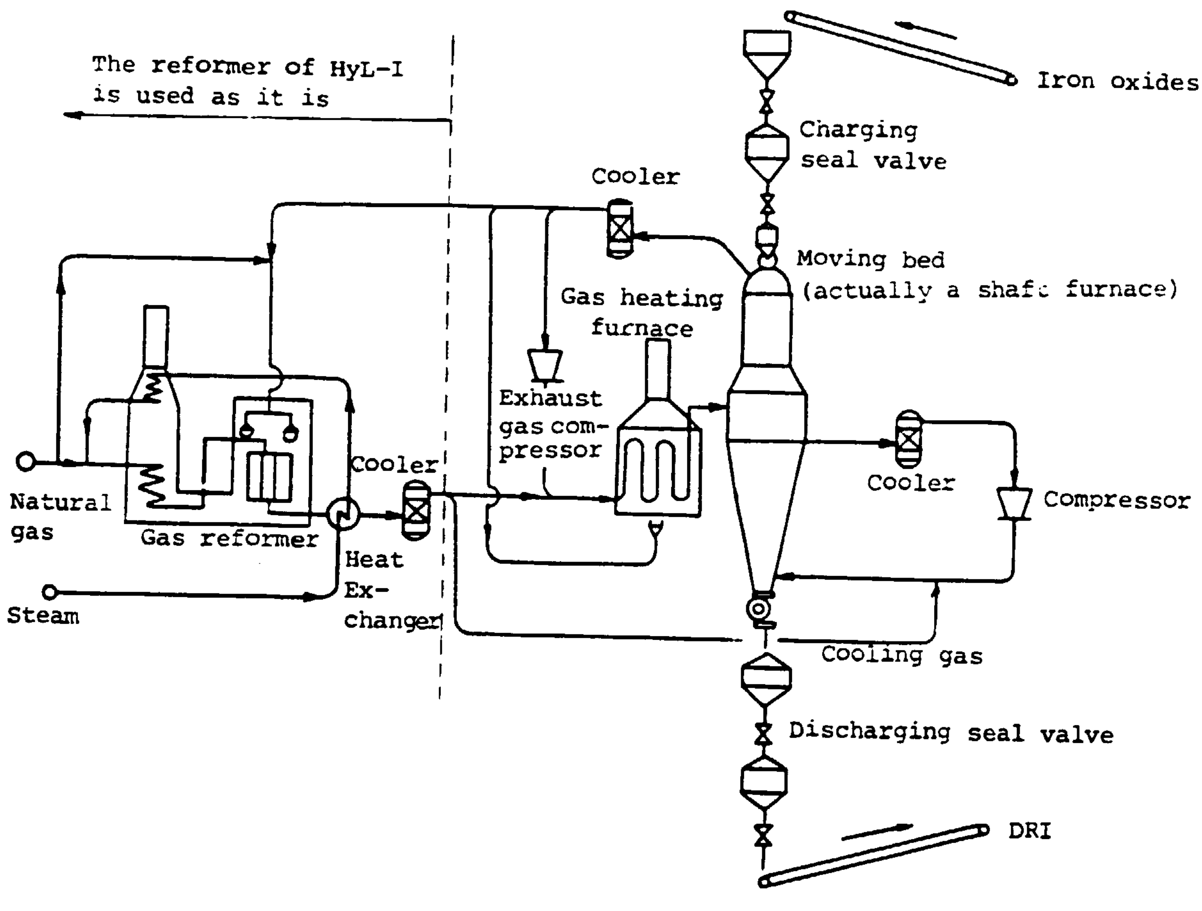
Fig. 4.2.5 Flow Diagramme for Midrex Process



Reactor –A: Cooling process
–B: Reduction process
–C: Reduction process
–D: Discharge/charge process

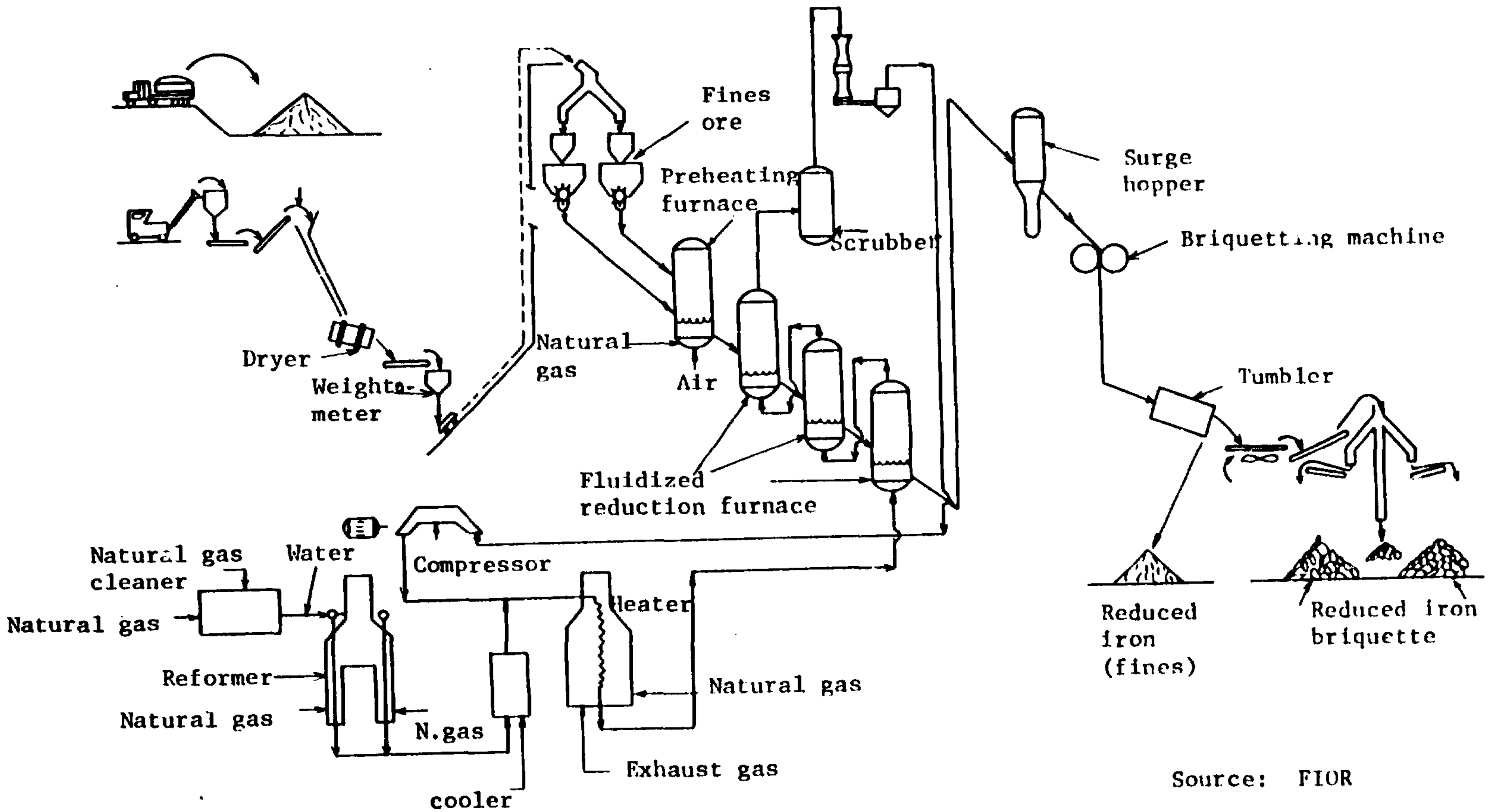
Source: HyL

Fig. 4.2.6 Flow Sheet of HyL Process



Source: HyL

Fig. 4.2.7 Diagramme for HyL-III Process



Source: FIOR

Fig. 4.2.8 Flow Sheet of FIOR Process

INRED, EURED, etc., is that the reduction system can be operated to supply by-product gases from coals which can be used for heating and heat treating, generating electricity, and raising steam. Accordingly, the plant could rely completely on coal for its energy, and a variety of types of coals could be used.

(3) Production of direct reduced iron

It is said that the total production equipment capacity of direct reduced iron (DRI) in the world is about 13 million tonnes (as of the end of 1979), and that the projects under construction (including orders received) have the total production capacity of about 6 million tonnes. However actual output of DRI in 1980 was about 7 million tonnes. Most of the existing DRI plants are either a part of ironworks or produce DRI for the exclusive use of ironworks even if they are independent plants.
No plant has so far been constructed for the purpose of being sold to outside users. A plant (800,000 tonnes/year) in Germany (GFR) scheduled to start up in 1981 is the first merchant plant. Table 4.2.2 shows the world output of DRI (estimated).

Therefore no DRI has so far been sold regularly, but it has been sold on the spot.

The DRI projects have been promoted over the past 20 years in comparison with the supply and price of scrap. Namely when the supply of scrap became tight and its price rose, DRI projects were planned and pushed forward. Soon the demand for scrap declined, their price lowered under the manufacturing cost of DRI, and the projects broke down. This pattern has been repeated.

Fig. 4.2.9 shows progress of prices of iron ores and scrap.

Scrap is a commodity subject to price changes under the influence of market conditions, while the price of DRI is determined based on the costs of raw materials, utilities and labour. The two have seldom been in gear smoothly.

(a) Situation of scrap and DRI

DRI is closely related with scrap as mentioned above, but the state of scrap is recently changing. Namely,

1) Scrap recognized as energy resources, because of EAF process using scrap as the initial material with a small energy consumption.

2) Expansion of EAF capacity in U.S.A., Korea, Spain and Italy.

3) Unstability of the supply and price of scrap.

4) Degradation of quality of scrap.

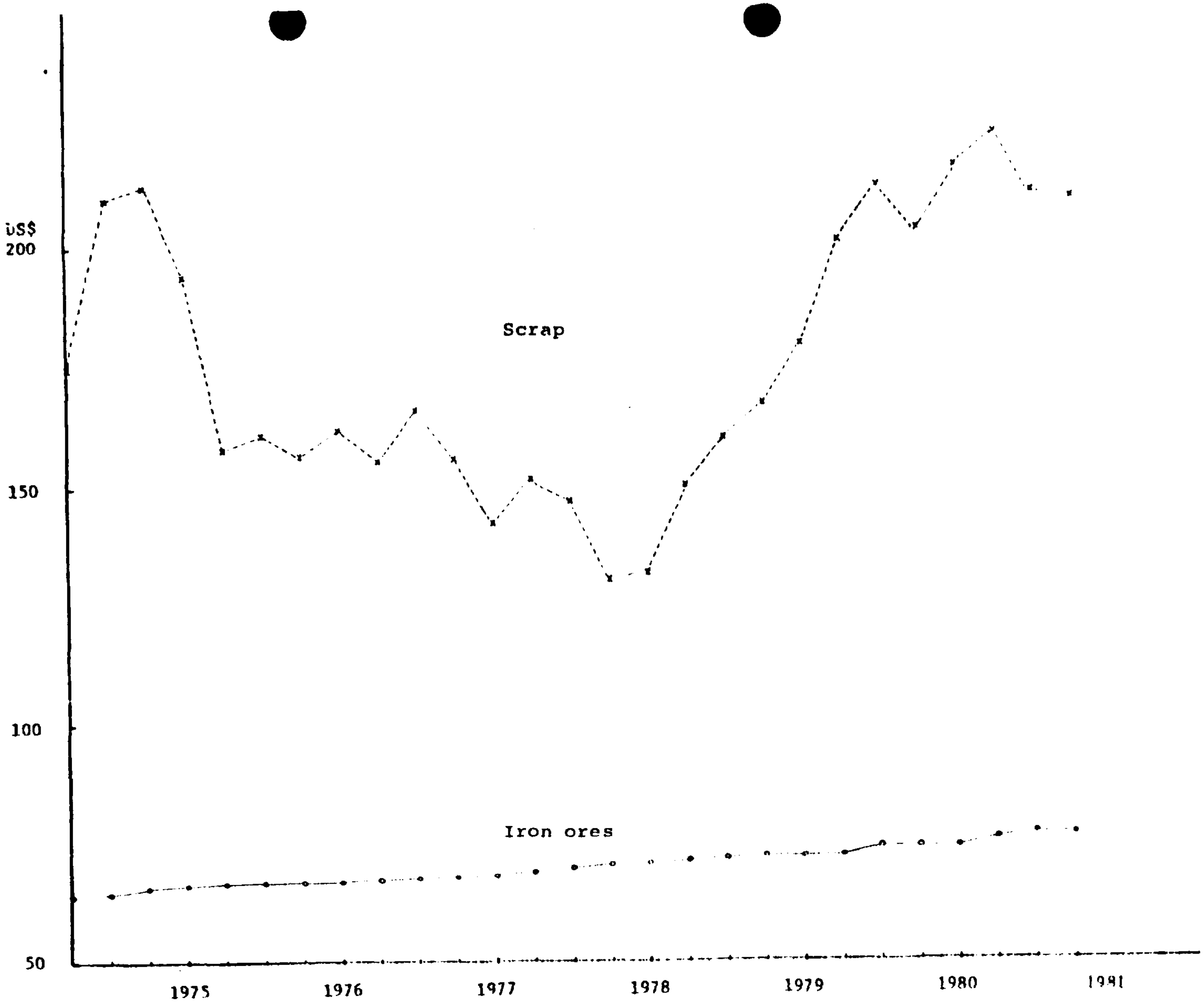


Fig. 4.2.9 Progress of Prices of Iron Ores and Scrap

(i) Since the oil crisis in 1973, the U.S. iron and steel industry, which is the major scrap exporter, has recognized scrap as not only the material for steelmaking, but also precious energy resources, because the EAF process using scrap has a small unit energy consumption per tonne of steel.

(ii) The world output of crude steel has increased by yearly 2.8% these 10 years. Especially the output of EAF-steel has increased by 5.3% every year. The world output of EAF-steel in 1979 was 151 million tonnes, or 23% of the world output of crude steel.

(iii) The supply of scrap may become tight in future even if the increase in the occurrence of scrap due to the economic development in future is considered, because the production rate of EAF-steel is increasing. Table 4.2.3 shows the forecasts on demand and supply of scrap in Western countries.

(iv) Scrap occurred consists mainly of the so-called recovered scrap, i.e. automobiles, refrigerators, etc. The scrap occurred from disassembled structures is decreasing in quantity.

Table 4.2.3 Estimated Supplies of Solid Metallics for Steel Industries in the Western World

(Unit : Million tonnes per year)

Case	Year	Crude Steel	Requirement of Solid Metallics *	Revert Scrap	Net Requirement	Scrap Supply	Apparent Deficit
Base	1978	469	211	115	96	95	1
	1985	550	269	121	148	112	35
(a)	1990	618	312	120	192	125	65
	2000	778	406	113	293	160	135
	1985	495	230	109	121	94	25
(b)	1990	510	241	99	142	97	45
	2000	535	259	78	181	102	80

Source : IISI, 1980

Case (a) : Annual growth rate is 2.8% based on the production of crude steel increased in the Western World for the past decade.

Case (b) : The growth rate is taken to be that of the growth rate in population, i.e. 1.74% annually to 1990, and 1.61% from 1990 to 2000.

* Scrap plus DRI

Based on the above factors, the U.S. exporting capacity of scrap is said to be 10 million tonnes/year. When it increases beyond this figure the call for restricting the scrap export will become strong in U.S.A.

Table 4.2.4 shows the actual export records of U.S. scrap.

The trade of scrap in Europe is about 8 - 9 million tonnes yearly. Major supplying countries are Germany (GFR), U.K. and Holland, and major consuming countries are Italy, Spain, Portugal, Sweden, etc.

Scrap trade is about 1 million tonnes including those of Australia and Middle East.
The world total is about 20 million tonnes per year at most.

Not a few people forecast that the supply of scrap will be difficult under the present conditions where the demand for scrap is increasing mainly in the middle-advanced countries like Korea, Philippines, Singapore, Spain and Italy.

Table 4.2.4 Export of Scrap from U. S. A.

(Unit: 1,000 tonnes)

Country	1972	1973	1974	1975	1976	1977	1978	1979	1980
Japan	2,110 (31.5%)	4,248 (41.6%)	2,703 (34.2%)	2,181 (24.7%)	1,141 (15.5%)	947 (16.9%)	2,894 (34.4%)	2,651 (26.2%)	2,575 (25.4%)
Korea (ROK)	412 (6.2%)	778 (7.7%)	691 (8.7%)	717 (8.1%)	867 (11.8%)	1,397 (25.0%)	1,364 (16.2%)	1,287 (12.7%)	1,575 (15.5%)
Taiwan	399 (6.0%)	745 (7.3%)	495 (6.3%)	276 (3.1%)	276 (3.7%)	405 (7.2%)	357 (4.2%)	575 (5.7%)	898 (8.8%)
Spain	659 (9.8%)	1,024 (10.1%)	813 (10.3%)	1,566 (17.8%)	1,695 (23.0%)	715 (12.8%)	675 (8.0%)	1,269 (12.5%)	1,055 (10.4%)
Italy	650 (9.7%)	321 (3.1%)	439 (5.6%)	556 (6.3%)	657 (8.9%)	189 (3.4%)	595 (7.1%)	1,076 (10.6%)	827 (8.1%)
Canada	821 (12.3%)	737 (7.2%)	858 (10.9%)	628 (7.1%)	808 (11.0%)	474 (8.5%)	939 (11.1%)	883 (8.7%)	717 (7.0%)
Mexico	564 (8.4%)	954 (9.3%)	850 (10.8%)	1,187 (13.5%)	540 (7.3%)	311 (5.5%)	409 (4.9%)	739 (7.3%)	1,052 (10.3%)
Argentina	209 (3.1%)	237 (2.3%)	135 (1.7%)	312 (3.5%)	82 (1.1%)	115 (2.0%)	–	7 (0.1%)	–
Others	873 (13.0%)	1,167 (11.4%)	904 (11.5%)	1,404 (15.9%)	1,301 (17.7%)	1,049 (18.7%)	1,184 (14.1%)	1,643 (16.2%)	1,474 (14.5%)
Total	6,697 (100.0%)	10,211 (100.0%)	7,888 (100.0%)	8,827 (100.0%)	7,367 (100.0%)	5,602 (100.0%)	8,417 (100.0%)	10,130 (100.0%)	10,173 (100.0%)

Source: JISF

According to Table 4.2.3, the iron resources will come short since 1985 on the order of several ten million tonnes. In future, the recovery rate of scrap must be improved or an additional number of DRI plants must be established.

It is difficult to discuss accurately how the scrap will grow in quantity, as the demand and supply of scrap in future, especially the recovery rate and quality of scrap are unclear. It is expected that, in the quality aspect, DRI will help the quality improvement of steel and stabilize by being mixed with scrap, while, in the quantity aspect, it will contribute to more stabilized price of scrap.

On the other hand, the rate of DRI to the total iron resources in the world will increase, as it is forecast that the EAF-steel will continue to grow in quantity at a rate twice faster than the increase rate of the world crude steel output.

(4) Project for merchant DR plant

As for merchant DR plants, special consideration must be given to such factors as market survey, the location and operation techniques, which need not be considered in the captive DR plant. Namely it is important for the merchant DR plant to satisfy the following conditions:

a) Product flexibility,
b) Lower operation cost,
c) Location,
d) Competitive material cost, and
e) Safe transportation of DRI.

That is,

a) As mentioned above, DRI tends to be considered in comparison with scrap, and it has served rather as a buffer. This is not the case in the merchant plant. The merchant plant is required to have the flexibility to develop the products according to the needs of consumers and thus acquire customers, or to manufacture raw materials for BAF at the time when scrap is low priced.

b) Needless to say, the prices of raw materials and reducing agents are the most important.

c) The basic factors will be raw material, reducing agents and DRI consuming place.

d) This is closely related with b) as mentioned above. The problem is how to secure the raw material source near the plant and how to transport them efficienctly.

e) DRI must be transported with safety as it is characterized by easy reoxidation. Further the countermeasures are needed against the problem of storage facilities on the counsumer's side.

Direct reduction-electric furnace operations are assumed to be self-contained relative to scrap. The lower energy usage per tonne of crude steel with ingot casting as compared to the value when continuous casting is employed arises because of the lesser percentage of DRI in the charge to the furnace with ingot casting. This seemingly anomalous condition does not appear when the use of energy is based on the production of finished. steel.

Approximately 65 percent of the DRI capacity in the world is expected to be located in the Middle East for the next two decades. It is anticipated that virtually all of the energy required for the production of DRI in that region will be from natural gas.

4.3 Steelmaking

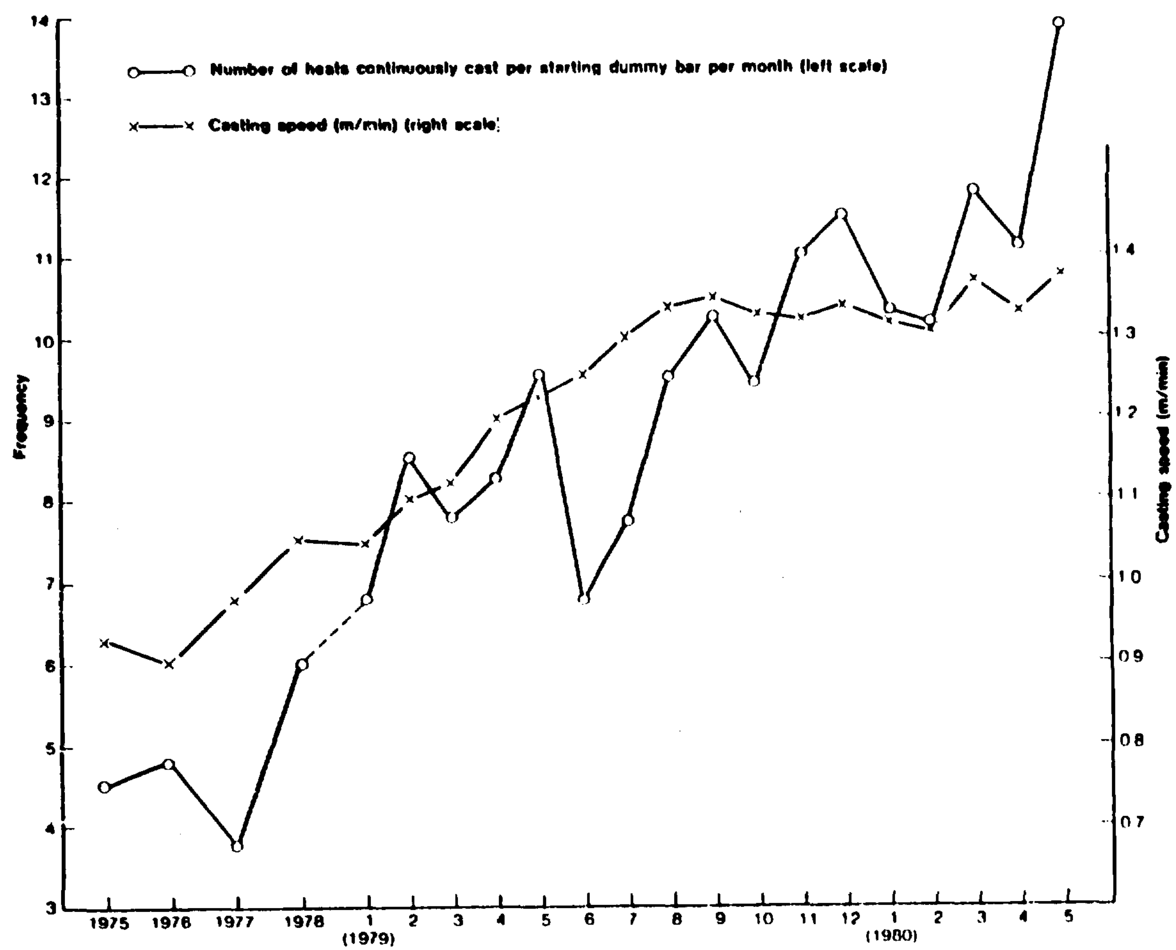
4.3.1 Converter Steelmaking Process

In the absence of any new and better process in the foreseeable future, it is considered that the converter-steelmaking process will continue as a mainstay of the industry for some time, though the use of bottom-blowing or top- and bottom-blowing furnaces may increase to some extent. Much research has been done on continuous steelmaking, but without a major breakthrough in refractory life this method is unlikely to replace the converter process.

A large number of technologies related to the steelmaking area from pretreatment of the hot metal to ingot casting have been developed. Of these, continuous casting has made the greatest contribution. Continuous casting has rapidly entered widespread use since the late 1960's, as this process helps to improve productivity, yield and energy saving.

In addition to the higher continuous cast (CC) ratio (percent of continuously-cast steel in total crude steel output), newly-developed technologies for the various rolling processes have greatly improved the crude steel to finished steel yield. For example in Japan, by 1979 the yield was about nine percentage points higher than its 1969 level, resulting in a nine-percentage-point saving which is equivalent to about 13 million tonnes of crude steel in the manufacture of finished-steel products.

Such a rise in the CC ratio is due not only to the growing number of continuous-casting facilities, but also to improvements in their technology. Fig. 4.3.1 shows examples of the increases in casting speed and the frequency of continuous-continuous casting. These rapid increases in both the speed and frequency are due to improvements in the secondary spray cooling process, the development of compression casting and the use of new mould powders, and improvements in the tundish and nozzle refractories.



Source: IISI, 1980

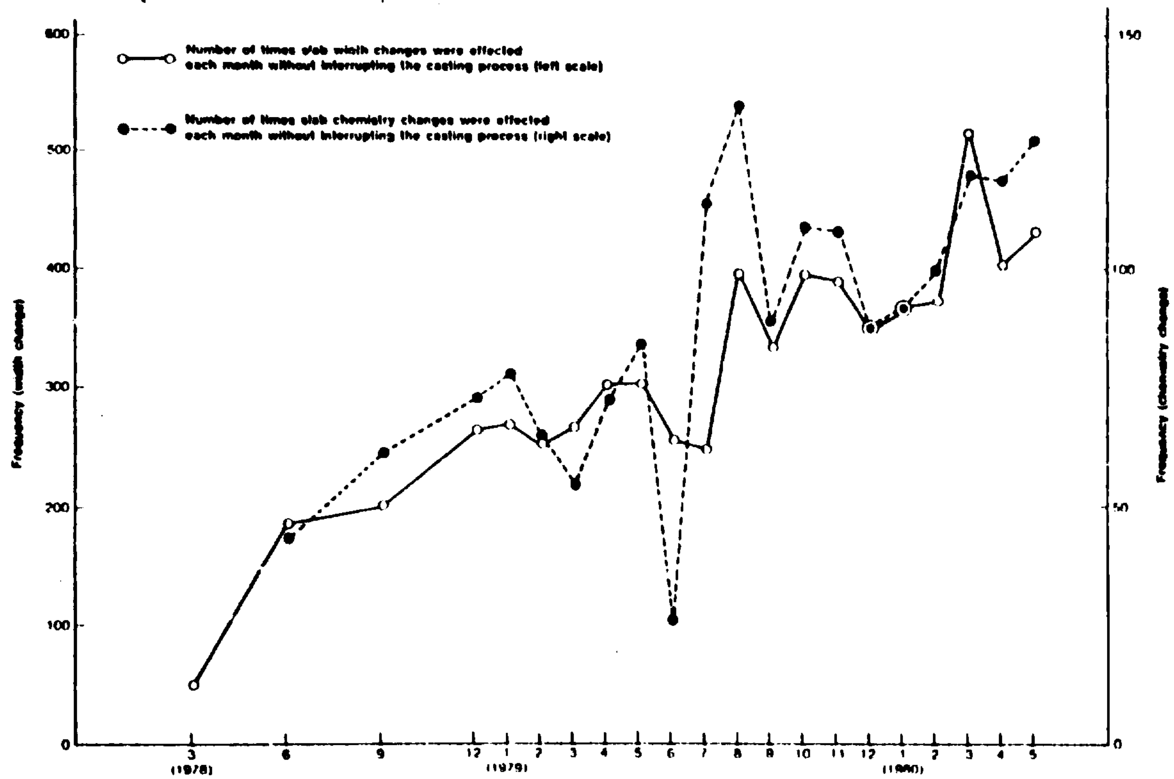
Fig. 4.3.1 Progress in Continuous-casting Technology at a Leading Works in Japan as Illustrated by Two Parameters

Technologies are now being developed which will make it possible to continuously cast different grades of steel in sequence and to change the width of a slab without interrupting the casting process. Fig. 4.3.2 shows the number of different steel grades cast in sequence and the number of times slab width changes were effected without interrupting the casting process.

Owing to such technological advances continuous casting is recognised as giving a better quality and surface finish than the ingot method, and is expected to play an increasingly important role in the iron and steel industry.

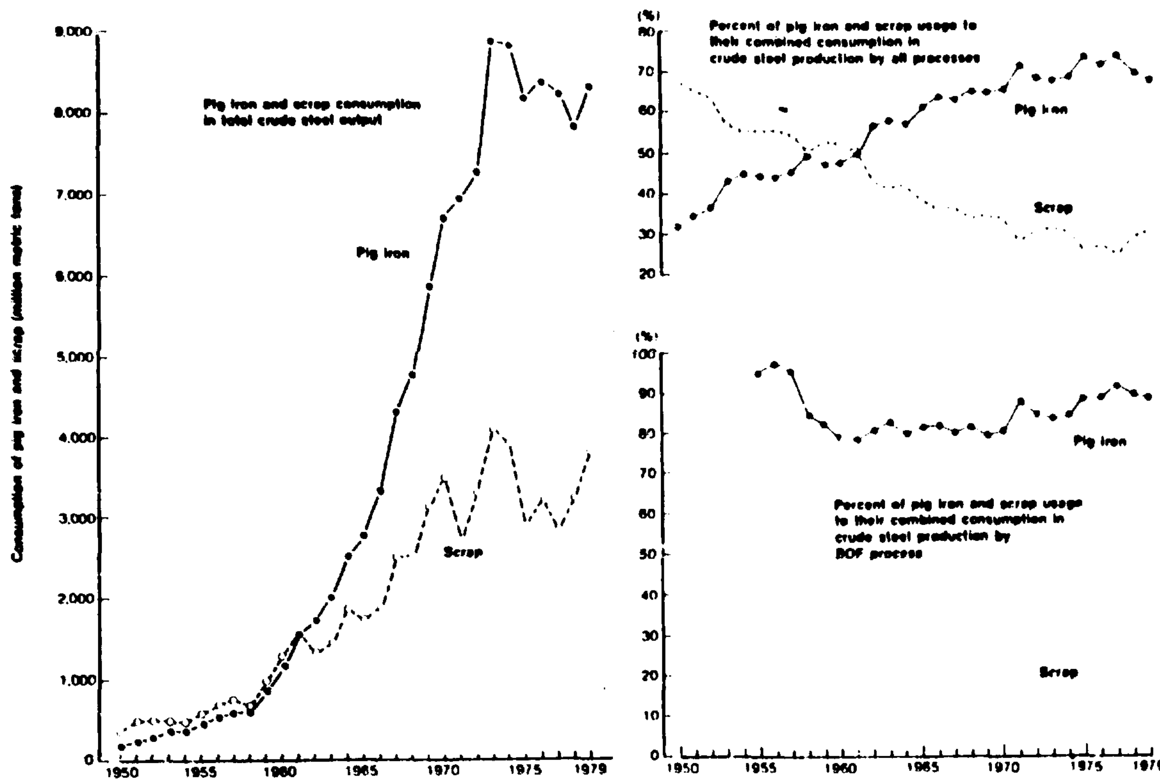
The following are some of the areas in which further technological development is expected: a) casting of semis, such as round billets, hollow ingots and thin slabs, which are closer to the finished products in shape. b) development of new machinery, such as horizontal and rotary casters, which can be built at low cost and will facilitate high-speed casting.

As shown in Fig. 4.3.3, it is expected that the hot metal ratio at integrated iron and steel mills in Japan will remain at around 90 percent levels in the 1980's. In view of this high ratio, the pretreatment of hot metal before it is charged into the converter takes on an increasing importance.



Source: IISI, 1980

Fig. 4.3.2 Progress in Continuous-continuous-casting Technology at a Leading Works in Japan



Source: MITI, Japan

Fig. 4.3.3 Consumption of Pig Iron and Scrap, and Their Ratios

Such desulphurising processes as injection of calcium carbide or a lime-based desulphurising agent into the hot metal transfer car have become established practice in most integrated iron and steel mills. Thus, in almost all cases, it is not necessary to desulphurise hot metal in the converter.

Research is also under way to develop a means of removing phosphorus together with sulphur. An example of such a method called soda-ash refining is shown in Fig. 4.3.4. By injecting 15-25 kg/t of Na_2CO_3 into the hot metal, phosphorus and sulphur can be reduced to less than 0.015 percent and 0.010 percent, respectively. The slag is reclaimed to recover the Na_2CO_3. After this process the hot metal needs neither dephosphorising nor desulphurising in the converter, and thus there is no necessity to add lime to make slag; only decarburisation is necessary. If this process can be adopted industrially, the problem of disposal of converter slag will be solved and increased yield can be expected.

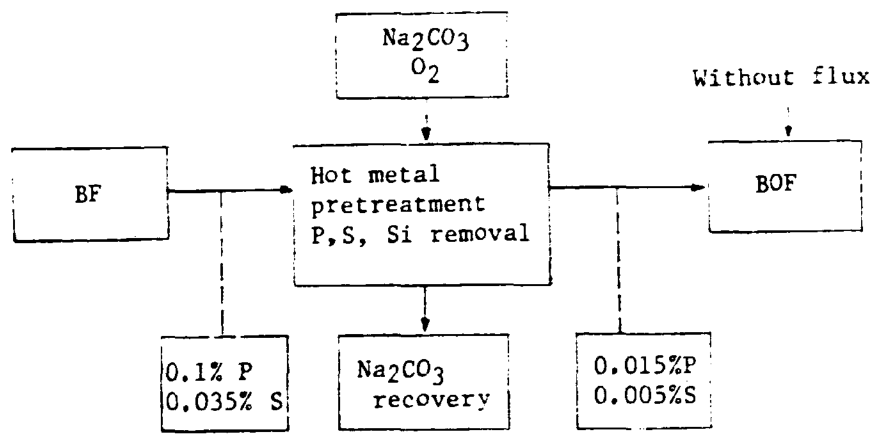


Fig. 4.3.4 Soda-ash Refining Process

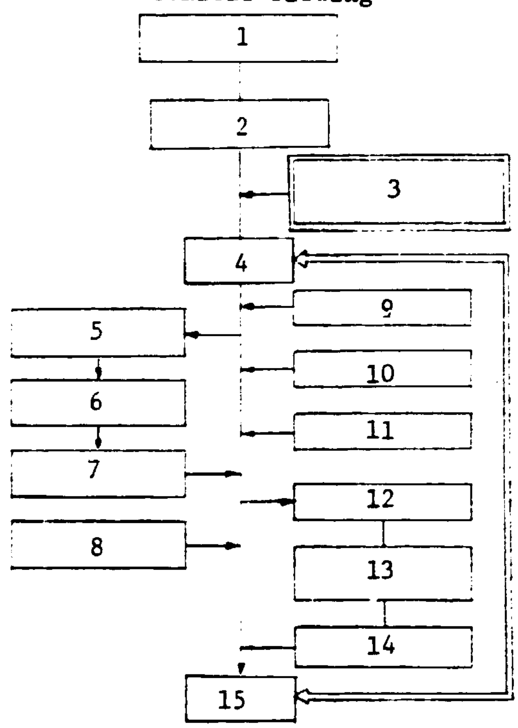
Dynamic control of top-blowing operation is gradually being superseded by complete automatic control, such as that seen in Fig. 4.3.5, in combination with various sensors to detect slag formation. Complete automatic control combines the following advantages: a programmed blowing process using sublances; an on-line mechanism for adjusting the lance height and the quantity of oxygen gas injection in response to slag formation and slag foaming inside the converter; improvement in the hitting rate of chemistry and temperature at the blow end point, and quick and direct tapping (QDT).

This method results in a higher yield of steel, higher productivity and longer furnace life. Fig. 4.3.6 shows an example of improvements in the hitting rate and furnace life.

The large Q-BOP* furnace is also contributing to the rapid development of blowing technology. In comparison with top blowing, bottom blowing as adopted in the Q-BOP results in stronger stirring of the bath and between the bath and slag. Thus the bath has a more uniform chemical composition and temperature, and there is less deviation from the equilibrium in the slag/metal reaction. For

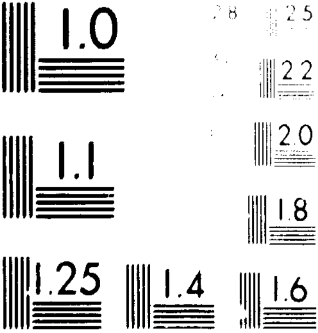
*Quiet, quick and quality - Basic Oxygen Process

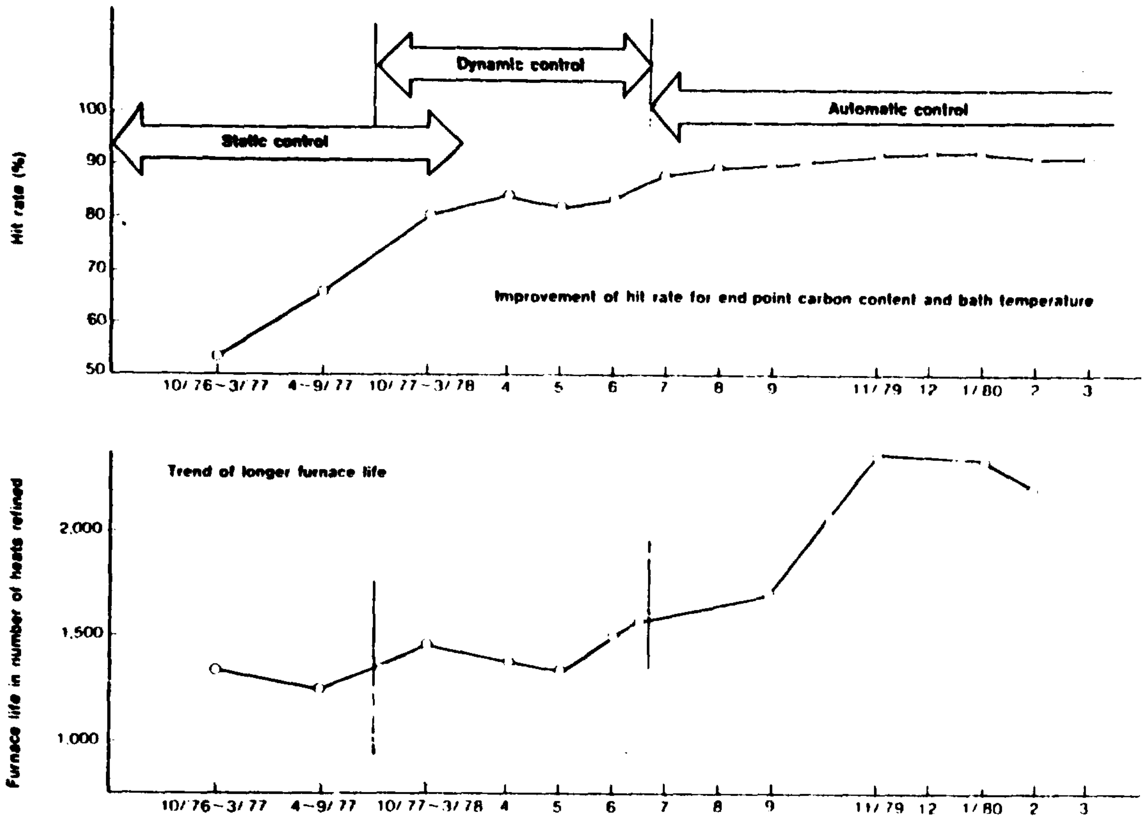
Flow diagram of automatic blowing



1. Charging of hot metal and scrap
2. Initial charging of fluxes
3. Selecting a pre-set program for lance height (LH), O_2 and fluxes
4. Blow start
5. Measuring lance vibration
6. Detecting slag formation
7. Adjusting LH and O_2
8. LD gas recovery (end)
9. Charging fluxes
10. LD gas recovery (start)
11. Charging LH and O_2
12. Measuring by sublance
13. End-point control calculation
14. Addition of coolant
15. Blow end

Fig. 4.3.5 Flow Chart of Automatic Blowing

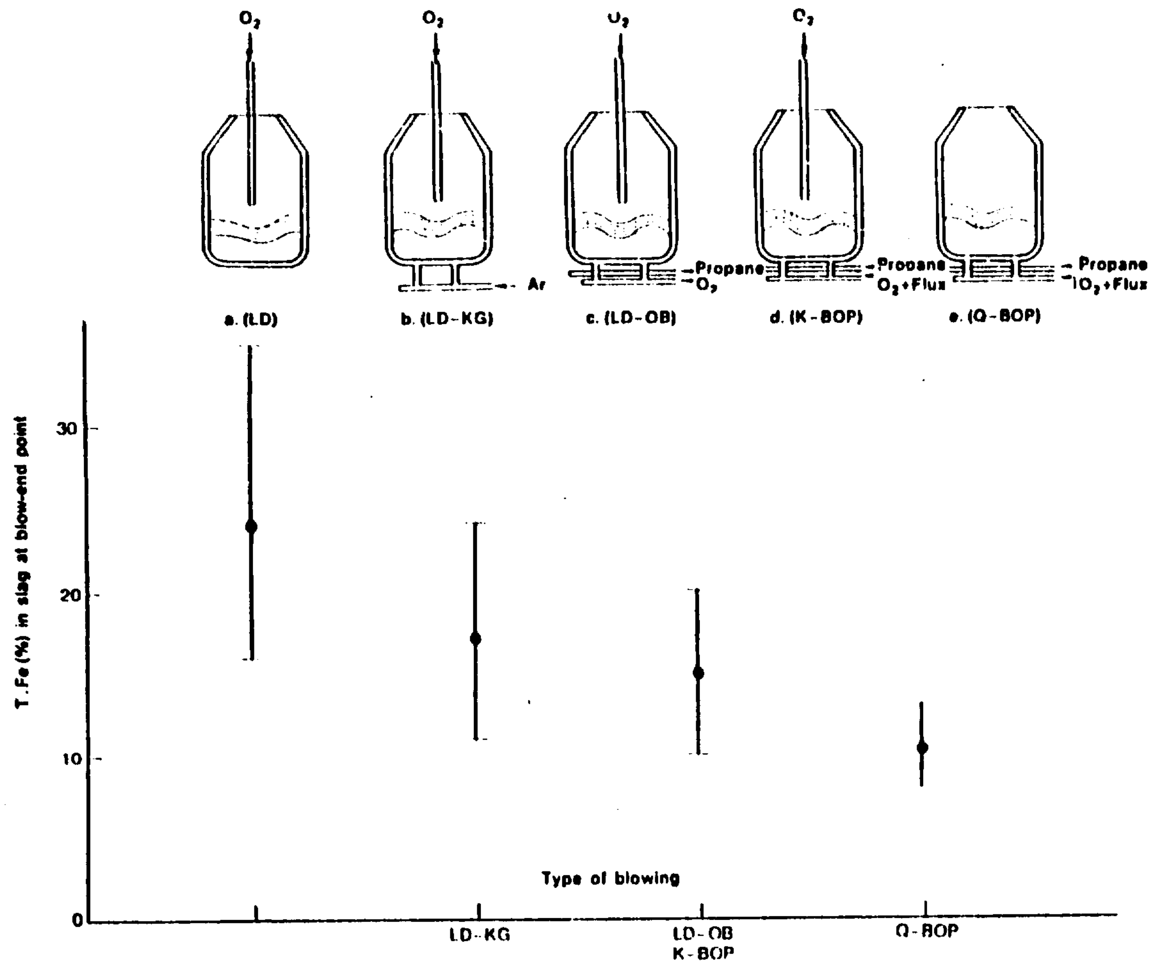

1.0
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6



Source: IISI 1980

Fig. 4.3.6 Favourable Effects of Automatic Blowing on Furnace Life example, in low-carbon steel blowing at a works in Japan, bottom blowing has proved to give a 0.72 percent higher iron yield and 0.13 percent higher blow-out manganese than can be obtained by top blowing.

As a result, top-and-bottom blowing is now being tested to take advantage of the strong stirring force afforded by bottom blowing. By using oxygen instead of an inert gas as the bottom-blown gas, and by using a larger quantity - i.e. by making the change from (b) to (d) shown in Fig. 4.3.7 - an effect closer to that of the bottom-blowing process can be obtained with a lower total iron (percent) within the slag at the blow end. Extensive testing of top-and-bottom blowing furnaces is in progress with good results, and this process is expected to be introduced in a large number of converters in the near future.



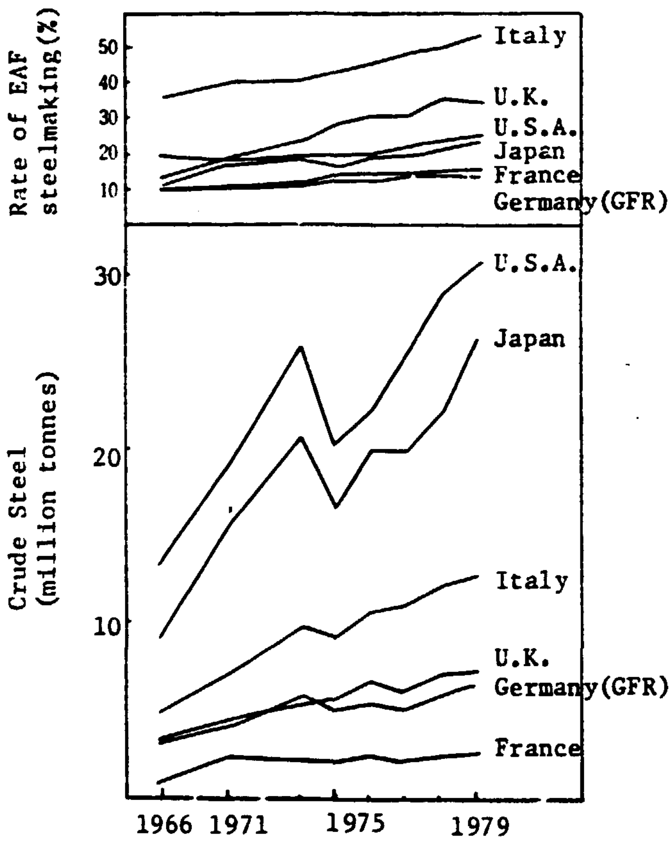
Source: IISI, 1980

Fig. 4.3.7 Relation between Total Fe (%) in Slag and Types of Blowing

4.3.2 Electric Arc Furnace Steelmaking Process

(1) General

Fig. 4.3.8 shows the crude steel output of electric arc furnace (EAF) in developed countries and production share of crude steel in each country. The EAF steelmaking process is the second largest process next to the converter steelmaking process. The recent EAF operation technique has resulted in some EAF's almost equal in the productivity to converter steelmaking through the adoption of large-sized EAF's with high power or ultra high power (HP or UHP EAF's), auxiliary fuel burners using oxygen or oil and oxygen enrichment method. Further some EAF's have recently appeared which marked a record electric power unit of 400 kWh/t by the adoption of the above oxygen enrichment and of scrap preheating equipment which utilize exhaust gas energy.



Source: ISIJ

Fig. 4.3.8 Crude Steel Output by EAF and Share in Crude Steel by Country

Further the EAF operation technique which uses DRI is also almost completely established. Various equipment and operation techniques for reducing the unit rates, automation and computerization are also under development. These trends towards improved productivity and reduced production costs will grow more and more in future.

(2) Recent EAF steelmaking technology

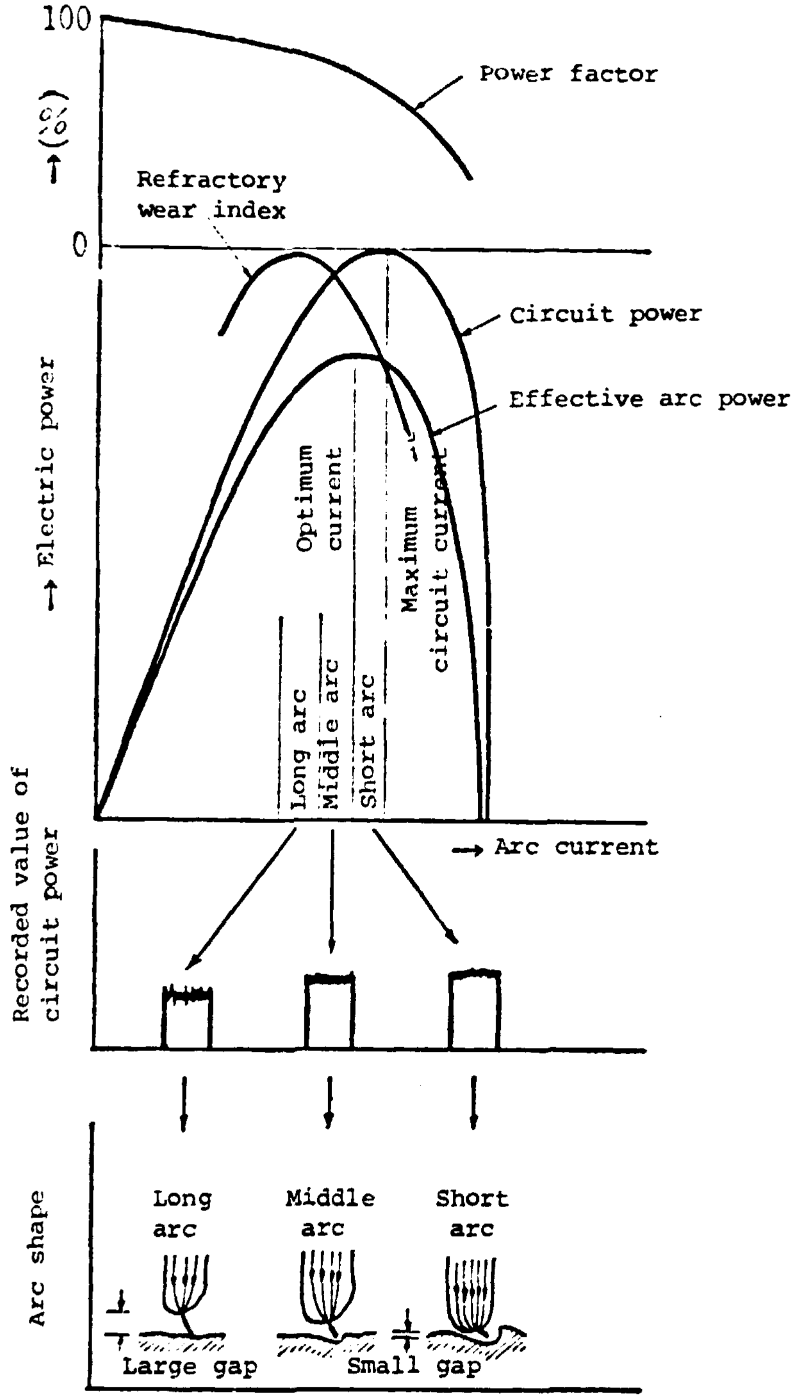
(a) Enlargement of EAF

Recently EAF's are increasingly enlarged in scale to improve the productivity and reduce the costs and have produced good results. This trend has resulted in a super large-sized EAF with a 400-tonne per heat capacity in U.S.A. Further there is a general tendency toward obtaining the same effects as from a largesized EAF by controlling the bulk density of scrap in the existing EAF's.

(b) UHP EAF

The UHP operation of the EAF steelmaking proposed in 1964 has introduced the era of UHP in the electric arc furnace technology.

Briefly describing the principle of the UHP operation, it is what is called the low-power factor and high-power factor operation system in which the power factor is lowered to about 70% to obtain a stable arc by a low-voltage and high-current short arc. Fig. 4.3.9 shows the characteristics of arc in the UHP operation.



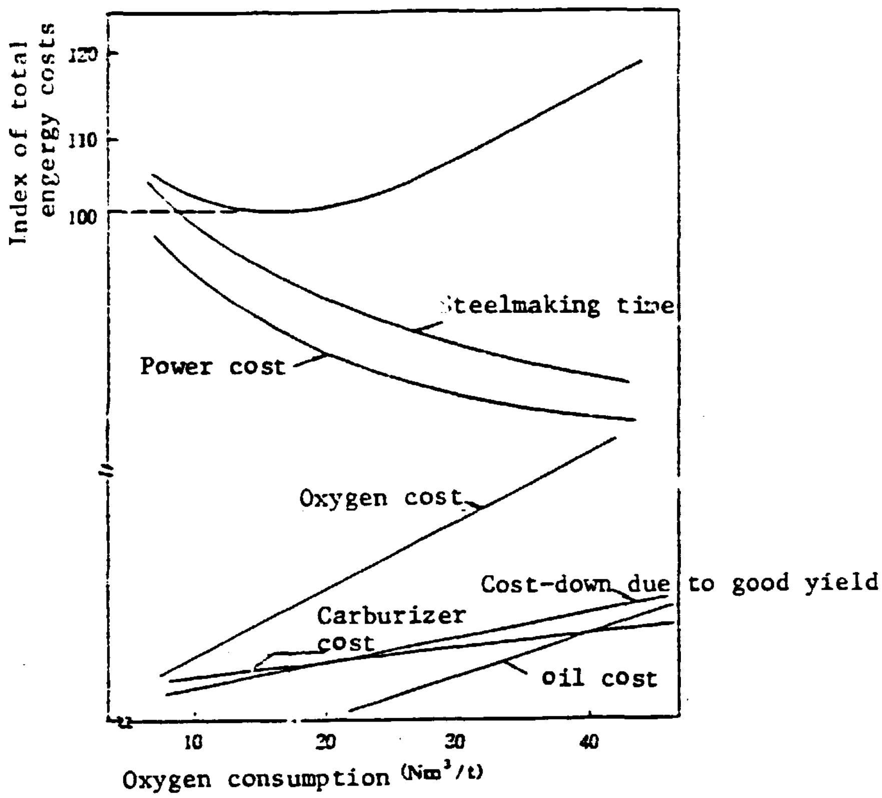
Source: IHI

Fig. 4.3.9 Arc Power Characteristic Curves and Arc Shapes

In the latest UHP EAF's, the decrease in electrode pitch circle diameter, shortening of the secondary conductor and various improvements are actively made to reduce the reactance and get a balanced reactance between the three phases. The UHP operation can put in a large electric power in a short time and can obtain large effects. Therefore, it can shorten the melting time by about 20-40% as compared with the regular power operation.

(c) Oxygen fuel burner and oxygen enrichment

Apart from the heating by electric energy, the method of accelerating the melting of the charge by oxygen fuel burner is also highly evaluated. Typical oxygen fuel burners are the use of toroidal or jet burners, in which oxygen and heavy oil or kerosene are blown in as supplementary fuel, and this method is now commonly used industrially. This method assures high thermal efficiency if used when the charge is still bulky in the furnace, that is, during the first half phase of the melting period. Fig. 4.3.10 shows relationship between oxygen consumption, steel-making time and index of total energy costs. Apart from this method, there is also employed a method in which oxygen gas and carbon are blown into the furnace and the heat produced by the oxidation of carbon and iron is used to accelerate the melting of the charged scrap.



Source: ISIJ

Fig. 4.3.10 Relationship between Oxygen Consumption, Steelmaking Time and Index of Total Energy Costs

(d) Scrap preheating

The scrap preheating device which utilizes the heat of exhaust gas from EAF has rapidly been put into practical use these years, and playing an important role in reducing the electric power unit and improving the productivity. Recently the heat recovery of EAF top exhaust gas has been made possible in a rather high efficiency through various improvements on the equipment, which has led to a 30 kWh/tonne—50 kWh/tonne reduction of the electric power unit.

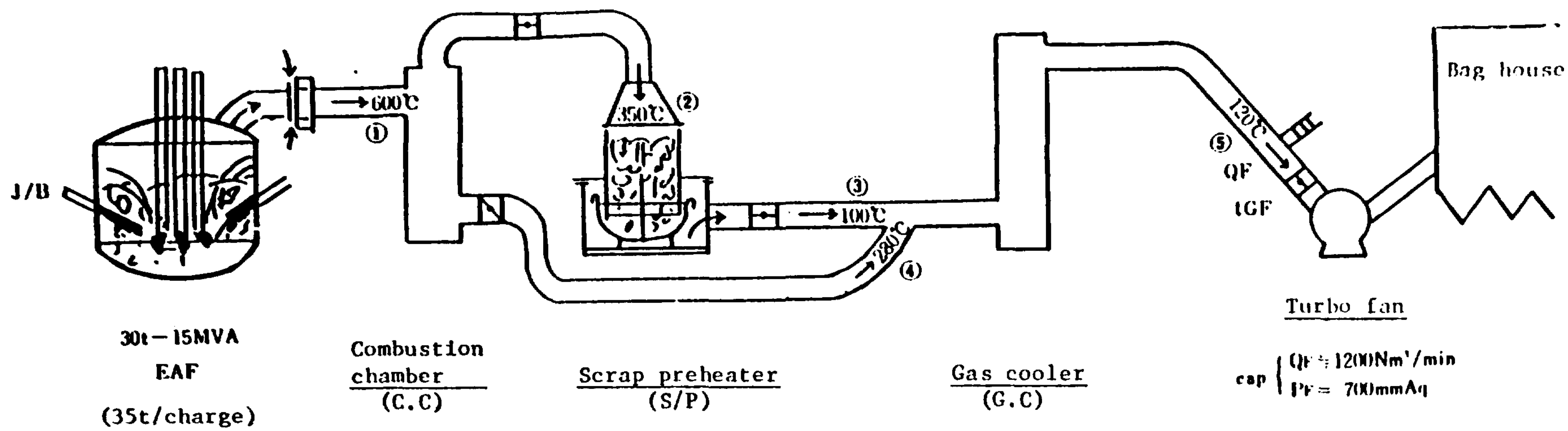
However there is left room for further development in respect to the energy recovery of exhaust gas, and many problems remain to be solved for this development. Particularly important among them are,

1) Improvement of the heat resistance of preheater ,
2) Rise of heat potential of the exhaust gas by preventing the entrance of cold air into between EAF and the preheater ,
3) Establishment of the method to use effectively the combustibles in scrap , and
4) Development of the method to use other exhaust heats than that from EAF.

Table 4.3.1 shows the effects of preheating scrap and Fig. 4.3.11 shows an example of the scrap preheating system.

Table 4.3.1 Effects of Scrap Preheating

Effects of scrap preheating	Power	40 ∿ 50 kWh/tonne
	Steelmaking time	5 ∿ 8 min/charge
	Unit consumption of electrode	0.2 ∿ 0.4 kg/tonne



Source: ISIJ

Fig. 4.3.11 An Example of Scrap Preheating Flow

(e) Bottom tapping

The bottom tapping technique developed in Germany (GFR). It is reported that it succeeded in reducing the electric power unit by about 20 kWh/tonne by shortening the required tapping time (4 minutes to 1.5 minutes) and preventing the heat diffusion from the tapping flow.

In this method, as the furnace body need not be tilted at the tapping time, the water cooled cable can be shortened and thus the reactance of the secondary conductor can be reduced. This will make possible water cooling of the tapping hole side which has so far been difficult to be cooled by water. In actual operations, there are some problems in opening/closing and repair of the tapping hole. These problems will have to be solved before the water cooling of the tapping hole side is materialized.

(f) Application of ladle refining process and vacuum degassing process to the arc furnace

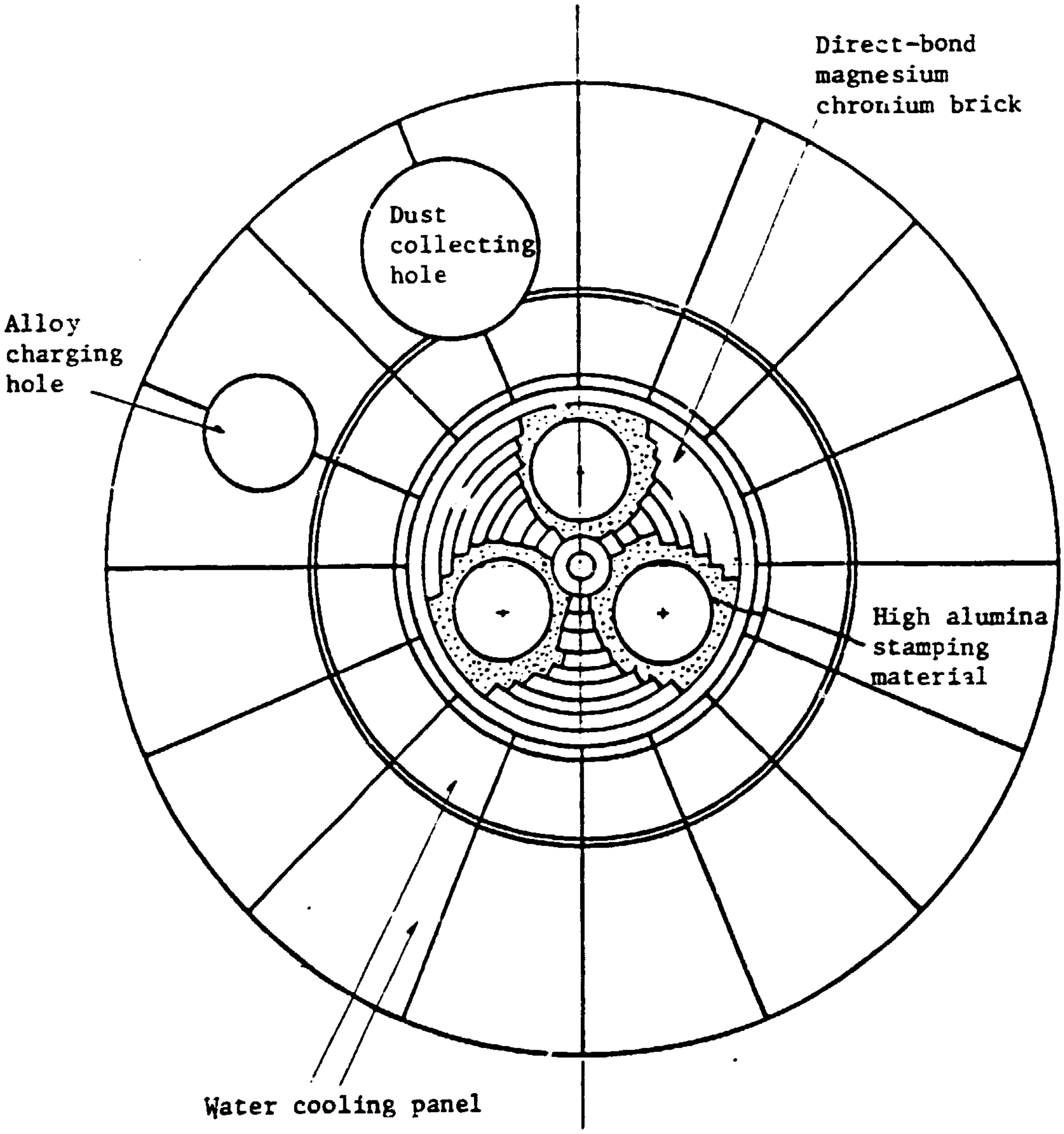
There are available various methods for the ladle refining process and vacuum degassing process. The techniques to improve the productivity of arc furnace by combining these processes with EAF steelmaking process have fairly long been used.

However it is on low alloy and high alloy which are refined for a rather long time, and special steel which is strictly required to have high quality that the combination of EAF and these processes has a large effect. It is, however, less effective for manufacturing plain carbon steel, for its refining time is short. The plain carbon steel by EAF steelmaking have not adopted this method.

(g) EAF refractories and their cooling

The EAF refractories have made a progress along with the progress made by EAF equipment and operations. As for the furnace roof refractories, silica bricks were used previously and then high alumina and basic refractories have been used combinedly to make the furnace roof of outer area with basic bricks and the furnace roof of centre area with alumina bricks and high-alumina and magnesia ramming materials.

The water cooling method for the furnace lid as shown in Fig. 4.3.12 has been developed and adopted making possible a 70-80% reduction of the refractories unit consumption.



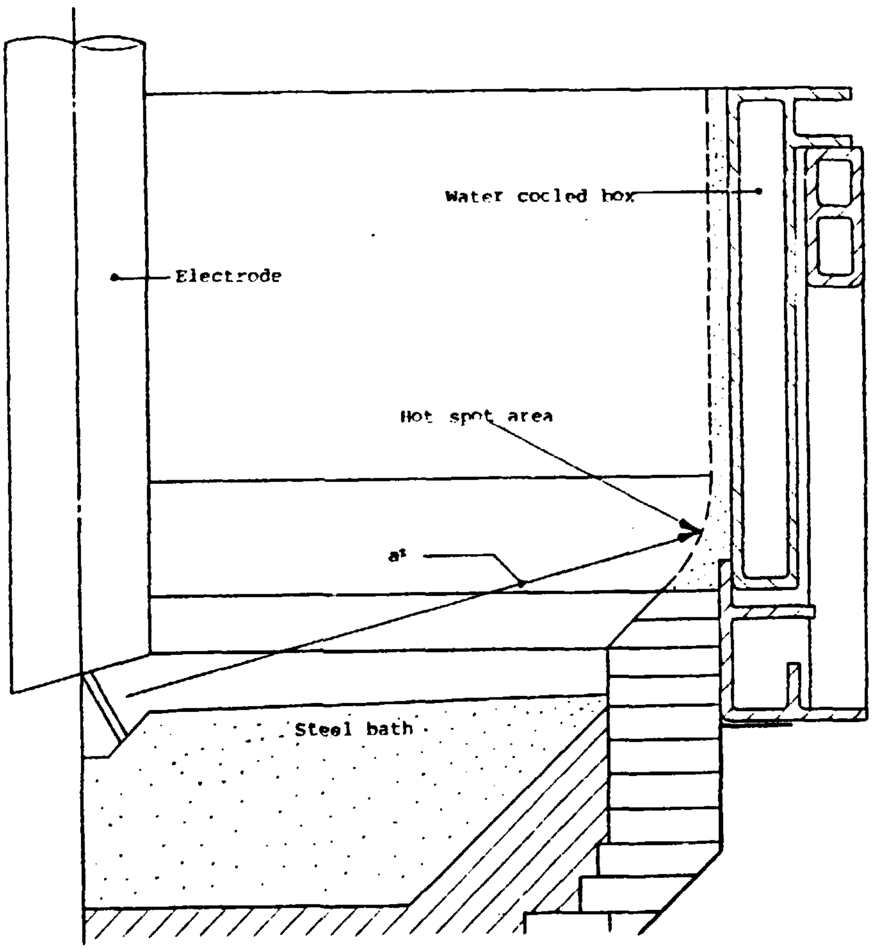
Source: ISIJ

Fig. 4.3.12 An Example of Horizontal Section of Water Cooling Roof for EAF

Further the central part of the furnace lid has recently become cooled by water. All water cooled roof has been developed but there remains the problem that troubles tend to occur due to insufficient insulation between the electrodes and between the central part and the circumference.

As for the furnace wall refractories, burnt or unburnt basic magnesia-chromium bricks and magnesia bricks have been used since the early days. In order to cope with the hot spot, the direct bonded magnesia-chromium and magnesia bricks or rebonded magnesia carbon bricks are presently used for the hot spot and near the sill level.

The water-cooled box is installed at the place which cannot be covered with such refractory bricks. Recently the water cooling system for the furnace wall as illustrated in Fig. 4.3.13 has been developed and used.



Source: Korf

Fig. 4.3.13 A Typical Water Cooling System for Furnace Wall

(3) Automation

The EAF have previously made less progress in automatic control other than types of furnace such as converters since steelmaking process was more complex and productivity was not so much required.

Recently, however, the automation in the EAF have been introduced according to the conditions of each operation stage. Some examples are shown as follows: -

a) Charging raw material - continuous charging of DRI

b) Melting stage - optimum control of electric power and demand control for power load by computer

c) Oxidation stage - feeding devices of auxiliary materials
   - automatic oxygen blowing and water cooled oxygen lance

d) Slagging - automatic slag remover

e) Reduction stage - feeding devices of auxiliary materials

f) Measurement and sampling - automatic temperature measuring and sampling device
   - analysis of results using a computer

Among these, some have already been adopted in most factories and some are still at the stage of development. They will be developed and adopted more and more in future.

(4) Utilization of direct reduced iron

The utilization of direct reduced iron (DRI) in EAF has made rapid progress in recent years, and increased in the mini mills particularly in the developing countries and a growing interest is taken in the utilization of DRI for this purpose due to the worldwide shortage and price increase of scrap.

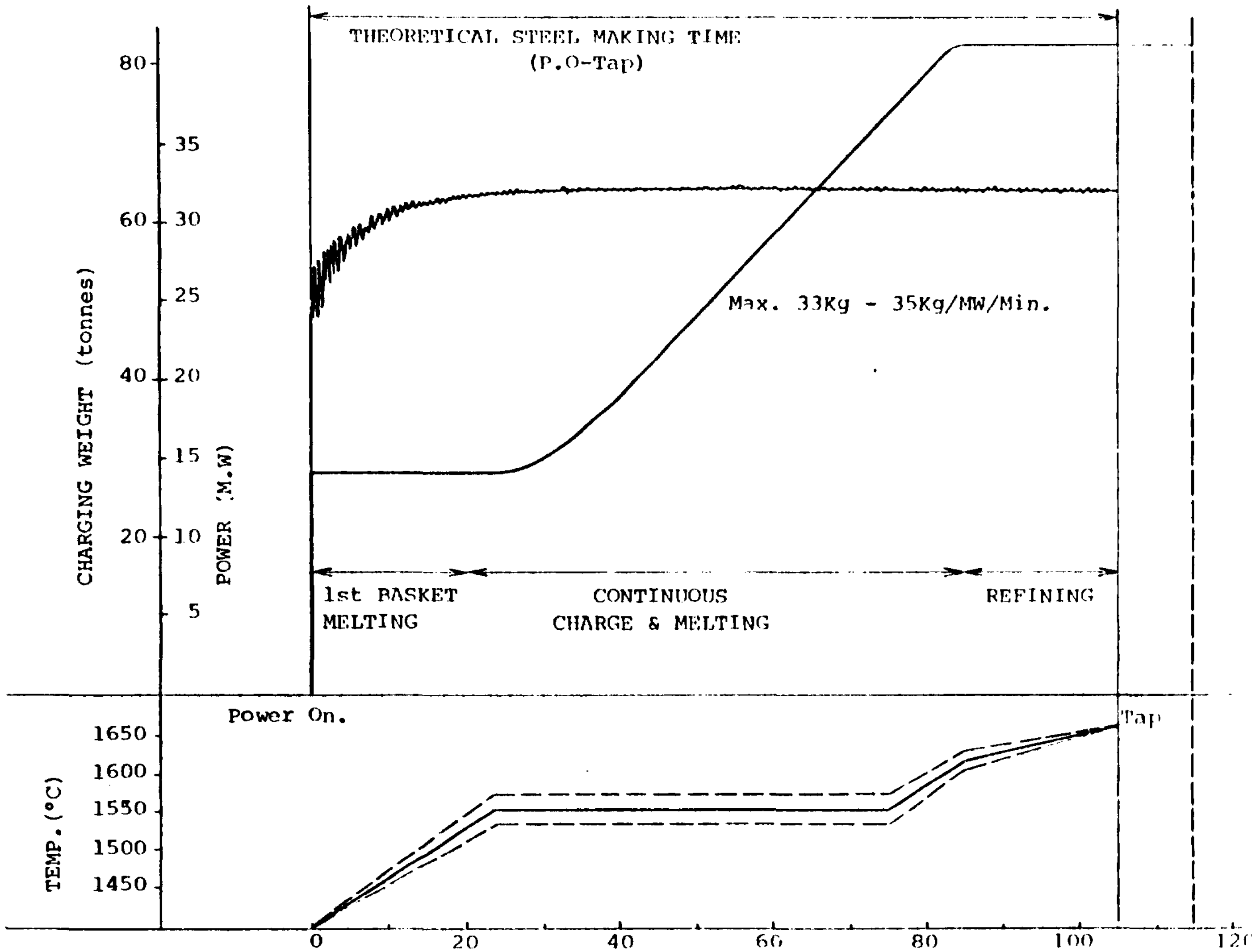
Table 4.3.2 shows a summary of the merits and demerits of utilization of DRI in EAF.

Table 4.3.2 Merits and Demerits of DRI in EAF

Merit	Demerit
1) Decrease of steelmaking time	1) Large quantities of lime required
2) Increase of productivity	2) Increase of electric power consumption
3) Stable shape and quality	
4) Easy handling	
5) Easy automatic control of EAF	

The charging rate varies 75-85%, but the melting techniques to make a continuous operation with DRI at a high rate, i.e. 85-100%, have already been established.

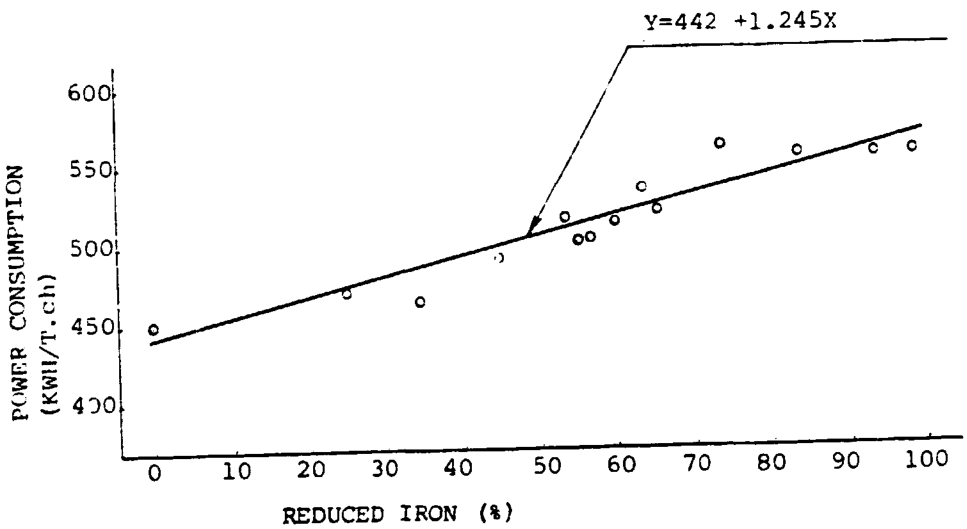
Fig. 4.3.14 shows the typical operation pattern.



Source: Kobe Steel

Fig. 4.3.14 Typical Operation Pattern of 85% Reduced Iron Melting

Fig. 4.3.15 shows the relationship between the DRI charging rate and power consumption. DRI can be continuously charged into EAF for its ease of handling and is advantageous in respect of the automation of furnace power load factor, and flicker compensation, and therefore the use of DRI is expected to have a significant effect in assuring the stable supply of the principal raw material for EAF.



Source: Kobe Steel

Fig. 4.3.15 Relation between Reduced Iron Charge Rate and Power Consumption

(5) Environmental control

The most serious problems associated with the preservation of environment are dust and noise.

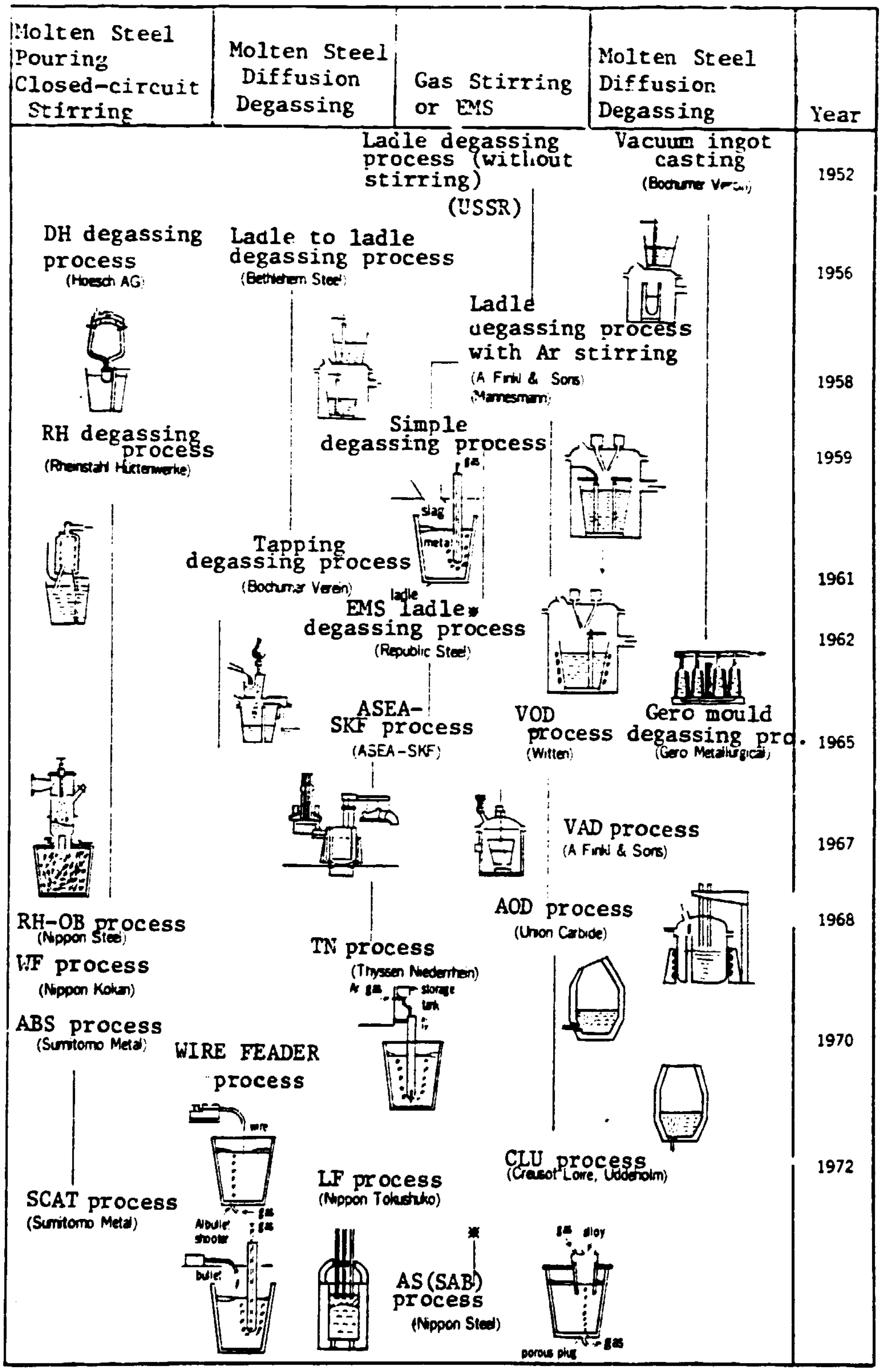
As for dust, the dust collector which such the dust directly through the furnace roof or the indirect suction type dust collector to collect the dust arising around the furnace were previosly used for the environmental control. Recently, the roof-dust collecting system to catch dust in the plant building as a whole has been employed.

4.3.3 Ladle Refining

(1) General

In paralell with the attempts to desulphurise and dephosphorise the hot metal during pre-treatment rather than in the converter, the use of ladle refining after the steel is poured out of the converter is also becoming widespread. This method serves to deoxidise, degas and adjust the chemical composition of these steels where quality requirements are especially strict. Vacuum degassing, for example by the Ruhrstahl Hansen (RH) or Dortmund Horder (DH) process, is now used in almost all steelworks. Recently, ladle furnaces incorporating arc-heating devices are coming into use for the production of steel which is to be subjected to rigorous supersonic wave tests.

Another method being adopted industrially serves to control the shapes of non-metallic inclusions in the steel by injecting calcium alloy or desulphurising agent into the ladle to which a deoxidising agent has been added. The application of such injection metallurgy methods to the ladle refining and pretreatment of hot metal is expected to increase in future (See Fig. 4.3.16).



Source: ISIJ

Fig. 4.3.16 Development of Ladle Refining Processes

The degassing and decarburization speeds have improved by such increase of the circulation speed in both RH and DH processes.

Fig. 4.3.17 shows the oxygen behaviour of silicon killed steel where the circulation speed is set at two levels by RH process. Through the adoption of this method in DH process, low oxygen values could be obtained in a short time as in RH (see Fig. 4.3.18)

The decarburization speed increases in proportion to the circulation speed. Fig. 4.3.19 shows the decarburization curve of a very low carbon steel.

The dehydrogenation speed is also clearly affected by the increase of circulation speed, as shown in Fig. 4.3.20 .

On the other hand, there is an oxygen bottom-blowing method (RH-OB-FD), which method tries to more diversify the metallurgical operations by giving RH process a temperature raising function.

The refining using a flux within the tank is also possible by this method as raising the temperature is possible. A very low sulfur steel has been obtained, as shown in Fig. 4.3.21, by adding a flux where quicklime and fluorite are evenly mixed to molten steel at a rate of 9 kg/t.

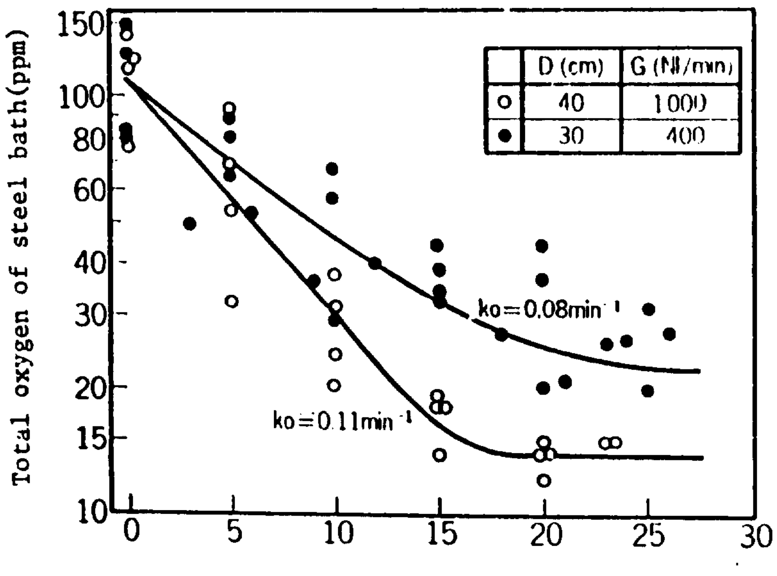
(2) Typical refining processes

(a) RH and DH degassing processes

Most of the large-sozed degassing equipment which have recently started operation have a large capacity and high efficiency. In the operational aspect, the RH and DH processes are mutually utilized to improve the operation techniques and the steel with a very low content of carbon and oxygen became able to be produced. In the field of refractories, too, the RH process, which has so far been regarded as disadvantageous compared with DH process, has much improved.

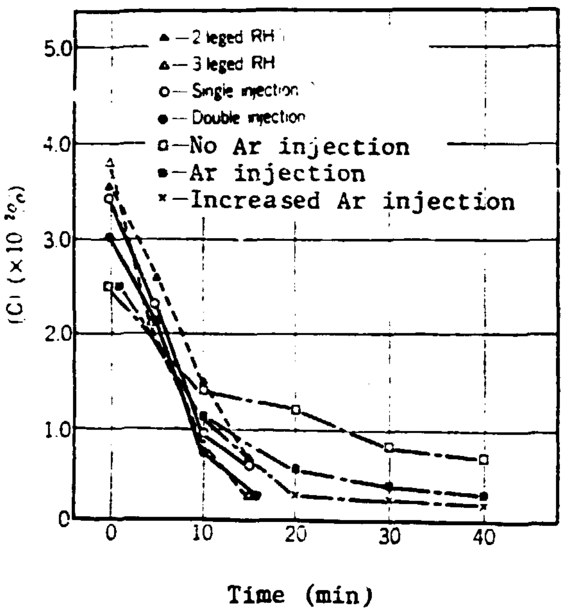
The closed-circuit speed of molten steel in RH process is the most important parameter for the operations as it determines the reaction speed. The closed-circuit speed is affected by the volume of inert gas blown from the rising tube, the distance from the steel bath surface in the RH tank to the gas blowing position and the inner diameter of the immersion tube.

On the other hand, in DH process the circulation volume depends on the suction volume of molten steel at each time and the number of tank lifting frequency, and the degassing speed is increased by accelerating the lifting speed.



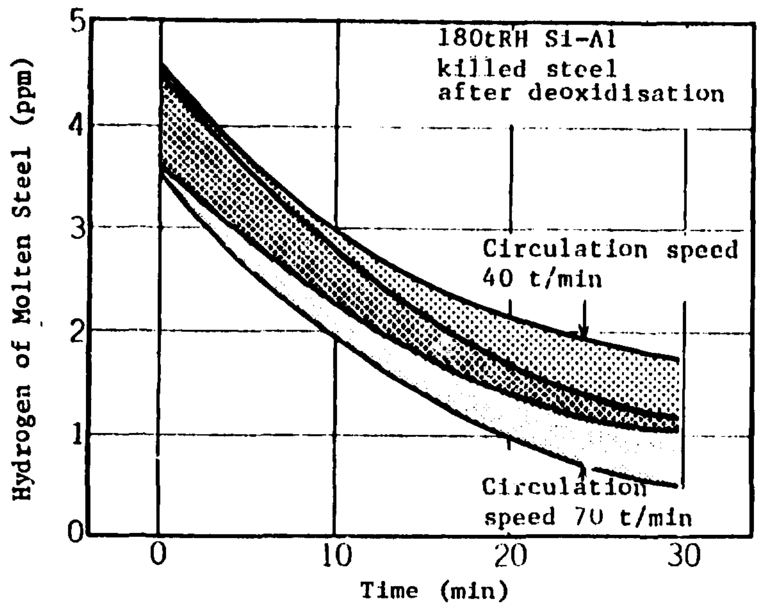
Source: JSIJ

Fig. 4.3.17 Behaviour of Oxygen in RH Degassing Process



Source: ISIJ

Fig. 4.3.18 · Decarbonisation in Vacuum Degassing Process



Source: ISIJ

Fig. 4.3.19 Behaviour of Hydrogen in RH Degassing Process

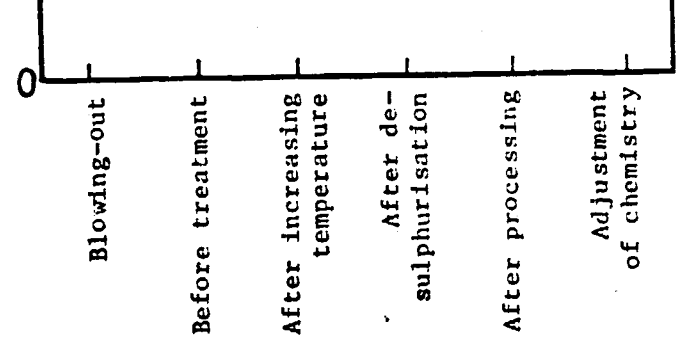
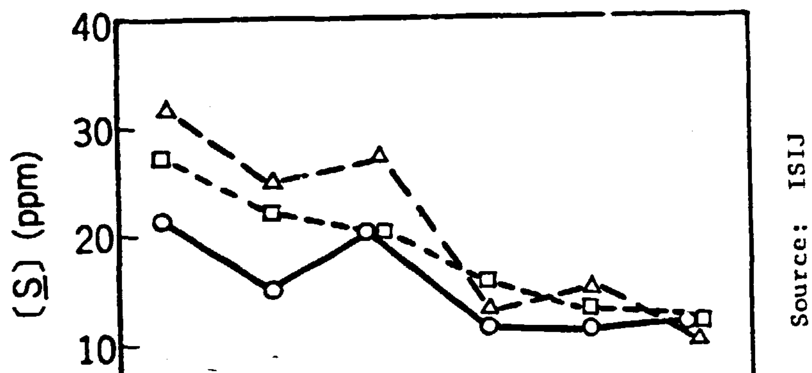
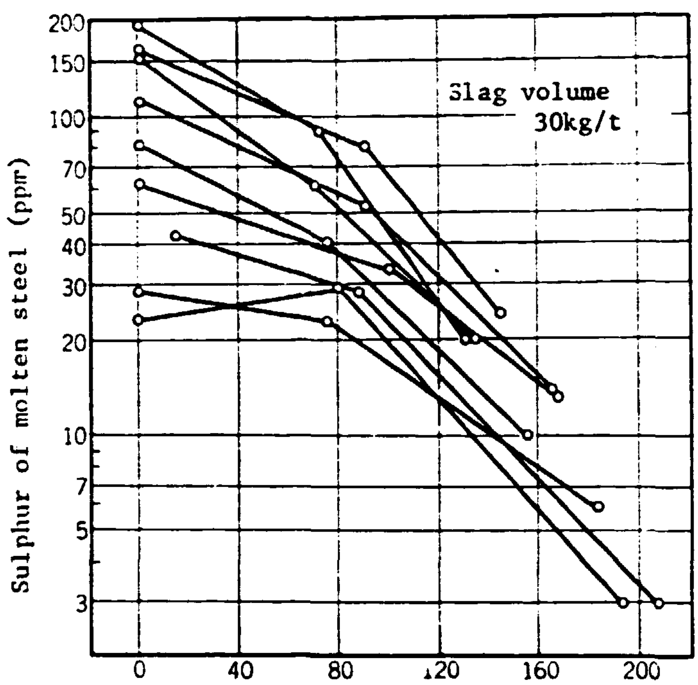


Fig. 4.3.20 Behaviour of Sulphur in RH Degassing Process


[S] (ppm)
40
30
20
10
Source: ISIJ



Source: ISIJ

Fig. 4.3.21 Behaviour of Sulphur in Desulphurisation (VAD) process

As mentioned above, the RH and DH processes have much improved in both degassing capacity and cost cut-down. Particularly the degassing capacity has been improving in parallel with the enlargement of equipment; the process time has been maintained at about 15 minutes irrespective of the increase in the amount of molten steel treated at once and further as for the range of value obtained, such limit values as could not so far be reached have become possible to obtain.

Thus this process is economically the most suitable process for deoxidation, dehydrogenation and decarburization. When deoxidation alone is considered, it is not economical and thus a substitute process will be considered for this.

(b) ASEA-SKF process and VAD process

Both of these processes are provided with an arc heating device and can make diversified metallurgical operations.

ASEA-SKF process has been thought unfit for dehydrogenation compared with other degassing process because it is a bath surface degassing process. But it can easily reduce the hydrogen value to 0.6 ppm if the steel bath surface is stirred by the ladle equipped with an argon porous plug.

In addition, an oxygen value of 9 ppm which is 4-5 ppm lower than the value by the existing Ar bubbling + degassing method has been obtained for bearing steel using an electromagnetic agitation, one of the characteristics of ASEA-SKF process, in the process for melting low oxygen steel.

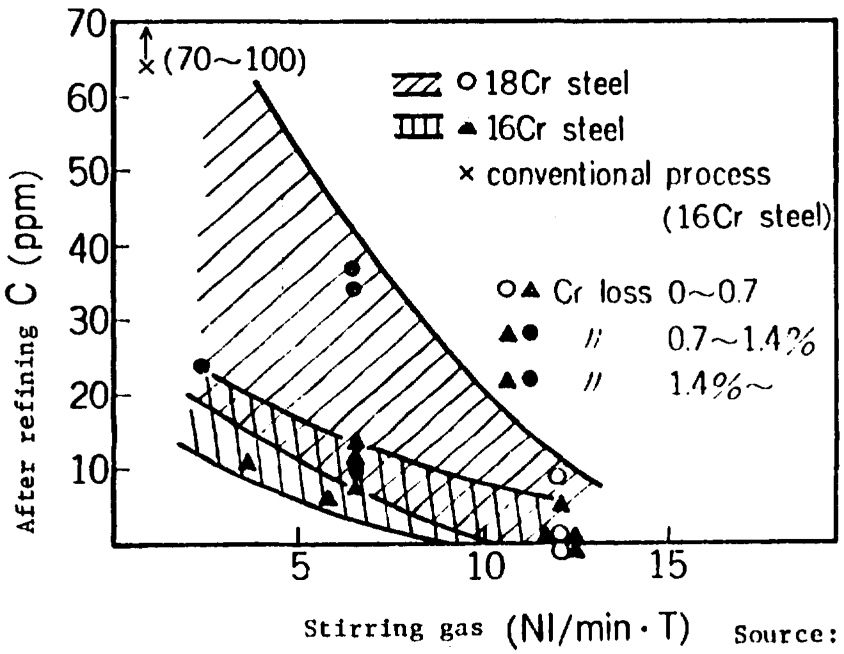
In VAD method which utilizes the refining function of flux, the value S = 50 ppm before the treatment can be reduced to 3 ppm by controlling properly the slag composition by adding a 30 kg/t flux as shown in Fig. 4.3.21.

(c) AOD and VOD processes

These processes have developed as an indispensable equipment for refining stainless steel. In AOD method, the furnaces have increasingly been enlarged in size and heightened in efficiency to pursue more economical operations, while VOD method has made possible the melting of even lower carbon or nitrogen steel than that by the electronic beam melting method by lowering the gas partial pressure under vacuum, and at the same time, stirring strongly by the gas bubbling process.

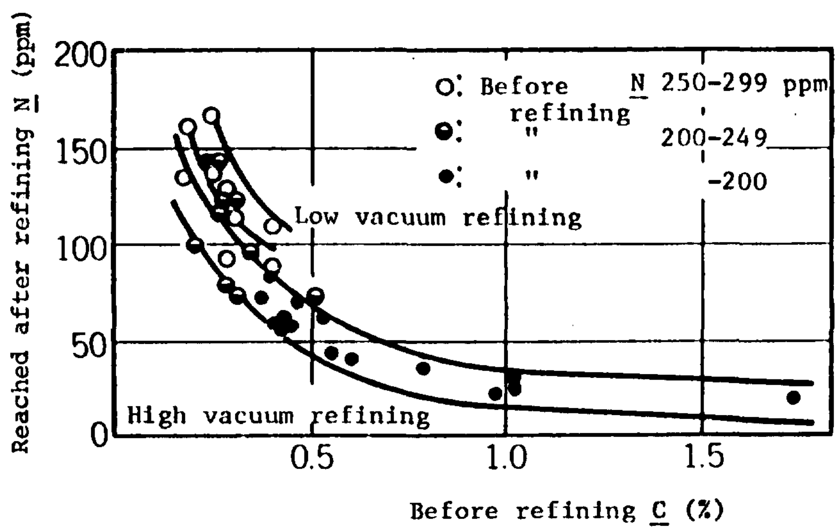
Fig. 4.3.22 shows the relation between the stirring gas flow rate and the range of carbon and Fig. 4.3.23 shows the relation between carbon before treatment and the range of nitrogen.

As mentioned above, AOD has made progress in the pursuit of higher productivity and economy, while VOD method has advanced in an extreme reduction of impurities.



Source: ISIJ

Fig. 4.3.22 Relationship between Stirring Gas and Carbon Reached after Refining



Source: ISIJ

Fig. 4.3.23 Relationship between Carbon before Refining and Nitrogen Reached after Refining (VOD process)

(d) Flux injection

In addition, there is available the flux injection process a more economical process used in palce of RH and DH processes, to blow flux into molten steel for the purpose of obtaining very low sulphur steel at a lower cost compared with calcium alloy. This process cannot avoid the increase in the hydrogen content of steel due to the injection agent and entrance of hydrogen from the atmosphere, but is used as a substitute process for refining the kind of steel where no low hydrogen level is demanded.

The flux injection process is thus worthy of attention as a deoxidation process useful for reducing the cost and also as a process to obtain the very low sulphur steel at a low cost.

In this method, the importance of the slag composition in the ladle has been recognized over again. It is necessary to establish the technique to make slag cutting in the tapping from the converter or removal of slag out of the ladle, at a low cost, in order to obtain the slag with a desired composition.

(3) Prospect

Generally, there still remains in the ladle refining the problem of economical efficiency compared with the converter and continuous casting processes which have played a very important role in improving the productivity, yield and energy saving in the iron and steel industry.

The ladle refining cannot avoid, in general,

1) high temperature tapping, and

2) increased retention time of molten steel in the ladle, and further it must consider the cost increase such as the increase in unit costs of converter and ladle refractories and decrease in the yield. Therefore the following should be taken into account in future when this process is reviewed from the standpoint of economic efficiency:-

   a) The technique to minimize the drop of molten steel temperature,

   b) A more economical heating source,

   c) The selection of an economical process according to the quality requirements,

d) Shortening of the treatment time, and

e) Slag cutting technique.

It will be necessary to make the above-mentioned improvements on the already developed processes, and at the same time, to undertake the development of a simpler process.

4.3.4 Continuous Casting

(1) Introduction

The continuous casting process was industrialized during the 1950's. Both facilities and operation were modified, and during the 1960's it became possible to combine the process with a large converter to mass-produce iron.

Table 4.3.1 shows continuous casting output and share in crude steel output for casting.

Table 4.3.1 Continuous Casting Output(1) and Share in Crude Steel Output(2) for Casting by Country

	1972		1973		1974		1975	
	(1) '000 t	(2) %	(1) '000 t	(2) %	(1) '000 t	(2) %	(1) '000 t	(2) %
Belgium	-	-	-	-	208	1.3	480	4.1
Denmark	-	-	-	-	-	-	73	13.1
F.R. of Germany	6,080	13.9	8,057	16.3	10,337	19.4	9,813	24.3
France	818	3.4	1,845	7.3	2,756	10.2	2,771	12.9
Ireland	-	-	-	-	-	-	-	-
Italy	2,524	12.7	3,375	18.1	5,165	21.7	5,904	27.0
Luxemburg	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-	-	-
United Kingdom (52 weeks: 53 in 1975)	522	2.1	811	3.0	1,126	5.0	1,704	8.5
Total EEC (9)	9,952	7.2	14,080	.4	19,592	12.6	20,745	16.5
Austria	419	10.3	505	11.9	766	16.3	866	21.3
Finland	1,076	73.9	1,256	77.8	1,290	77.9	1,233	76.3
Norway	29	3.2	120	12.5	143	15.7	140	15.7
Portugal	18	4.2	E 28	E5.5	30	7.5	35	7.9
Spain	1,401	15.5	2,038	18.9	2,2?8	19.3	2,333	21.0
Sweden	841	16.0	889	15.7	1,156	19.3	1,390	24.8
Yugoslavia	-	-	-	-	-	-	330	11.3
United States	6,973	5.8	9,270	6.8	10,722	8.1	9,653	9.1
Canada	1,393	11.7	1,551	11.6	1,873	13.8	1,735	13.3
Argentina	..	..	..	..	574	26.1	565	25.6
Brazil	144	2.2	228	3.2	379	5.1	477	5.7
Chile	8	1.3	7	1.3	9	1.4	7	1.4
Mexico	569	12.8	576	12.1	650	12.7	695	13.2
Australia	-	-	133	1.7	223	2.9	47	0.6
Japan	16,462	17.0	24,716	20.7	29,411	25.1	31,814	31.1
Republic of Korea	..	..	..	..	..	..	393	19.7
South Africa	784	14.7	917	16.0	1,105	18.9	1,393	19.7
Taiwan	..	..	..	..	..	..	..	..
Total of Above Countries	40,149	9.6	56,322	11.9	70,141	14.7	73,884	18.2
Percentage of Western World Steel Output Covered		96.4%		96.4%		96.5%		95.8%
USSR	6,907	5.5	6,968	5.3	7,355	5.4	9,729	6.9
Czechoslovakia	71	0.6	92	0.7	91	0.7	69	0.5
German D. R.	303	5.0	398	6.8	481	7.8	525	8.1
Hungary	-	-	59	1.8	422	12.2	775	21.1
Poland	309	2.3	309	2.2	320	2.2	332	2.2
Total Eastern Europe	683	1.9	858	2.4	1,314	3.5	1,701	4.3
Total All Listed Countries	47,739	8.2	64,148	10.0	78,810	12.1	85,314	14.5
Percentage of World Steel Output Covered		91.9%		91.8%		91.8%		90.9%

	1976		1977		1978		1979	
	(1) '000 t	(2) %	(1) '000 t	(2) %	(1) '000 t	(2) %	(1) '000 t	(2) %
Belgium	693	5.7	1,655	14.7	2,672	21.2	3,143	23.4
Denmark	312	43.2	347	50.7	481	55.7	473	58.8
F.R. of Germany	12,014	28.3	13,272	34.0	15,670	38.0	17,848	39.0
France	4,212	18.0	5,244	23.7	6,288	27.5	8,000	29.5
Ireland	-	-	-	-	-	-		
Italy	7,559	32.2	8,986	38.5	10,073	41.3	11,243	46.4
Luxemburg	-	-	-	-	-	-	-	-
Netherlands	-	-	-	-	-	-	-	-
United Kingdom (52 weeks: 53 in 1975)	2,165	9.7	2,554	12.5	3,149	15.5	1,627	16.9
Total EEC (9)	26,955	20.1	32,058	25.4	38,331	28.9	43,114	30.9
Austria	1,244	27.8	1,533	37.5	1,723	39.8	2,338	47.5
Finland	1,255	76.1	1,831	83.4	2,054	88.0	2,187	88.8
Norway	E 140	E15.8	E 140	E17.0	E 140	E17.6	E 140	E15.7
Portugal	69	15.0	195	35.5	244	38.0	245	36.6
Spain	2,493	22.7	2,887	25.8	3,287	29.0	3,030	32.1
Sweden	1,451	28.2	1,214	30.6	1,561	36.1	1,824	38.5
Yugoslavia	398	14.5	824	25.9	1,186	34.3	1,288	36.4
United States	12,246	10.5	14,268	12.5	18,903	15.2	20,577	16.7
Canada	1,582	12.0	2,169	15.9	3,011	20.2	3,192	19.9
Argentina	665	27.4	737	27.5	1,120	40.4	1,567	49.0
Brazil	1,119	12.1	1,957	17.4	3,016	24.8	3,831	27.6
Chile	11	2.2	11	2.0	9	1.3	E 10	E 1.8
Mexico	682	12.9	1,615	29.1	E2,000	E29.7	E 2,100	E30.0
Australia	-	-	-	-	33	0.4	411	5.4
Japan	37,629	35.0	41,807	40.8	47,159	46.2	58,116	52.0
Republic of Korea	770	21.9	1,376	31.7	1,829	16.8	2,318	30.4
South Africa	1,861	26.2	2,739	38.1	3,431	43.4	4,384	49.4
Taiwan	..	..	420	23.7	1,341	39.1	1,910	14.9
Total of Above Countries	90,570	20.7	107,781	25.5	130,307	29.2	151,776	32.1
Percentage of Western World Steel Output Covered		96.6%		95.1%		95.2%		95.2
USSR	11,729	8.1	12,200	8.3	14,400	10.4	15,100	11.1
Czechoslovakia	107	0.7	110	0.7	E 110	E 0.7	E 110	E 0.7
German D. R.	566	8.4	623	9.1	677	9.7	718	10.5
Hungary	1,019	27.9	1,054	28.3	1,151	30.5	1,261	32.8
Poland	297	1.9	446	2.5	519	2.8	691	3.6
Total Eastern Europe	1,989	4.9	2,233	5.1	2,477	5.5	2,020	6.2
Total All Listed Countries	104,288	16.7	122,214	19.9	147,264	22.9	171,816	25.7
Percentage of World Steel Output Covered		92.1%		90.7		89.7		89.4

Note: (1) Excludes steel for casting, (2) Steel for casting, E: Estimated

Source: IISI

The continuous casting process is a high yielding, energy-saving process. The recent trend is to charge heated slab and/or billet into a reheating furnace to further improve energy savings. As a result of active works to improve the quality of slab and/or billet it has become possible to produce almost all high quality steel by means of the continuous casting process. Also, due to a considerable improvement in productivity, it has become possible to cast a substitute steel for rimmed steel which was considered difficult to be produced by the continuous casting process in terms of cost.

This conditnuous casting process has become a major technology to produce slab and/or billet, replacing the ingotmaking—blooming process. In order to further increase the proportion of continuously cast steel, there are many tasks, such as the achievement of stable operation and the continuous operation with rolling process, which need to be solved, moving away from the past practice of the continuous casting process and the ingotmaking—blooming process mutually supplementing.

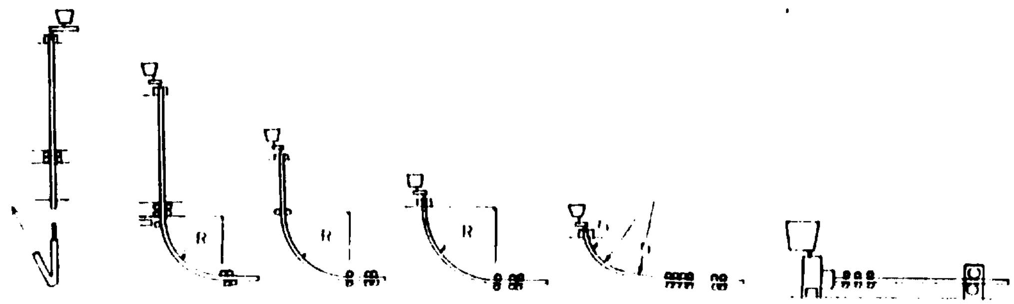
(2) Productivity and equipment

Existing major continuous casting machines are shown in Fig. 4.3.24. The vertical type has a poor productivity due to short metallurgical length and its equipment cost is considerably high. In order to cover such defects of the vertical type, a benging type continuous casting machine has been developed which can be adjusted for any metallurgical length. Today, machines of this type are being used almost for all production of slabs which needed to be mass-produced.

Also, as special-purpose continuous casting machines, horizontal and rotary type continuous casting machines have been developed. They are both less expensive compared with vertical and bending types.

For the future, it is strongly desired to develop low-head type continuous casting machines which are capable of mass-production, less expensive and somewhat better qualitywise.

Continuous casting is highly applied in the field of platemaking. The steel products by continuous casting are shown in Table 4.3.2 by continuous casting.



Source: ISIJ

Fig. 4.3.24 Existing Continuous Casting Processes

Table 4.3.2 Rate of Steel Products by Continuous Casting

Item		Rate of Application (%) 1976	1980
Plate	Structural steel	60	90
	High tensile steel	50	80
	Line pipes	20	55
Sheet	Deep drawing	50	70
	Tin plate	20	65
Bloom	Rails	50	65
	Seamless	60	80
	Low alloy steel	10	60
Billet	Spring steel	70	95
	Piano wire	80	100
	Cold heading steel	40	80

Source: JISF

On the other hand, continuous casting in sheet have been behind much in plate. This is due to the fact that the proportion of rimmed steel products was 70 to 80 % in the field of sheet in the conventional ingot making and rimmed steel was replaced by killed steel in continuous casting, resulting in lower cost merits.

It has become possible to use a substitute steel for rimmed steel which is less expensive in continuous casting. Therefore, an adoption of continuous casting is expected in this field.

In the field of bar steel including mass-produced special steel where continuous casting is least spreaded, that large bloom continuous casting machines have commenced operation.

(3) Continuous casting technology

In order to improve productivity, it is necessary to:-

- achieve higher operation rate,
- establish high speed casting, and
- establish high quality production technology.

Today, there are continuous casting machines which are capable of producing 260,000 tonnes/month of slab or 100,000 tonnes/month of bloom.

(a) Achievement of high operation rate

(i) Raising of continuous-continuous casting rate

- process to continuous-continuous casting of different steel products.
- on-line process to change width during continuous casting operatior

(ii) Process to rapidly replace rolls.

(iii) Reduced cast exchanges by extending cast life from 200 to 300 changes to 800 to 1,000 changes.

(iv) Decrease in roll exchanges by improving roll material and shape.

(v) Prevention maintenance.

(vi) Device to check spray nozzle blocking.

(vii) Casting method for dividing slab into double width.

(viii) Reduction of hours to charge dummy bars (from bottom charging to top charging)

(ix) Unit exchange method.

Through the development of the above-mentioned processes and techniques, the operation rate of continuous casting machines has been greatly improved. There are continuous casting machines with more than 90 % operation rate.

(b) High speed casting process

Higher casting speed tends to creat problems of increased accumulation of large inclusions and of internal cracks. As for the mechanism of internal cracks, one leading view attributes it to bulging. Also, cracks due to improper roll pressure, cracks due to deformation during bending correction and those due to roller mis-alignment have been reported.

In order to prevent internal cracks, therefore, it is necessary prevent bulging. As counter-measures to prevent bulging:

(i) To strength solidified shells by strong cooling,

(ii) To reduce roll pitch to reduce bulging or

(iii) To support the surface with walking bars.

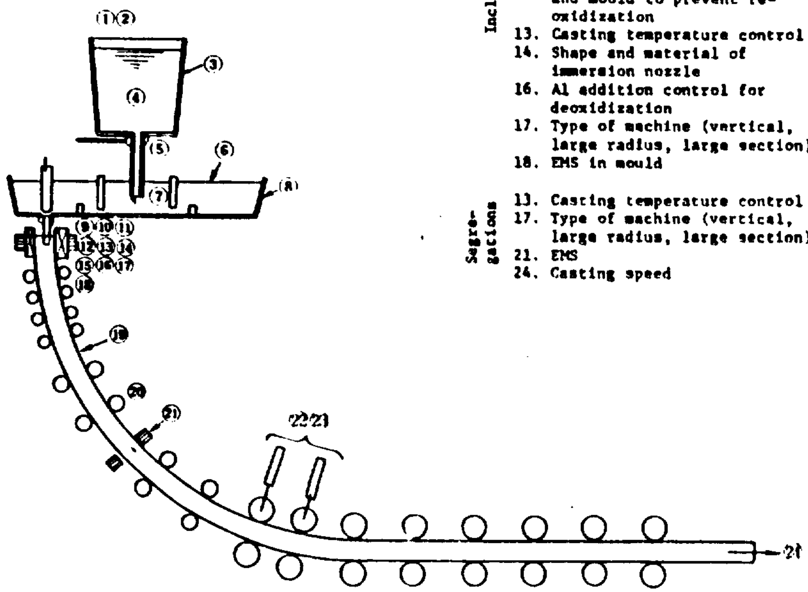
Strong cooling suggested in (i) tends to cause surface cracks due to thermal deformation. The most rational measure would be walking bars suggested in (iii).

As for cracks due to correction distortion, single radius one point straightening tends to make distortion larger, and thus multiple-point correction is considered better as it spreads distortion. However, a special technology has been developed to reduce correction distortion in single point correction by means of the compressing casting process (CCP).

In the past, casting speed was less than 1.0m/min for slab continuous casting machines. Today, there are continuous casting machines which are capable of casting at the speed of 2.0 m/min.

(c) Production technologies of high quality product

In order to obtain high quality, it is necessary to reduce various defects of cast products and to realize uniformity which is a merit of continuously cast products. The technology to reduce various defects is outlined in Fig. 4.3.25.



Countermeasures

Inclusions

1. Control of slag flow into ladle
2. Secondary refining
3. Ladle refractories
5. Sealed teeming between ladle and tundish to prevent reoxidization
6. Large tundish
7. Tundish dam
8. Tundish refractories
9. Sealed teeming between tundish and mould to prevent reoxidization
13. Casting temperature control
14. Shape and material of immersion nozzle
16. Al addition control for deoxidization
17. Type of machine (vertical, large radius, large section)
18. EMS in mould

Segregations

13. Casting temperature control
17. Type of machine (vertical, large radius, large section)
21. EMS
24. Casting speed

Countermeasures

Surface Defects

4. Composition control (Mn/Si, Cu, Sn, etc.)
9. Sealed teeming between tundish and mould to prevent reoxidization
10. Mould level control
11. Plating of mould interior (Cr, Ni, etc.)
12. Mould cooling water control
15. Quality control of oil for oil
17. Al addition control for deoxidization
18. EMS in mould
19. EMS in mould
20. Roll alignment control
24. Casting speed

Internal cracks

17. Type of machine (vertical, large radius, low machine, height)
20. Roll alignment control
21. EMS
22. Inline reduction
23. Multipoint straightening

Source: ISIJ

Fig. 4.3.25 Countermeasures in Continuous Casting

One of major defects in continuous casting is that axial segregation of elements will occur to cast products. Also, rate of continuous casting is lower in comparison with ingots making and tend to be influenced by solidified structure. It is therefore desired to improve solidified structure. Electro-magnetic stirring (EMS) has been developed to perform this role. As a recent trend, continuous casting machines for slab or billet are provided each with EMS.

Also, a combination stirring technique has been developed, which is capable of improving both surface and internal quality by combining EMS within caster and EMS in the secondary cooling zone.

As mentioned above, it has been possible to greatly improve the quality of cast products through the combination.

Moreover, it is possible to remove gas foams by means of EMS within caster, and thus it is possible to cast weakly deoxidized steel without creating foams.

Therefore, it has become possible to continuously cast rimmed steel. Further, technological development is expected for the continuous carting of rimmed steel in future.

(4) Hot direct rolling

As a result of improved quality, rolling without surface traditioning and hot direct rolling have become common practices. In this case, quality guarantee is mainly based upon the estimated evaluation of quality through casting conditions or sampling test scarf. Also, various defect detection devices have been developed.

In connection with the practice of rolling without surface conditioning and direct rolling trimming machines, automatic marking devices, etc. have been introduced. Also, in order to prevent temperature lowering during the transportation of slab and/or billet, lagging covers and/or pits have been applied.

A combination of electric furnace —— billet continuous casting machine —— bar mill, and large bloom continuous casting machine —— billet mill can be easily made continuous from the standpoint of productivity, there are many examples of simultaneous hot charging being practiced. In order to make simulateous operation with rolling process easier, lot sorting function is on-lined for discharge adjustment in continuous casting.

As for slabbing, on the other hand, although hot charging is being practiced, there are no examples of simultaneous continuous operation. This is due to various restricting conditions (slab width, rolling order, etc.) of both continuous casting machine and rolling mill. In order to promote continuous casting, it is necessary to decrease such restrictions.

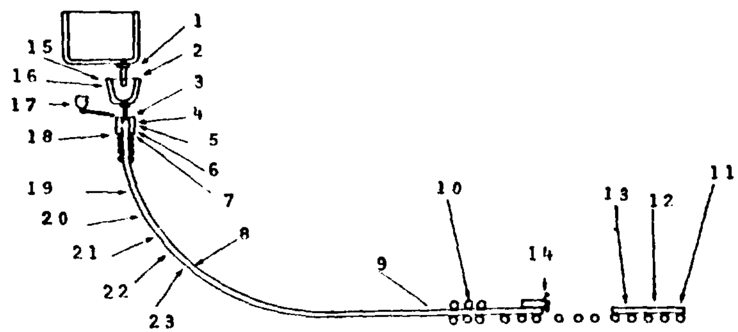
The repeated raising of energy costs are creating a trend to review the layout between continuous casting machines and rolling mills. Also, at some plants, continuous casting machines are located at the entrance to a rolling mill so that slab and/or billet could be directly sent to the rolling mill.

Automation has made a great progress under constant conditions in continuous casting operation, but has not made much progress under non-constant conditions such as commencement and termination of casting. However, automation will have a great impact upon continuously cast products, and thus further automation is expected. Fig. 4.3.26 shows an example of major automation items in continuous casting.

(6) Prospects for continuous casting

Increased confidence in continuous casting and its excellent achievements in terms of yield, energy saving and quality have made continuous casting as an important indicator for the modernization of the steel industry. Further employment of continuous casting is expected both in the construction of new steelworks and in the modification of existing plants. Also, direct connection to the following rolling process will be intensified.

As for continuous casting machines themselves, flexibility of product sizes such as in slab-bloom combinations machines and technologies to meet effectively diversified requirements both in production lot and specification are demanded. Also, studies are being carried out to utilize rolling technologies, including effective use of cogging mill, for the expansion of the functions and usefulness of the continuous casting process.



Principal Automized Items of Slab Caster

1. Automatic hadle pouring
2. Automatic temperature measurement
3. Automatic moulding
4. Mould cooling water control
5. Oscillation control
6. Mould width changing
7. Taper adjustment for narrow mould plate
8. Remote control of roll gap
9. Slab width measurement
10. Solidified thickness measurement
11. Control of shipment, cooling and stock
12. Surface crack detection
13. Automatic marking
14. Automatic cutting
15. Slag detector
16. Automatic tundish preheating
17. Automatic powder feed
18. Breakout detection
19. Secondary cooling water control
20. Spray nozzle blockage detection
21. Roll gap measurement
22. Pass-line measurement
23. Roll revolution measurement

Source: ISIJ

Fig. 4.3.26 An Example of Major Automation Items in Slab Continuous Casting

Horizontal continuous casting machines or rotary caster may be used for the mass-production of steel in the future.

4.3.5 Castings and Forgings

(1) Castings

(a) Outline

Recently there has been a conspicuous development in the field of casting technology. Casting technology is just true to the expression termed inter-cience that has come to be used recently, and is a field which requires a very wide scope of science and technology.

(b) Equipment and productivity

The automation of casting process of foundry shop has made a remarkable progress, and thereby the productivity has increased.

Most of the foundry shop process is occupied by moulding process, and the automation of this process has been sufficiently made by the development of researches on moulding technology, that is, on treatment of sand, binder and others, and further productivity has also increased. The last process of flash removing and finishing process has been seen partially automated.

The above mentioned shops are for the most part shops of mass production system, and the partial automation is widely prevalent in shops of big sized castings and other shops in general, but the all the manufacturing processes have not yet been systemised.

(c) Moulding sand and moulding

The especially remarkable progress in casting technology in recent years would be the moulding sand and the moulding method with the said sand. A great number of moulding methods have been developed such as high pressure moulding method, shell-mould method, CO_2 method, further self-hardening mould applying various inorganic caking agent and organic caking agent, hot box, cold box, well flowable formed mould, etc., accordingly the productivity has increased remarkably.

Recently a method of moulding under reduced pressure has been developed which applies no caking agent to moulding sand while making mould, and it is attracting worldwide attention. Furthermore, active researches have been made to put to practical use the SO_2 method, frozen mould, water soluble mould and others.

(d) Melting

The melting of cast iron is mostly made by cupola, which has been being replaced with low frequency induction melting furnace in view of environmental public nuisance, however, due to the effect of oil shock the trend to return again to cupola melting is to be seen as well. As an example of the cupola getting larger, recently appeared a large size cupola with a maximum capacity of 110 tonnes.

On the other hand, though melting by low frequency induction furnace was easy to control but had problem in material affairs, this problem was solved with the development of inoculation technology and at present this furnace seems to be very widely applied.

(e) Special casting

As for special casting, there are centrifugal casting, precision casting, metalic mould casting and others.

In the centrifugal casting there are not so much technical problems. In this field, the replacement of sand mould with metalic mould has been made, and with the development of casting machine, there has come an increase of productivity to be seen. The production amount of precision casting has been increasing of late.

In general, the ceramic shell mould using wax is mostly applied in this casting. The metallic mould is mostly applied to iron castings, and has come to be put to practical use fairly widely. It may well be considered in another point of view that the spheroidal graphite cast iron is a suitable material for metallic mould casting, which material is being planned for practical use as well as being studied under the present situation.

(2) Free forging

(a) Trend of production and installation

However, the production installation which had been so far more than enough against demand has shown a shortage of capacity in these ten years for the first time, and at the same time the required forgings have become greater in size and in weight, so the renewal of various installations includng forging machines has been made actively. Further it can be pointed out as the characteristic during the said period that in order to get rid of the production style of intensive form of labor, measures to cope with public nuisance and others including automating and reduction of labor have been taken in to a greate extent.

Table 4.3.6 shows the change of kind and number of sets of forging machines indicating that total number of sets has decreased in spite of the increase of production amount, and we can guess that the intensive movement has been promoted among the enterprises.

(b) Trend of forging technology

Although the production amount of forgings has increased, it does not mean the numerical increase of those of same quality and same shape, and thus the small amounts of wide varieties are always forced to be followed. On the other hand, the generation of demand for the forgings of very big dimension and very heavy weight has made the character of forging shop more complicated.

The main purpose of forging is divided into the improvement and forming of internal properties such as squeezing of cracks or holes existing in the interior of ingot, making the casting structure more fine and so forth. It is quite difficult to completely

A queeze the cracks and holes, and so in order to increase the effect of squeezing a special forging method has been developed. However, in recent times owing to the fact that a special steel ingot is available by the unique steel-making and ingotmaking technology applying the vaccuum carbon deoxidation process on the extreme decrease of impure elements and that the heat treatment condition suitable for the dimensions of the forged and the amount of alloy is determined and thereby sufficiently enough internal strength of forgings can be easily given by applying computer. The important point of forging technology has come to lie on the point of forming and productivity rather than on the improvement of interior properties.

(3) Die forging

(a) General

In the forgings, from the view point of energy and resources saving, activities have been pointed to improve the yield and minimizing the subsequent process, and the die forging itself is proceeding toward precision. Accordingly, the free forgings are changing to semi-closed forging and the semi-closed forging to closed forging.

(b) Hot forging

(i) Forging equipment

The innovation of equipment has been made to match the increase of production. The leading process of die forgings in 1960's was the upsetter by split-die for parts of axial symmetry or die forgings with flash by hammer or press for parts of non-symmetry, and the manufacturing rate was on a level of 10 pieces per minute. However, the automatic forging machine has been developed, and by means of the multistage continuous processing machine it has become possible to manufacture goods of high precision by closed system. This depends much upon the improvement of die material and lubrication and in consequence the difference between hot forging and cold forging has been shortened.

To such application of automation much contribution is made by the change of heating system from burning system to induction system.

As most of the hot forgings have small amounts of wide varieties, it requires going automatic which satisfies the following conditions:-

1) It is possible to manufacture small amounts of wide varieties in the automation line with high flexibility.

2) High safety can be secured and necessary measures are taken against public nuisance such as noise, vibration, etc.

3) The preparing time required for the change of manufacturing goods is made short and the net manufacturing time long.

(ii) Forming technology

The basic characteristics for the die forged goods to be adopted as structure parts of various kinds are as follows:-

1) to minimize the machining cost or processing time, and to raise the yield of material,

2) to have no need of machining or to be able to obtain parts with complicated shape easily,

3) to increase the strength to resist a heavy load by giving forged line of flow,

and further it is indispensable that the total cast required for the manufacturing is cheaper than that of other principal shaped material.

At present the actually measured data of forging load and metal flow, and theoretical analysis data are being accumulated, and thus it can be considered that in the near future CAD (Computer Aided Design) and CAM (Computer Aided Manufacturing) will come into wide use in forging shops.

(c) Cold forging

At an early stage when the cold forgings were introduced mainly concerning motorcar parts, this process was taken for a sort of rough processing, however, wish the development of periferal technology such as material, tool material, forging process, press and others, the scope of application has been enlarged from the range of rough processing to the range of finishing process. The flow of cold forging process, as is shown in Fig. 4.3.27, can be broadly classified in the replacement of hot forging with cold forging, the cold forging of parts of high precision and the automatic forming line to cope with mass production.

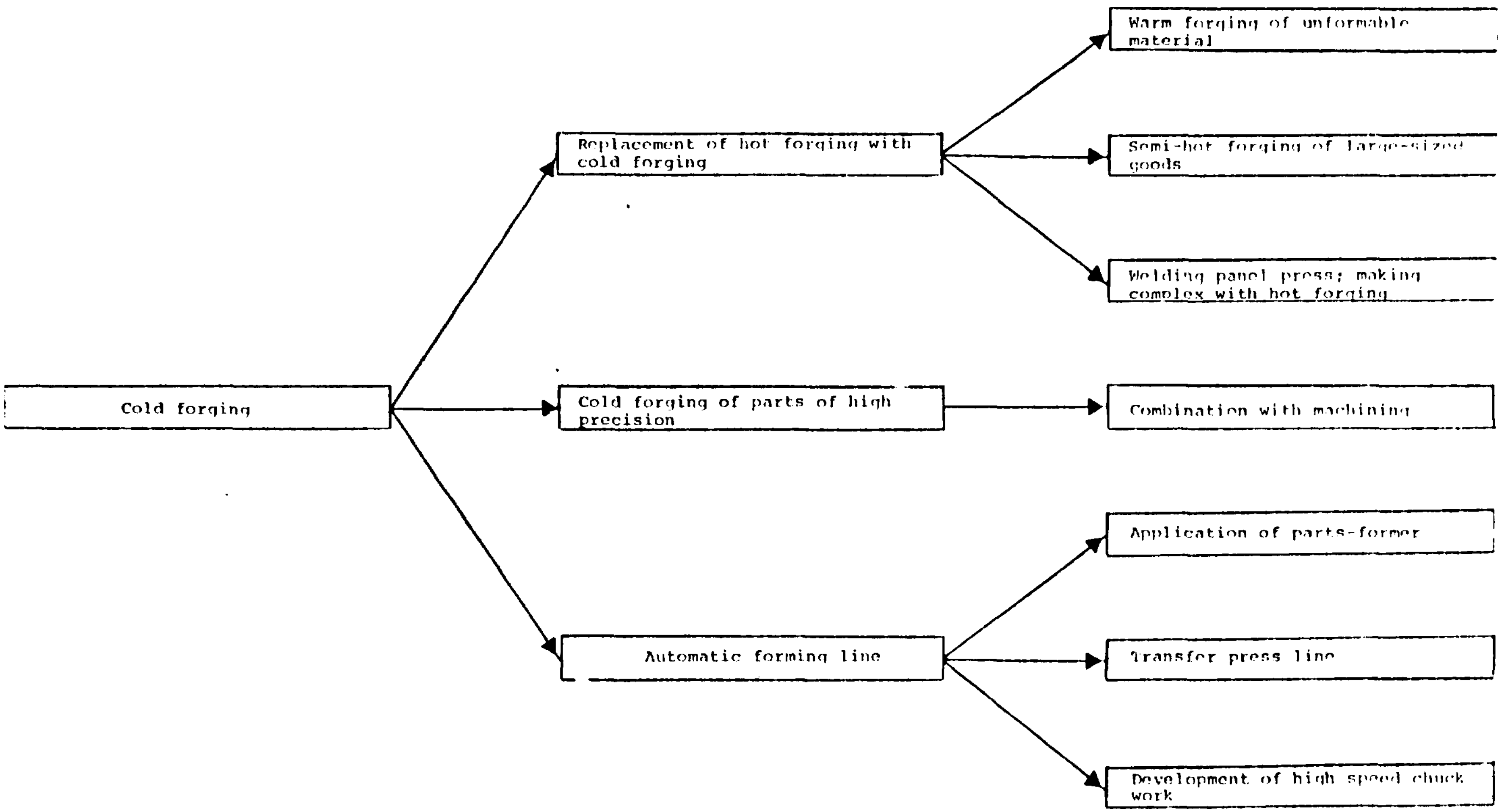


Fig. 4.3.27 Development Procedure of Cold Forging Processing

In the replacement of hot forging with cold foring, the processing machine gets larger. For that reason there lies an economical limit, and accordingly a combination with warm forging or hot forging comes to be pointed to.

The series of annealing - lubrication treatment - press work is the general manufacturing process of cold forgings, and thus the more increases the amount of forming process, the higher becomes the weight of annealing and lubrication treatment. The same holds true as regard dies also. Accordingly, concerning the reasonable design of shape of forging and the prolongation of life of dies, it requires further technical development hereafter.

(d) Special forging

The special forging has several kinds such as rotating forging, powder forging and others, and the forging of such kind has been thought much of or disregarded according to the change of ages. As the beginning of the 1970's the advantages of powder forging was made clear by research while the economical efficiency was thought questionable, however, in recent times the good characteristics and uniformity of material have been perceived and the forging technology by high-speed steel powder metallurgy and ultra-alloy powder metallurgy is being developed.

Further, for the forming of ring shape piece, the rotating forging has been recognized anew and has been applied to forming large sized parts.

4.4 Rolling

4.4.1 Blooming

(1) General

With the prevalence of the continuous casting process, the conventional ingot making - blooming - rolling processes are becoming rather obsolete. However it is not that the continuous casting method will be adopted right now in all iron and steel making processes, but the blooming process will still remain for the time being. So active technical development in the blooming process is still necessary. As the quality of ingot depends by almost 100% on the casting stage, the following two points have been pursued in the technical development of the blooming process.

(a) Saving of the fuel unit cost.

(b) Improvement of blooming yield rate.

(a) Saving of fuel consumption

Shortening of track time, decreasing of heat loss of continuous cast bloom for hot direct rolling and development of automatic combustion control are necessary for saving of fuel consumption in soaking pit furnace.

Table 4.4.1 and Fig. 4.4.1 show the recent measure for saving of fuel consumption of unit of product and its effects and the changes of fuel consumption and track time in some blooming mills respectively.

Table 4.4.1 Measures for Reducing the Fuel Unit Consumption

Classification	Item	Contents	Effect
Reduction of track time	Reconsidering the standard solidification ratio (rimmed steel)	Reconsidering the standards using the central segregation survey results. (Some non-solidified rolling is made.)	5-10% reduced
	Reduction of the placement and cooling times (killed steel)	Reconsidering the placement time using the top segregation survey results. Concerning some high-class Si-Al killed steel, the cooling time is shortened by using the slow heat to prevent scars.	20-30%
Improvement of furnace operation method	A proper heating pattern is adopted	Especially for rimmed (capped) steel, the slow heat (heat raising by 2 stages,) utilizing the potential heat of ingot is adopted	10-40%
	Set temperature is reconsidered	Controlling the set temperature according to the kind of steel, size of steel ingot and track time. (Application of low-temperature rolling.)	8-15%
	Making the charge proper.	If charge varies with the kind of steel or furnace, the optimum hearth covering ratio is secured by mixed charge.	10-20%
Improvement of facilities	Provision of recuperator	Preheating air by the recovered waste gas heat.	7-20%
	Reduction of waste gas port	Improving the burning at the ingot bottom at the waste gas port side.	10%
	Control of air-fuel ratio.	Proper control of air-fuel ratio by introducing an oxygen analyser.	3-5%

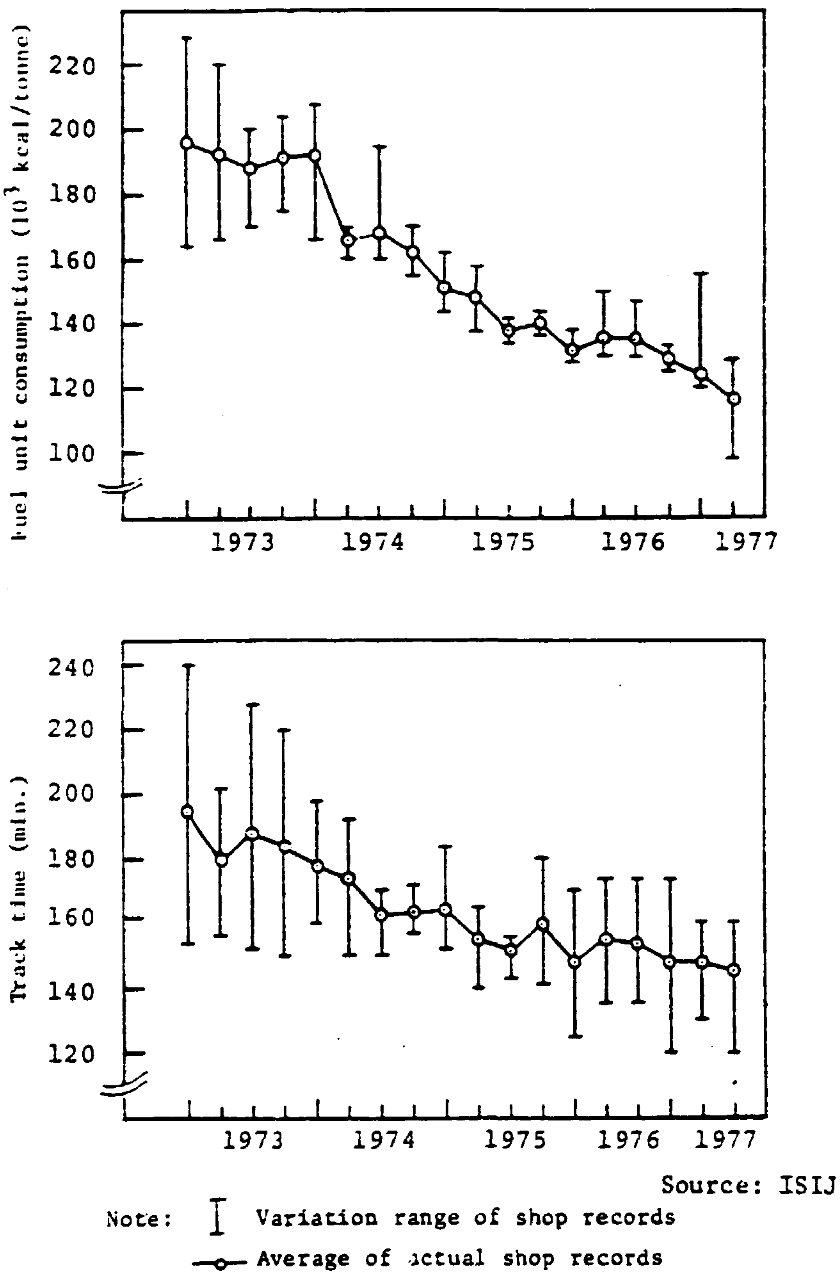


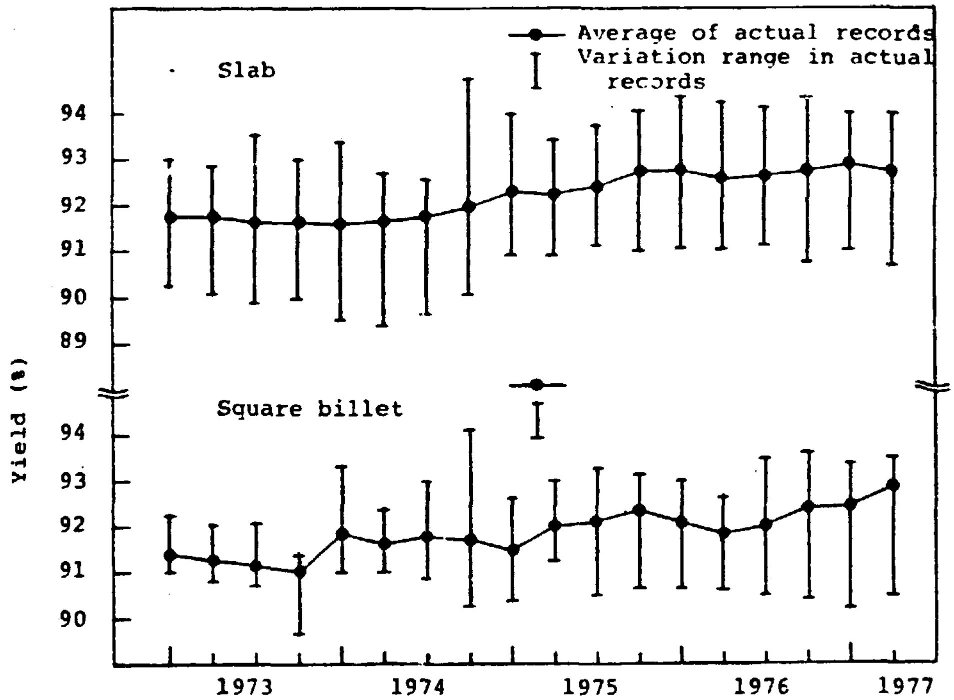
Fig. 4.4.1 Fuel Unit Consumption and Track Time of Rimmed Steel Ingot

(b) Improvement of blooming yield

The improvement on the scarfing method in a hot scarfer, the rolling schedule and the shape of steel ingot will much contribute to the improvement on blooming yield. Table 4.4.2 shows the measures and their effects, and Fig. 4.4.2 shows the transition of the improved yield.

Table 4.4.2 Measures for Improving the Yield

Item	Contents	Effects
Improvement of scarfing method	Defective parts only are scarfed by judging them in hot process.	0.3-0.4%
	The part with many defects is deeply scarfed, while one with few defects is shallowly scarfed. (Taper scarf)	0.4-0.5%
Improvement of rolling schedule	The edge rolling time in slab rolling is increased at the latter half of pass.	0.3-0.5%
	The rolling reduction is varied between even and odd passes.	0.3-0.4%
	Growth of fish tail is reduced by one way reduction.	1.0-2.0%
	Growth of fish tail is prevented by forming concaves on the material ends by roll.	1.0-1.5%
Improvement on the shape of steel ingot	Improvement of the well of ingot bottom.	0.7-1.0%
	Improvement of the ingot top shape.	0.5-0.7%
	Improvement of mold series to reduce the total rolling reduction in the steel ingot-to-slab process.	0.5-0.9%



Source: ISIJ

Fig. 4.4.2 Transition of Improved Yield

(c) Hot direct rolling

In the present advanced countries, hot direct rolling is actively conducted mainly on rimmed steel for the energy saving purpose.

Hot direct rolling does not need the reheating by heating furnace, and can save more than 200,000 kcal/tonne of energy, besides the fuel to keep the reheating furnace hot during rolling.

Further the scale loss due to reheating is reduced, and the yield is improved by about 1%.

Fig. 4.4.3 shows changes in the quantity of hot direct rolling and hot charge in Japan.

But in the hot direct rolling, it is first of all necessary that the blooming line and the product rolling line are directly connected with each other. The shops which rely mainly on continuous casting method are saving energies rather by charging hot continuous cast ingot or steel ingot in the reheating furnace.

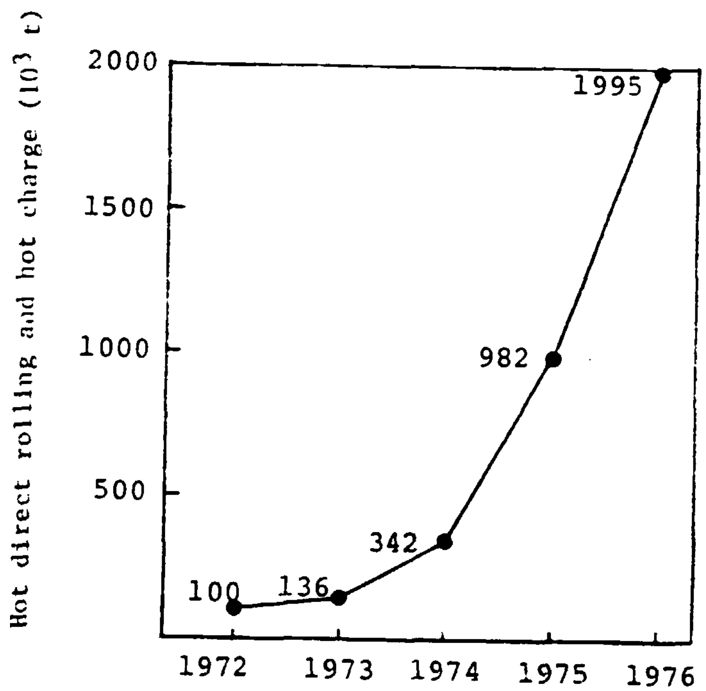


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Fig. 4.4.3 Changes in the Quantity of Hot Direct Rolling and Hot Charge in Japan

(d) Improvement on the surface quality

Killed steel and continuously cast ingot have defects on their surfaces, and are generally subject to machine scarfing. But recently the manufacture of cast steel with no defect is becoming possible as the quality of continuously cast material is improved, which has made possible the production of materials that need no surface conditioning, or direct rolling. On the other hand, the development of a hot defect detector for steel ingots is now also active from the standpoint of quality assurance or for making clear the steelmaking conditions and feedback to steelmaking. It is likely in future that the hot defect detection and a spot scarfing will be combined to reduce the scarf loss.

4.4.2 Plate Rolling

(1) General

The plate manufacturing industry has been growing together with shipbuilding and other heavy industries. Up to 1950's, the output of plates was monthly about 25,000 tonnes per mill by using 2-high mills or Lauth 3-high mills. In the latter half of 1950's, large-scale modern plate shops equipped with large-sized 4-high mills were constructed one after another to cope with the increasing demand, and the production scale has increased to more than 100,000 tonnes monthly in shops having a finishing mill, and more than 200,000 tonnes monthly in those equipped with each one finishing and roughing mill. The product size range has been expanded year by year, and shops have appeared which can produce 5.3 m wide and 36 m long superthick plates. Some of them can deal with heavy plates with a unit weight of more than 100 tonnes.

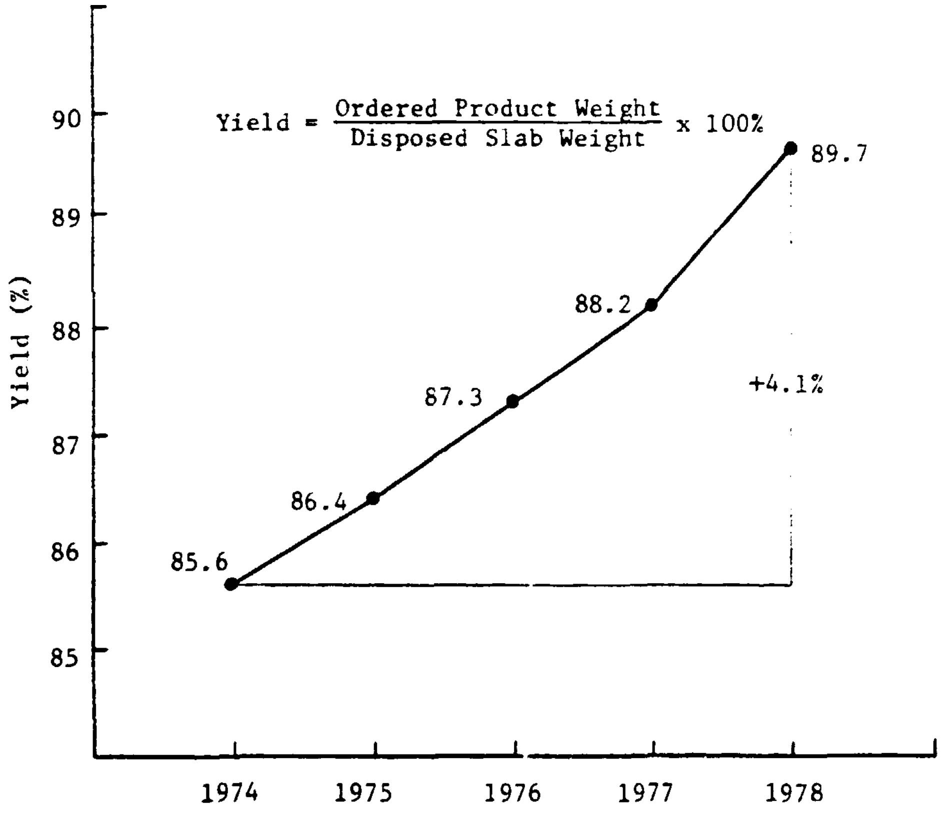
Besides enlarged production facilities and accelerated production speed, many labor-intensive works have been mechanized or automated. Further, full-scale computerization of the production, process and equipment control works has remarkably improved the productivity, almost doubled it these 10 years.

(2) Considerable increase of the yield

The gauge control technique in the rolling process has made a rapid progress. A grease hydraulic AGC (automatic gauge controls) has begun to be adopted in place of the existing electric type. This AGC is excellent in respondency and can be applied to the existing electric type mill. The thickness control method has now changed from the one to select the thickness at a point of the plate as the standard and reduce the longitudinal thickness variations at other points, into the one to control the thickness of the entire plate at a target value. Further automatic rolling by the use of a process computer has become popular, and the reduction schedule now includes also the control of plate crown and flatness, not to mention plate thickness, making it possible to obtain the plate thickness with smaller variation or deviation.

Efforts have recently been made to make the plane shape of plates (rectangularity) as square as possible using a rolling method which combines properly the plate thickness control at the rough rolling stage and the broadside rolling, in order to reduce crop loss and trim loss as far as possible.

The yield of plates has much been improved by the increase in the use of continuously cast high-quality slabs where the material size can freely be selected, and by the progress in the material design system.



Source: ISIJ

Fig. 4.4.4 Improvement on Yield of Plate Rolling

(3) Progress in the controlled rolling technique

Materials with low-temperature toughness and good weldability are demanded as the steel plate materials for line pipes to transport petroleum and gas to the arctic areas, for which demand has recently increased. The controlled rolling is a method which can reduce the carbon equivalent without making heat treatment and meet these requirements by the rolling process alone. It is also capable of mass production. Its main effects are to increase the material strength and lower the transition temperature by fining the transformation structure of material. The recrystallization process of austenite and its grain size after the recrystallization depend on the rolling temperature and draft. The grain size becomes finer as the rolling temperature lowers and the draft increases. Since ferrite grains are generated on the former grain border of austenite at the time of $\gamma \rightarrow \alpha$ transformation, the finer the austenite grain becomes, the more the ferrite nuclei are generated and the finer the grains are made after the transformation. In the actual controlled rolling operation, various operation factors are related with one another, and various different measures can be taken for the same purpose, as shown in Fig. 4.4.5. The main methods available are fine recrystallization of austenite, the processing at a lower temperature than the recrystallization temperature and the low-temperature heating for fining the early stage austenite.

In the production of large-diameter pipes, the material plates have become wider and a more than 5000-tonnes rolling load is required for making a strong screw-down at a low temperature. For this purpose, a gigantic mill having a width of 5,500 mm and equipped with 2 units of 8000 kw mill motors has recently been constructed. Further against the controlled rolling process of heating once and rolling once, has been developed and put into practical use a process of twice heating and twice rolling to present the rolling efficiency reduction due to waiting for the cooling of material in the course of rolling. Also the process of once heating and twice temperature adjusting, having a cooling device at the outlet side of the roughing mill, has been developed and put into practical use.

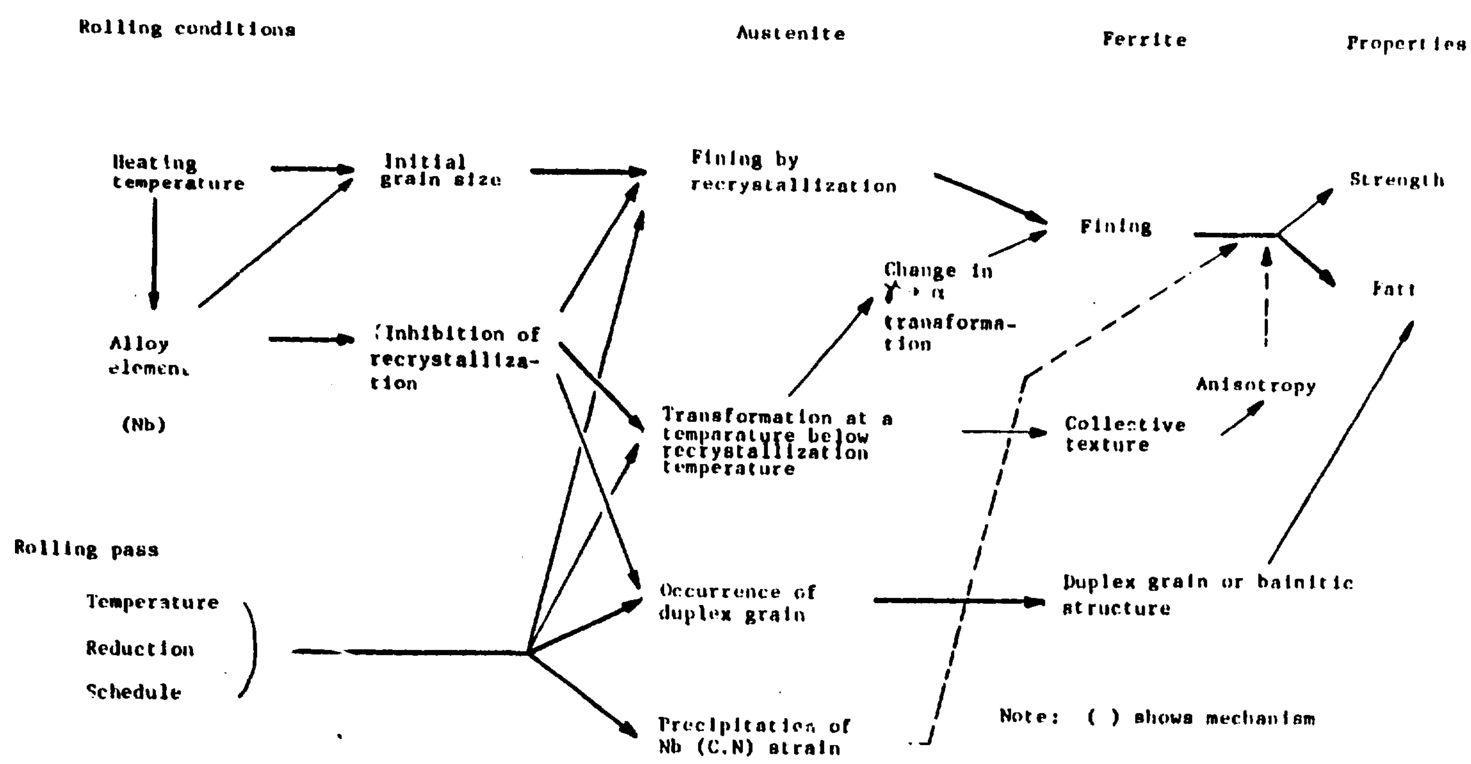


Fig. 4.4.5 Relationship between Various Factors in Controlled Rolling

Source: ISIJ

(4) Development of the accelerative cooling technique

(a) The accelerative cooling technique is to obtain steel plates equal or superior in quality to those produced from the existing off-line heat treatment, by rapidly cooling them right after the hot rolling process. Since if this technique is established, the heat treatment process can be omitted and many other merits such as energy and labor saving, saving of alloy elements, decrease of the steel grades produced and improvement of productivity can be expected, many manufacturers are endeavouring to develop this technique for its practical use.

(b) Continuous quenching system

Immersion quenching and press quenching methods have so far been used for steel plates. In the immersion quenching method, the cooling speed can not be made enough even if the cooling water in the water tank is stirred. In the press quenching method in which the cooling water is sprayed from spray nozzles over the steel plate fixed by the press boards provided on and under the table, the material parts around the legs of the boards are unevenly cooled, and further the cooling speed cannot be much accelerated because the volume of cooling water per area is limited as it has to be sprayed all over the plate at once in this method.

It is the continuous quenching method, the most typical of which is roller quenching that has been developed to improve these points. This is the method to continuously quench the heated steel plate by extracting it in succession by the roller table.
It can remarkably increase the cooling speed because the time from the extraction to quenching is short enough to prevent the lowering of steel plate temperature, and because the cooling zone is so small in area that a larger quantity of water can concentratively be used. As a result, it has made it possible to make very thick quench-temper steel plates. With its further merits that there is no limit on the length of steel plates to be quenched, that there can occur no uneven quenching, etc., this method has become the main force for quenching high-tensile strength steel plates today.

(5) Progress in the control by computer

The control by computer throughout the stages from order entry to the shipment of products has recently become indispensable for the plate manufacturers. Main functions of this computer system will be described below.

(a) The operation control information system

Every steel plate usually has a different size and specification, and there will easily take place confusion in each production process, not to mention the case of process and shipment control, unless the operation instructions are properly transmitted and the operation information is enough collected. It is important for the management of shops to put all the processes under the control of computer, give proper instructions timely, collect the accurate information and take the necessary steps instantly. This system helps simplify the operations, improve the efficiency, prevent errors, and cut down the number of necessary personnel for various control.
At the same time, it also functions effectively for the control of delivery time and product quality by collecting the actual production records and grasping the process conditions

and product quality information quickly and accurately.

The CRT (cathode ray tube) display system is adopted in many shops for giving the operation instructions or as the operator's input device.

Further this system is usually connected with the process control computer for the direct transmission of operation information necessary for the control of rolling mills and other various equipments.

(b) Process control system

This system is intended to save labor, raise the efficiency, improve the work precision and stabilize the product quality through the automatic operation of equipments. The control range has so far been limited to the surrounding equipments centering around the rolling mills, but recently almost all the equipments from reheating furnace to warehouses are being placed under the control of this system. Generally this system has the following functions.

i) Tracking control of slabs and steel plates
ii) Positioning control of each equipment
iii) Positioning control of slabs and steel plates

iv) Calculation of the rolling schedule of rolling mills

v) Data logging

In some newly constructed shops, these functions are combined with one another for realizing the full-automatic operations where the operators are only needed to supervise abnormal conditions, intervene at the critical points and make judgements. In the vicinity of the reheating furnace, a series of operations, i.e., the reception and transport of slabs — weighing — centering of slabs in front of the furnace — charging them in the furnace through the control of pusher stroke — transport within the furnace — determination of the discharging time — discharging — sending to rolling mills, are almost fully controlled by the computer. Further the reheating furnace calculations for combustion control according to the furnace conditions are increasingly controlled by a computer.

As for the equipments around rolling mills, the control of reduction schedule calculations has remarkably been developed. The rolling control can be divided into 3 stages; that of the rolling until the completion of broadside rolling, that of the final pass rolling where the plates with good flatness are rolled precisely according to the planned thickness, and that of a rolling process between these two. The three have different characteristics. The data of rolling pressure and temperature of each pass are used to calculate and set up a proper screw-down in the next pass. In the broadside rolling, an accurate and less variable screw-down is given to help the yield increase. In the intermediate rolling, the capacity of the rolling mill is fully utilized to reduce the pass number and improve the efficiency. In the final pass rolling, the optimum schedule for flatness and thickness precision is determined according to the width and thickness of each plate, which has a large effect on the improvement of efficiency and yield rate.

In the shear line, too, the inspection and marking/display equipments are being put under the control of process computer.

The full automation of a series of work processes including the automatic set-up of the equipments and the positioning in shearing, and also the control of automatic transport of steel plates between the equipments are made, which has led to the improved product precision and the accelerated line production speed.

4.4.3 Hot Strip Rolling

(1) General

In a hot strip mill, slabs with a thickness of 130-300 mm produced by continuous casting or ingot-slabbing mill route are heated in the reheating furnace, or charged in it as they are in hot condition. Then they are hot rolled by roughing and finishing mills into 1.0 mm - 25.4 mm thick strips, coiled by the coiler, and cooled. Then they are treated in various finishing lines such as skin pass mill, slitter, shear and become various hot-rolled products. The kinds of hot-rolled products covers a wide range normal carbon steel, low alloy steel, stainless steel and silicon steel.

Here will be described the equipments and new manufacturing techniques for the hot strip mill and their prospects in future.

(2) Improvement of productivity

(a) High-speed operation of rolling mill

(i) Roughing mill

Roughing mills have been changing from semi-continuous operation type into the full-continuous to cope with the increase in the slab unit weight and the rolling capacity, the necessity to secure the final rolling temperature and stabilize the product quality. Recently three-quarter (3/4) type rolling mills each consisting of one reverse mill and 2 or 3 non-reverse mills are becoming the mainstream, due to the appearance of a large-capacity motor (8000 kw/unit).

(ii) Finishing mill

The number of finishing roll stands has been increased from 6 to 7. The speed of the final finishing stand began to increase from about 1950 with the improvement on the rigidity of rolls, roll bearings and finishing stand, and the progress in the AGC and shape control techniques. It has recently reached 1500 m/min. (See Fig. 4.4.6)

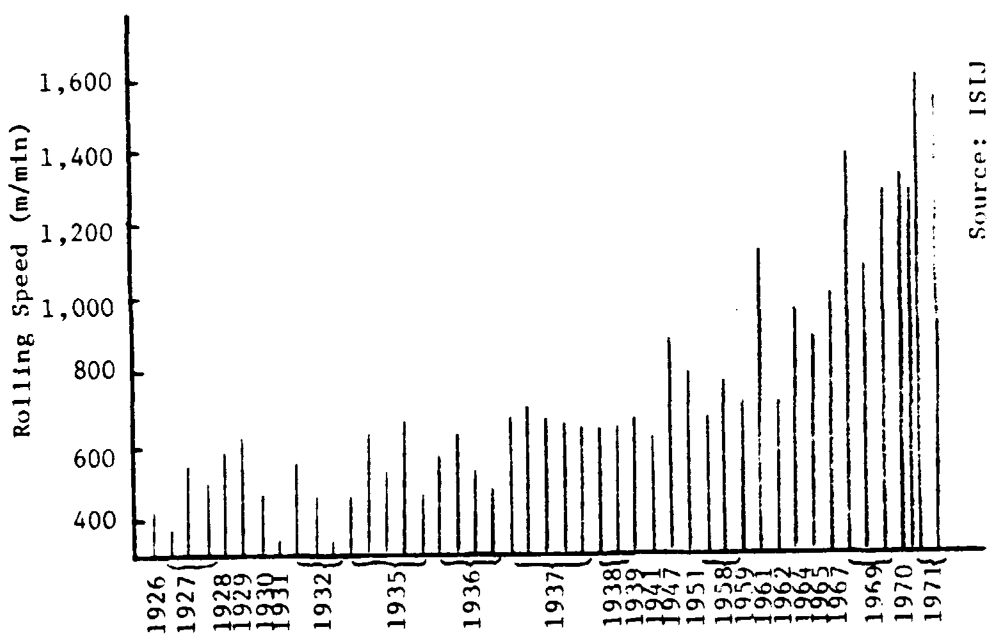
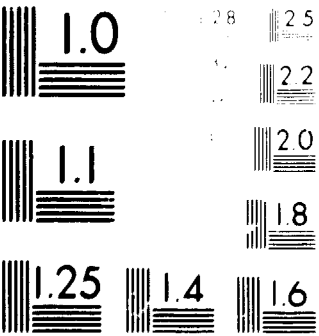


Fig. 4.4.6 Increase of Rolling Speed of Hot Strip Mill


1.0
2.8
2.5
2.2
2.0
1.1
1.8
1.25
1.4
1.6

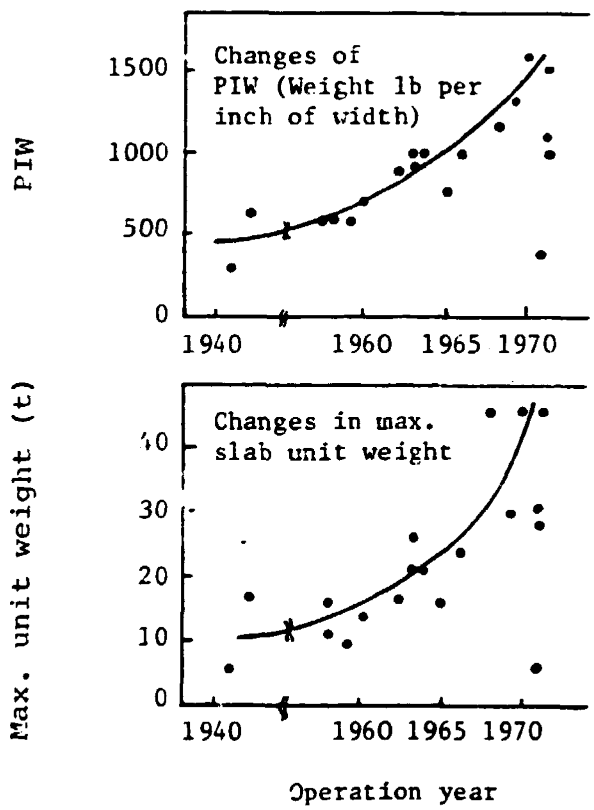
(b) Increase in the unit weight and enlargement in size of materials

The material unit weight has been increased and its size enlarged to improve the efficiency and yield rate.

The width of slab is determined depending on the width of strip coil.

The slab width is related with the edging width in respect to the edger capacity and width precision. Recently the edging capacity of edger has remarkably been strengthened.

The weight per inch of width of materials handled in the hot strip mill is expressed in terms of pound and called PIW (pound per inch of width). This is an index to determine the distance between roll stands, the outer diameter of coil, the width of reheating furnace, motor power and the max. thickness of slab in the equipment specifications. This index has changed as shown in Fig. 4.4.7 which suggests the recent trend toward larger-sized mills.



Source: ISIJ

Fig. 4.4.7 Changes in PIW and max. Slab Unit Weight

(3) The progress of hot rolling equipments

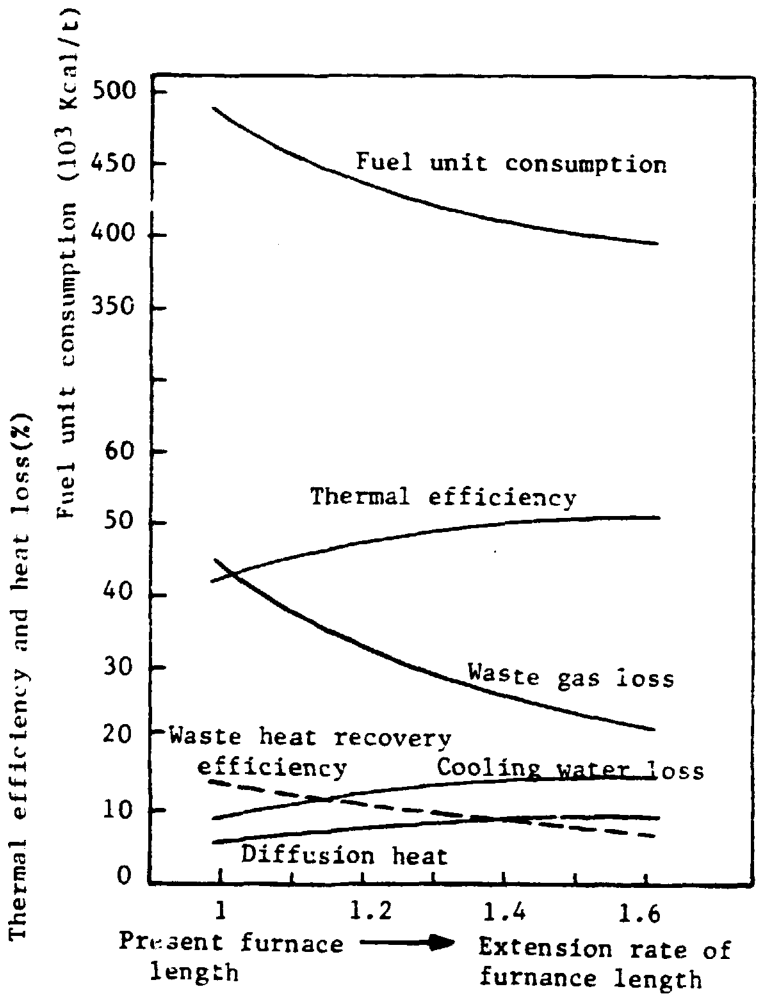
(a) Reheating furnace

Various energy saving measures are being taken reflecting the recent energy conditions.
The main measures are;

(i) Extension of furnace length

If the furnace length is increased, the heat exchange between slabs and combustion gas will be made enough and the temperature of waste gas at the furnace bottom lowers resulting in an improved thermal efficiency. On the other hand, cooling water loss and heat loss from the furnace wall increase, which restricts the extension of furnace length. (See Fig. 4.4.8)

In recently constructed furnaces, the furnace length is increased by about 20-30% compared with the existing furnaces.



Source: ISIJ

Fig. 4.4.8 Effect of Fuel Unit Consumption Reduction by Increasing the Furnance Length

(ii) Control of reheating furnace

The main controls in a reheating furnace are automatic combustion control (ACC), furnace pressure control and recuperator protection control. The ACC consists of the furnace temperature control, fuel flow rate control, upper and lower cascade control, air ratio control, heavy oil ratio control and automatic turn-down (burner thinned-out operation) in order to control the temperature with accuracy and maintain the combustion conditions.

The reheating furnaces which adopted these automatic combustion control have been increasing in number.

(iii) Double insulation of skid pipe

The skid pipe is remodeled from the former single insulation into double insulation using ceramic fibres to reduce cooling water loss heat. This method is very useful for preventing the increasing tendency of cooling water loss heat due to the recent enlargement of furnace size and adoption of walking beam furnaces.

(b) Crop shear

A flying crop shear for hot strip mill is provided at the entry side of a finishing mill and used for cropping of the front and rear ends of materials rolled by a roughing mill in order to pass them smoothly through the finishing mill, and prevent the occurrence of cobble and tail marks (hollows on the roll made by biting of material at low temperature).

Crop shears are generally classified into such 3 types as drum type, crank type and swing type. The most popular drum-type has circular track blades. It is easy to maintain due to its simple structure compared with other types.

Recently crop shears with a large capacity have appeared as rough bars before finishing train were increased in thickness and thus relatively decreased in surface area for the purpose of reducing the heat diffusion for saving energy and reducing the secondary scales for improving the yield. The shearing ability of recent drum-type crop shears have reached 600 tonnes in terms of cutting force, while crank types with the max. cutting force of 1200 tonnes and the swing types with the max. 2000 tonnes cutting force have started to operate.

(c) Hydraulic mill

The invention of hydraulic screw-down devices has made a great contribution to accelerating the operation speed of rolling equipments and improving the product quality and yield. The hydraulic mill was first adopted in a reversing type cold rolling mill and later fully adopted in a tandem type cold rolling mill. Recently it has begun to be used in hot strip mills and plate mills.

This hydraulic mill is characterized by quick response, high-precision roll positioning control and mill modulus variable control. The acceleration and deceleration compensation control, roll eccentricity compensation control and tension control by screw down which had some problems under the electromotive screw-down device have become able to be smoothly made in this mill.

(d) Width control

The adoption of AWC (automatic width control) was studied for each of roughing and finishing processes, and the system has partially begun to be put into practical use to improve the width precision.

(e) Looper

Low-inertia electrically driven loopers and highly respondent hydraulic loopers have been developed to cope with high-speed mills and further improve the width precision.

(f) Dimensional control

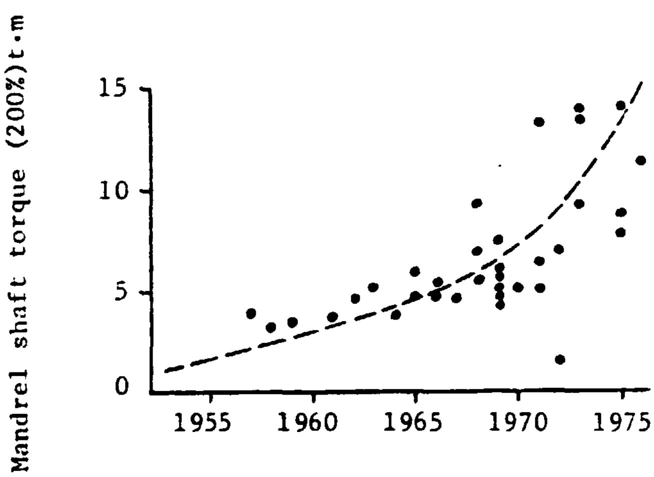
A roll bending device has been put into practical use for the shape and crown control. To obtain larger control effects, have been developed and put into practical use the method to shift the intermediate rolls in a 6-high mill, and the method to hydraulically swell the back-up roll to control the roll crown.

(g) Coiler

(i) Heavy-duty down coiler

The upper limit of strip thickness in hot strip mills depends mainly on the capacity of coiler. It is expressed by the torque on the mandrell shaft. Fig. 4.4.9 shows changes in the coiler capacity. It has been increased year by year, and in 1968, a 9.4 tonnes-m coiler appeared and the max. 19 mm thick strip became possible to be coiled by this coiler.

Later the demand for high-tension steel strip such as line pipe materials increased and heavy-duty down coilers with the mandrel shaft torque of more than 13 tonnes-m have appeared since 1971. This coiler in low-carbon steel can coil the max. 25.4 mm thick strip, and has considerably expanded the range of product in hot strip mills.



Source: ISIJ

Fig. 4.4.9 Changes in the Coiling Capacity of Coiler

(ii) Top end markless coiler

The coiler coils a strip synchronously with the speed of the finishing stand, so a large impact occurs from the first through several wraps of the coil.

When the strip wrap enteres the second wrap, there occurs a difference in level on the coil by the thickness of the strip. This level difference together with the above mentioned large impact causes a hollow called the top end mark on the surface of the 2nd wrap.

This defect is cut off in the finishing process, which reduces the yield.

A hydraulic-controlled mechanism was recently developed to make up for the level difference of strip thickness between the 1st and 2nd wrap of strip by controlling the positions of the blocker roll or the wrapper roll for coiling the strip around the mandrel. This coiler is called a top end markless coiler, which is actually used in several mills.

(4) Manufacturing technique

(a) Hot direct rolling (H.D.R.)

This is a method where slabs after slabbing are not cooled, but directly rolled by a hot strip mill. It is very effective for saving energy as it can omit the reheating furnace process. The precondition for this method is that the slabbing mill is directly connected with the hot strip mill. Further the countermeasures to surface defects and the control of continuous process operation are necessary.

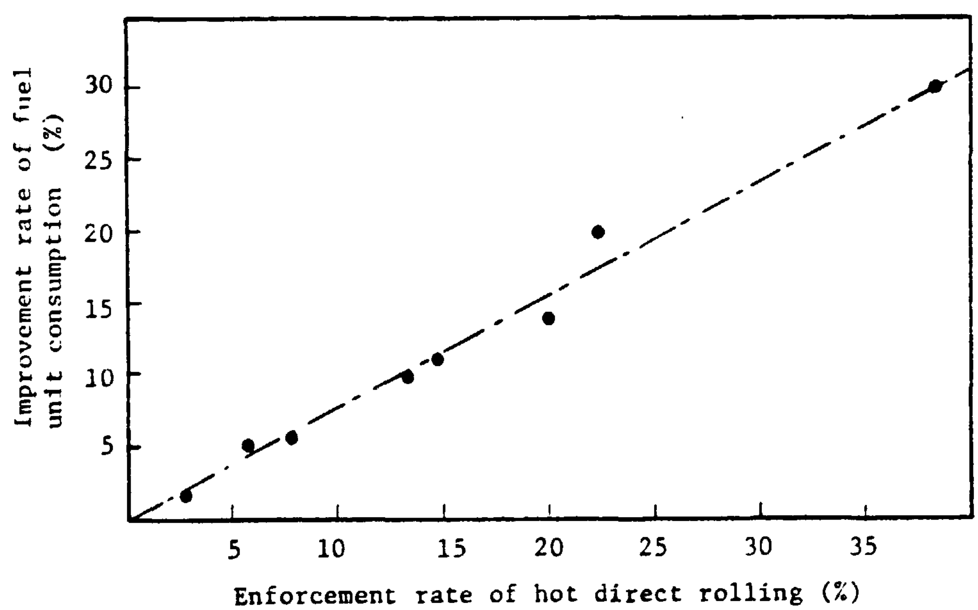
(i) Slab temperature change at the H.D.R.

The temperature of materials at the end of slabbing process is fairly lower than the temperature of the reheated materials when it is discharged from the reheating furnace. But the temperature of ingot for H.D.R. when it is discharged from soaking pit is actually about 10-30°C higher than that of the reheated material, because a recovery of heat occurs during the rough rolling operation.

(ii) Effects of hot direct rolling

The fuel unit cost can considerably be

reduced by the adoption of hot direct rolling. Fig. 4.4.10 shows the relationship between the enforcement rate of hot direct rolling and the improvement rate of fuel unit consumption.



Source: ISIJ

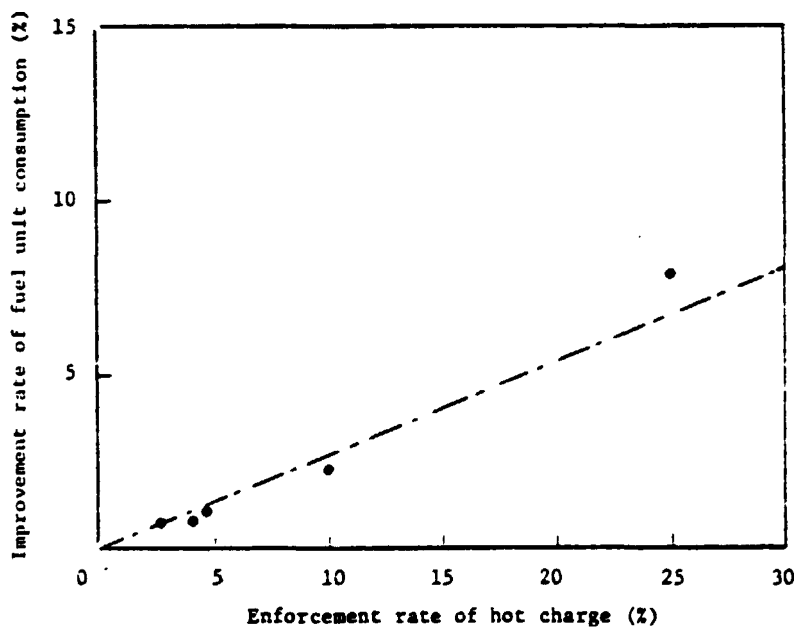
Fig. 4.4.10 Relationship between the Enforcement Rate of Hot Direct Rolling and the Improvement Rate of Fuel Unit Consumption

(b) Hot charge

This is a method in which the slabs after continuous casting or slabbing are not cooled, but charged in the reheating furnace as they are in the hot condition, so as to reduce the fuel consumption in the furnace.

Actually, are needed careful countermeasures to prevent defects and the consistent process control throughout steel making, continuous casting, slabbing and hot strip rolling processes.

Fig. 4.4.11 shows the relationship between the enforcement rate of hot charge and the reduction rate of fuel unit consumption.



Source: ISIJ

Fig. 4.4.11 Relationship between Enforcement Rate of Hot Charge and the Improvement Rate of Fuel Unit Consumption

4.4.4 Cold Rolling Mill

(1) General

Cold rolled products are made from hot-rolled coil passing through such processes as cooling, pickling, cold rolling, annealing, and finishing line.

Cold-rolled steel sheets, as compared with hot-rolled ones, are thinner and have greater dimentional accuracy, smoother surface, higher flatness, and a wider range of applicability for working.

Apart from the so-called cold-rolled steel sheets there are many other cold-rolled products such as low yield point steel sheets, very deep drawing steel sheets, enameling steel sheets, corrosion- and weather-resistant steel sheets, low-grade electro-magnetic steel sheets, high-tensile strength steel, and embossing steel sheets.

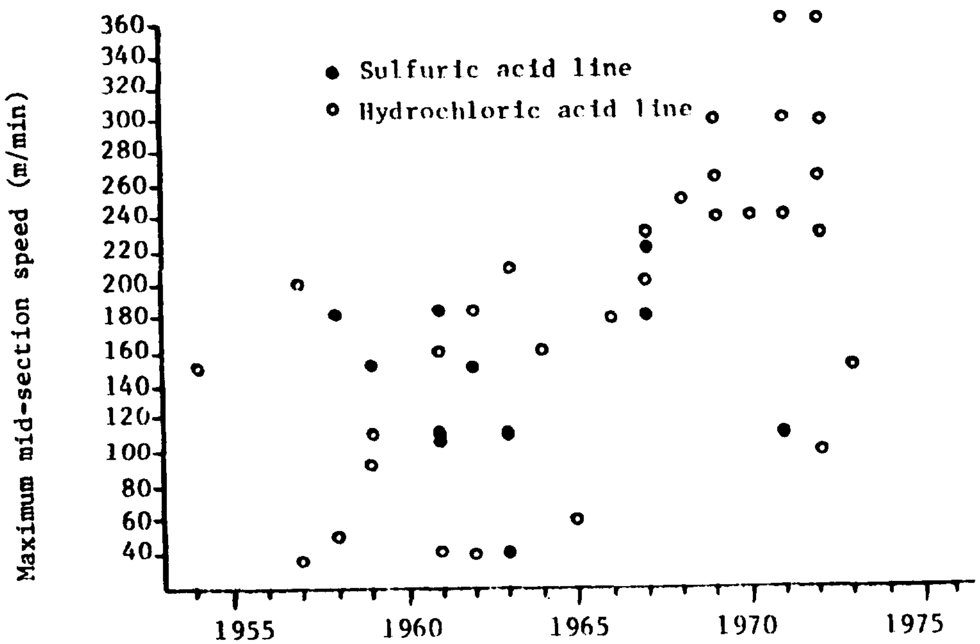
Here will be described the cold-rolling mill facilities and related manufacturing techniques and their future prospects.

(2) High-speed pickling

The use of hydrochloric acid in the large pickling line has rapidly increased since the coming into operation of the horizontal pickling line combined with hydrochloric acid recovering facility. Since its advent, various improvements have been incorporated in the pickling line, thus making remarkable advances such as increased speed and working efficiency automation, labor saving, and environmental improvements. Nowadays there are so large pickling lines capable of handling more than 120,000 tonnes of steel material a month.

(a) Increased speed, automation and labor-saving

The changes in the mid-section speed of the pickling lines in the past are shown in Fig. 4.4.12. Since 1965, the increase in the speed has been greatly accelerated and recently it has reached 360 m/min. This is due to the introduction of various new technologies such as the increase in the descaling speed by the use of hydrochloric acid, increased size of pickling tanks to handle greater amounts of strips at one time, improvements in steel sheet feeding equipment and cut ends disposing equipment, and automation of welding machines.



Source: ISIJ

Fig. 4.4.12 Changes in the Mid-section Speed of Pickling Lines

(b) Scale breaker

The use of scale breakers has sometimes been omitted in hydrochloric acid pickling. Recently, however, the effectiveness of scale breakers has been recognized anew and there is an increasing tendency of using the secondary scale breakers in pickling. This is effective in making up for the decrease in the descaling efficiency resulting from the increased high-temperature steel sheets to be coiled up.

Scale breaking is achieved by giving strains to the surfaces of strips.

From the standpoint of scale breaking effectiveness, the bending and stretching method and the skinpass method are commonly used.

In general the effect of scale breaker is responsible for about 10% increase in the pickling speed.

On the other hand the mechanical descaling method using no acid has also been developed and is now entering the stage of practical utilization.

(c) Spray cleaning cascade rinse system

The pickled strip is cleaned with water at the exit of the pickling tank. As a result of the increased pickling speed, the amount of water used for this purpose has so increased that there are some pickling lines which use water at the rate exceeding 100 m^3/h. In order to conserve the water by reusing it, the cascade method has been used.

In this method, the amount of water which is supplied into the final tank is so small as about 10 m^3/h. The density of the waste water after rinsing which overflows No. 1 tank is increased up to about 80 g/m^3 of iron and 2% acid, thus making it possible to recover the acid.

(3) Full continuous cold rolling mill

The world's first 5-tandem full continuous cold rolling mill for low carbon steel which is able to continuously roll the coils of different sizes was completed in 1971.

The continuous rolling mill is high in cost but has many outstanding merits in productivity, yield, product quality, and labour cost.

(a) Equipment configuration

The full continuous rolling mill system resembles a continuous process like the pickling line.

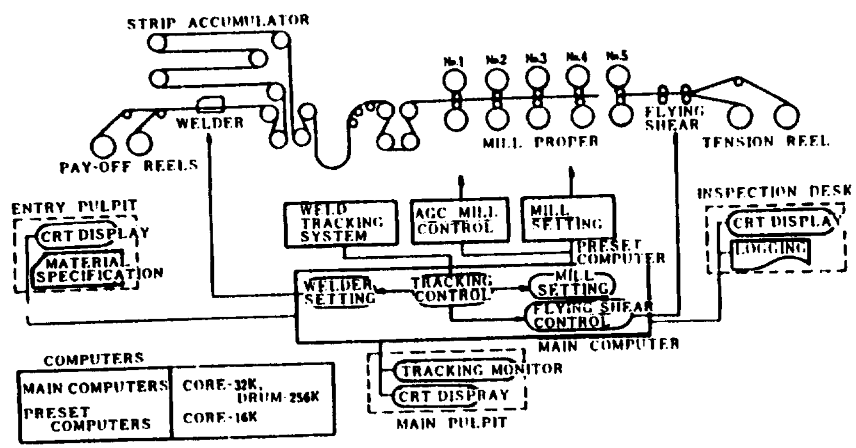
As for the inlet equipment, the accumulator of the loop car type is provided to enable the continuous rolling operation even when the strip is stopped for welding.

At the entrance to the rolling mill, the strip is tensioned by the bridle rolls. In order to prevent slippage, the strip is not coated with oil.

Since the welding section is a place where the end of a coil comes and also an important position where the change in the sheet thickness is controlled, the magnetic (permeability differences) system or magnetic mark type detector is located here.

(b) Computer control

The computer control system has been introduced to take the place of the previous manual control and feedback control and is very effectively working in the improvement of rolling technology, particularly in the completely continuous rolling mill system, the configuration of which is shown in Fig. 4.4.13.



Source: ISIJ

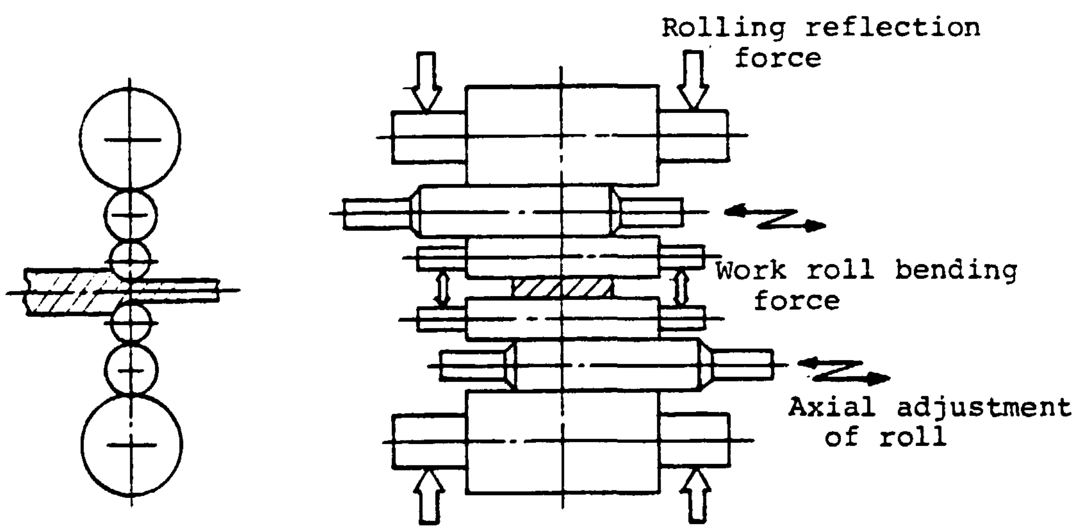
Fig. 4.4.13 Full Continuous Cold Rolling Mill Equipment and System Configuration

The changing technology of sheet thickness during movement is a technology to change the pass schedule during rolling and the most important function of the computer. This technology is required to perform a dynamic and time-series change operation accurately as calculated beforehand.

(4) 6-high mill

In the most common type of 4-high rolling mill, excessive bending moment acts on the work rolls outside the width of the sheet being rolled, thus so much increasing the deflection in the rolls. Since the restraints of the backup rolls extend up to near the ends of the work rolls, the effect of roll bending force is not sufficiently transmitted to the center of the rolls. In order to solve this problem, 6-high rolling mill has been devised.

(a) As shown in Fig. 4.4.14 this 6-high rolling mill has work rolls and backup rolls and between them are intermediate rolls which move in the axial direction so that their ends may be adjusted to match the width of the sheet to be rolled. Since the work rolls are kept out of contact with the backup rolls in this way, outside the width of the sheet, they are less influenced by the bending moments at the ends of the backup rolls and as a result the bending of the work rolls is so much reduced, thus making it possible to produce a better shape of the rolled sheet and to so much increase the effectiveness of work roll bending so that a flat shape may be obtained for varying sheet width with the roll's initial crown being zero.



Source: ISIJ

Fig. 4.4.14 Construction of 6-High Rolling Mill

(b) Characteristics and effects of 6-high rolling mill

As compared with 4-high rolling mill, the 6-high rolling mill has various outstanding characteristic features such as the ability to roll the sheet under very strong force, reduction in the diameter of work rolls, elimination of the initial crown, and reduction in edge drop. This system is already put to practical use in cold tandem mills and skinpass mills and its application to hot strip mills is being studied.

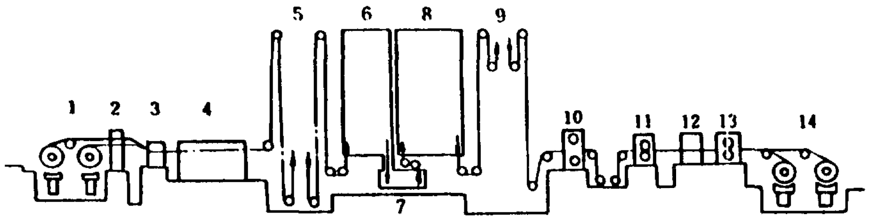
(5) Continuous annealing equipment

The production of deep drawing steel sheets for press work on the parts of automobiles, household electrical appliances and so forth required many highly complicated and time-consuming stage of processing following cold rolling such as electrolytic cleaning, batch annealing, coil cooling, skinpass rolling, and finishing.

Of such operations, the inefficient batch annealing has already been made continuous in such applications as the production of tinplates, galvanized steel sheets and the like for which not much workability is required. However, it has been delayed in the production of cold-rolled steel sheets for which deep drawability is required because of metallurgical restrictions such as the very rapid heating required for continuous annealing and the hardening of the material due to rapid cooling and also because of the equipment technical restriction that the above five processes which are independent and different in nature from one another could be linked together in a simple manner. It is the continuous annealing equipment that has solved these two difficult problems above and successfully linked together the five processes from the electrolytic cleaning process through finishing process.

(a) Outline of continuous annealing equipment

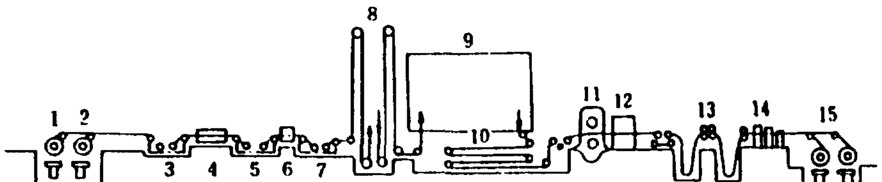
Fig. 4.4.15 shows a typical configuration of the continuous annealing system. It can be roughly divided into electrolytic cleaning section, furnace, skinpass roll, and inspection and finishing equipment from the inlet side in that order.



(a) NKK-CAL

1. No. 1 and No. 2 pay-off reels
2. Double cut shear
3. Welder
4. Electrolytic cleaning tank
5. Inlet looping Tower
6. Recrystallization annealing furnace
7. Quenching equipment
8. Over aging furnace
9. Outlet looping tower
10. Skinpass rolling mill
11. Side trimmer
12. Oiler
13. Drum shear
14. No. 1 and No. 2 tension reels

(a) NKK-CAL



(b) NSC-CAPL

1. No. 1 pay-off reel
2. No. 2 pay-off reel
3. Hot caustic tank
4. No. 1 Scrubber
5. Electrolytic tank
6. No. 2 Scrubber
7. Rinse tank
8. Inlet-looping tower
9. Continuous furnace
10. Outlet-side loop car
11. Skinpass rolling mill
12. Tension leveler
13. Side trimmer
14. Oiler
15. No. 1 and No. 2 tension reels

(b) NSC-CAPL

Fig. 4.4.15 Configuration of Continuous Annealing System

Source: ISIJ

The furnace section consists of the heating zone with radiation heating tubes, electric resistance soaking zone, primary cooling zone, over aging zone with electric resistance heating or radiation tube heating, and secondary cooling zone. In the over aging process, in order to precipitate carbide in solid solution, the steel material is first quenched to below 500°C to achieve the oversaturation of carbon solid solution and then heated at 300 to 400°C to precipitate carbide.

The difference between the two systems lies in the quenching system in the secondary cooling, that is, NSC-CAPL system uses the gas jet cooling system and NKK-CAL employs water quenching method.

(b) Evaluation of continuous annealing equipment

The continuous annealing technology is characterized by the integration of the five processes from electrolytic cleaning following cold rolling to finishing line in an attempt to achieve a thoroughgoing rationalization of the annealing process for cold rolled steel sheets. Fig. 4.4.16 shows the comparison of the continuous method with the conventional method, from which it is seen that the continuous method has greatly saved labor, energy and cost.

The heat cycle of continuous annealing system has very flexible characteristics such as that the rapid heating method is employed and the heating temperature and cooling speed can be selected over a considerably wide range and as a result there is the hope for the development of new products such as high tensile strength steel sheets.

Item	Contents
Required number of days (from after cold rolling to the final finished product)	A 100% 10 days B 10% 1 day (10 minutes in net)
Required personnel	A 100% B 27%
Land space requirements	A 100% B 40%
Equipment Cost (not including land cost)	A 100% B 74%
Yield loss	A 100% B 52%
Energy	A 100% B 81%

Note
A: Conventional method
B: CAPL process

Source: ISIJ

Fig. 4.4.16 The Merits of the Continuous Annealing Method (NSC-CAPL) Compared with the Conventional Method (Batch Annealing)

(6) Hydrostatic tension leveler

Thin steel sheet such as tin plates and tin-free steel sheets tend to become more and more thin. There are growing demands for more complex shapes and higher quality of such thin steel products and as a result it is now common practice to correct their shapes by means of tension levelers.

The conventional tension leveler gives a high tension to the strip by means of the tension bridle rolls at the inlet and out let sides and gives an elongation to it to correct its shape. This system, however, has a shortcoming that its shape correcting ability decreases as the steel sheet to be handled becomes thinner.

The newly developed hydrostatic tension leveler uses the hydrostatic pressure of a fluid to support and float the steel sheet and correct its shape by repeatedly bending it, thereby solving the various problems involved in the previously used method.

The hydrostatic tension leveler has the following advantages:

(a) As compared with the conventional roller leveler, the continuous system makes it possible to reduce the radius of bending to be given to the steel sheet and to reduce the tension of the steel sheet necessary for correcting the shape.

(b) The correcting heads and the steel sheet are separated from each other by a fluid, thus making it possible to increase the speed of the leveller and also causing less damage to the rollers.

4.4.5 Shape Steel

(1) General

The shape steel manufacturing technology, like other technologies, has made advances such as the increase in the scale of equipment, integration of various processing operations, increase in speed, automation, and production of products with high value added. The technological advances achieved specially in the manufacture of shape steel are as follows:

(i) Tandem rolling of shape steel

(ii) Rolling of hot billets

(iii) Production of shape steel by universal mill

(iv) Computer control of shape rolling operations

(v) Progress in finishing techniques

Advances of particular importance are automation and integration of operations. The following will concern the above-mentioned five items and future prospects.

(2) Tandem rolling operations

The continuous tandem rolling system has the following advantageous features:

(a) Highly efficient rolling is made possible to greatly increase productivity.

(b) The rolling conditions change so little that the finished products have so much improved dimensional accuracy.

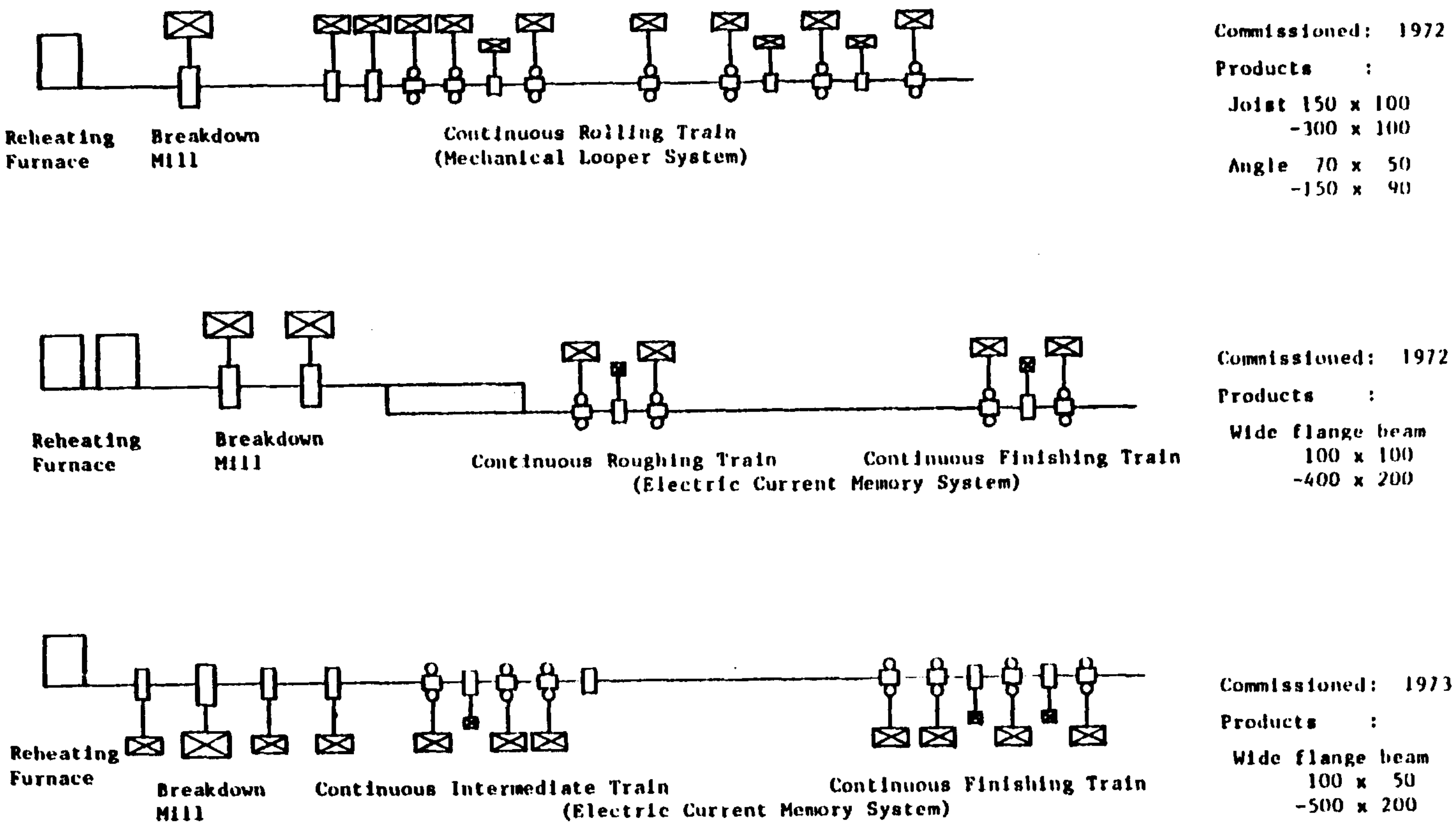
(c) The finishing temperature is so high that thinner sheets can be rolled. For these reasons, this is the most effective system for enhancing productivity. In order to carry out continuous rolling of shape steel, however, it is necessary to assure accurate control of the material running speed from stand. In the rolling of large sections, it is difficult to employ the loop rolling technology which is used in the rolling of wire rods and bars of smaller cross-sectional area. The occurrence of tension or/and compressive force between the stands would cause cobble and damage to the rolling equipment and also greatly affect the dimentional variations of the finished products. Thus, it becomes necessary to have an adequate system to control the speed at which the material is advanced so that the tension which is produced when there arises an imbalance in speed between two adjacent stands may be zero or minimized.

Table 4.4.3 shows a comparison of different tension controlling methods.

These methods have overcome the various technical difficulties associated with the continuous rolling of shape steel and are now put to practical use. Fig. 4.4.17 shows the typical layout of continuous shape rolling mills.

Table 4.4.3 Comparison of Different Tension Controlling Methods

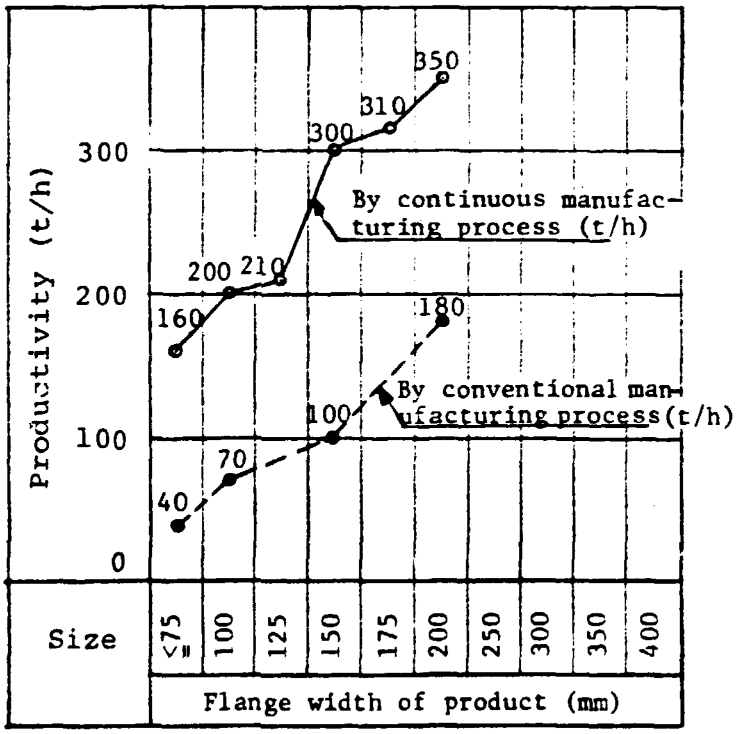
Mechanical looper	Control by tension between adjacent stands	Control by measuring roll	Electric current memory system
A loop is made of the material being rolled between the stands and the amount of the loop is detected by the looper, thereby to control the mill speed.	The tension of the material being rolled between the stands is detected by the press ductor, thereby to control the mill speed. (The stand is placed on the pendulums which defect by the tension.)	The speed of the material being rolled is measured by measuring rolls and the value of the tension is detected in terms of the changes in the speed of the material, thereby to control the mill speed.	The valve of the current of the mill motor is measured so that the value of tension may be detected in terms of the changes in the valve of current, thereby to control the mill speed.
1. This method is used when the flange width is less than 125mm. If the flange width is larger, it is difficult to form a loop. 2. When a loop is formed, the finished product may have defects such as deformed webs and the like.	1. When there are a wide range of sizes, two or more different kinds of pendulums must be changed according to the size of the material to be handled. 2. The tension detectability will be less accurate when there are more than three stands.	1. It is practically difficult to properly maintain the accuracy of many measuring rolls.	1. Of the changes in the current, there are those which are caused by tension and those which are due to the changes in the rolling load (temperature changes). The accuracy will decrease when the latter is larger.



Source: ISIJ

Fig. 4.4.17 Typical Layout of Continuous Shape Rolling Mills

The introduction of a continuous rolling system like this makes it possible to achieve so that a productivity nearly three times greater than that by the conventional system as shown in Fig. 4.4.18. It is predicted that advances will be made in the systematization technology for the integration of this system.



Source: ISIJ

Fig. 4.4.18 Sizes of Wide Flange Beams and Production Efficiency for Respective Sizes

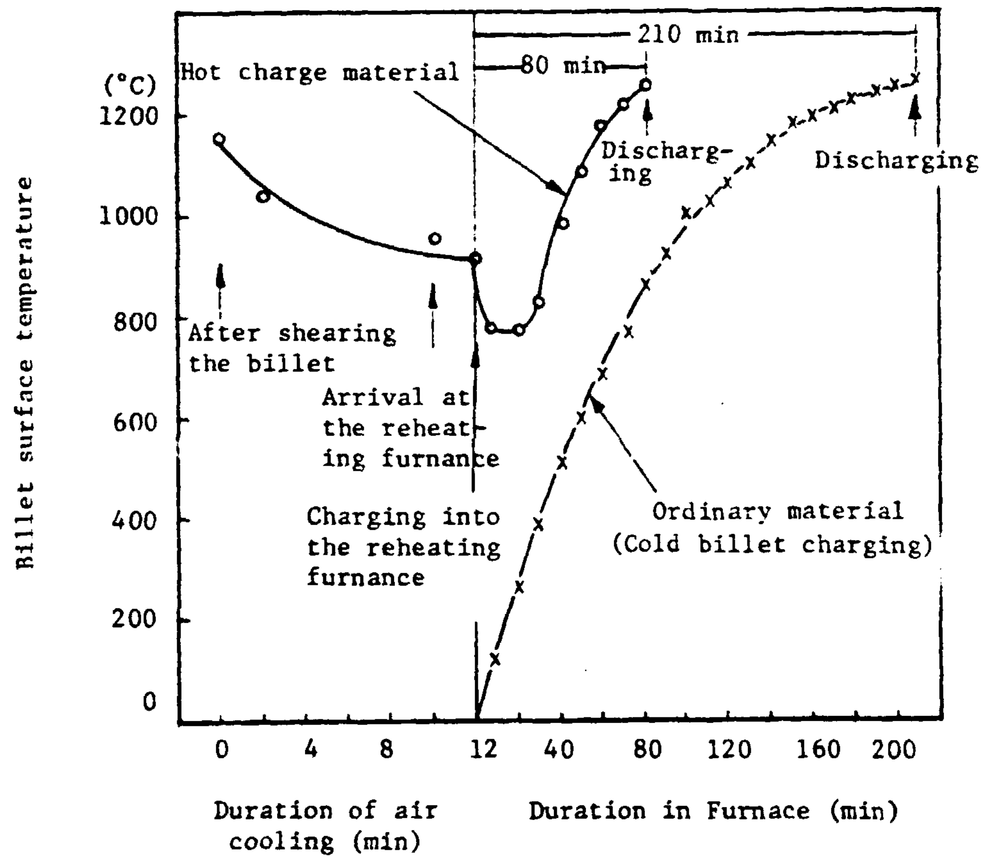
(3) Hot charge and direct rolling technology

Due to the recent rise in energy prices and advances made in shape rolling-related technologies, a rapid progress has been made in the practical application of hot charging and direct rolling technology. The problems involved in this process are the prevention of product defects and information processing. As for the former problems in particular, if adequate defects preventive measures are not taken in the stage of steelmaking and blooming, there is the damager of the hot billet rolling process's own merits being lost. The merits and demerits of hot charge applications are given in Table 4.4.4. A typical temperature change of hot charged material is shown in Fig. 4.4.19. From this figure, such merits of this system can be pointed out as the reduced time of heating in furnace, reduced number of reheating furnaces in operation, and increased rolling productivity.

Table 4.4.4 Merits and Demerits of the Use of Hot Charging

Factory	Merit	Demerit
Steelmaking		1. Increased cost due to the improved deoxidation method. 2. Increased cost due to the improved ingot-making method.
Blooming	1. Increased yield due to the reduction in the defects correction for the material being rolled. 2. Reduced cost of defects removing for the material being rolled.	1. Decreased yield due to hot scarf (0.6%)
Large-scale	1. Increase in yield due to the reduced scale loss (1.5% up when combined with the increase in yield due to reduced material defects removing). 2. Improvement of fuel consumption per unit of product (240 x 10^3 kcal/t).	1. Decreased yield due to surface defects (0.04%). 2. Increased cost of surface defects removing (2.0%). 3. Increased percentage of products out of orders (Improvement can be made by the on-line operation of sawing programme).

Note: The figures in brackets were obtained from actual operations at a certain steelworks.



Source: ISIJ

Fig. 4.4.19 A Comparison of Hot Charge Material and Ordinary Material (Wide flange beam 300 x 300)

In order to achieve further energy conservation, in addition to the low-load operation of furnaces, further advances are expected for the shape steel making technology aimed at the minimization of total energy consumption taking into consideration the electric power requirement per unit of products.

(4) Production of shape steel by the universal mill process

Most of the recent shape steel rolling mills are aimed at making wide flange beams by the universal process but some of them have to be used for the rolling of other types of product such as rails, steel sheet piles, and angle steel. These products are usually groove-rolled by 2-Hi rolling mills. Efforts have been made to apply the universal process to such shape rolling operations with a view to improving the internal quality of the product by the forge strengthening of the flanges which is an advantage of the universal process and also to stabilizing the rolling operations and improving the dimensional accuracy of the product by the increased freedom of roll adjustments. Since 1970, the universal rolling process has been used for the production rails at a certain steelworks, where the same process is also used for the intermediate rolling operations for the production of U-type steel sheet piles.

Here horizontal and vertical rolls are used for forming the joint without putting undue strain on the material, thus achieving the following advantageous effects:

(i) The forging effect for the flanges are sufficient to make it possible to obtain good products.

(ii) The rolling force from above and below and also from both sides can be adjusted properly to assure great improvement in the demensional accuracy of the product.

(iii) The wear of the rolls has been reduced.

In addition to the above, great improvements have been made in rolling efficiency and hield. There is no necessity for shape rolling to be carried out entirely by the use of the universal process but it is likely that the universal process will be increasingly introduced in some of shape rolling operations.

(5) Computer control technology for shape rolling

Steel shapes, as compared with steel sheets, are so complex-shaped and the rolling deformations are so diverse that the shape rolling involves many factors which influence the shape and dimensions of the finished product and therefore there have been many problems to be solved before the realization of automation of the shape rolling operations. In introducing the computer control system for the rolling of shape steel, it was necessary to do the following things:

(i) Development of such sensors for accurate detection of rolling conditions, as load cell, thermometer, length meter, roll gap meter, thickness meter, and width meter.

(ii) Accumulation and analysis of rolling data for the development of estimation formulas for rolling load, rolling power, temperature, and forward slip.

(iii) Preparation of control model and its application in practical use.

This technology is expected to make further developments along with the advances being made in instrumentation technology.

(6) Advances in Finishing Technology

The mechanization and automation of the finishing operations have been difficult to achieve because a large number of workers are required for processing the rolled shapes one by one in so many operations such as straightening, inspection, labeling, bundling, and conditioning.

In order to cope with the increased productively due to the integration of rolling operations, it is necessary to increase the capacity of the finishing line following the cooling operation and efforts have been made also for increasing the efficiencies of sawing and straightening equipment and for speeding up the material transporting equipment. There are many modern steelworks where two or four finishing lines are operated for one rolling line to have a balanced production capacity.

(a) Increased length of cooling and straightening operations

The straightening operation, except for large wide flange beams, has mostly been carried out by means of variable-pitch cantilever roller-type straighteners.

However, there is a drawback to this type of straightener that the front and rear ends of the rolled material cannot be straightened fully as long as the length of the roller pitch. Thus, the cooling and straightening equipment capable of handling material as long as possible are now used in many steelworks such as Topy Industry and Kimitsu Steelworks of Nippon Steel Corporation in Japan, U.S. Steel, South Chicago, and Cockerill in Belgium.

(b) Increased efficiency of cutting operations

The cutting methods are of two types - cold cutting method and the hot cutting method in which the material is cut before cooling. The hot cutting method has long been in use. Due to the temperature differences between the earlier and later products, it was difficult to cut many products at one time and therefore special consideration has been given to the arrangement of the sawing machines to match the increased efficiencies of rolling. At a certain medium-size factory for instance, they use one top cut saw, two fixed saws, and one moving saw to cut products of 120 m in as-rolled length into length of 10 to 15 m in 90 to 120 seconds.

In cold cutting the cutting time is longer than in hot cutting but many products can be cut at one time. At a Japanese modern large steelworks, three sawing machines are capable of production at the rate of 80,000 t/month.

There is also a reported case where the shearing method is employed, in which complex-shaped sections can be cut by the use of four cutting blades (two fixed and two moving blades).

(c) Automation of other finishing operations

Inspections can be divided into dimensional inspection and surface defect inspection. As for the former inspection, instruments such as thickness and width meters have been developed.

In order to achieve the automation of all the measurements necessary for sufficient quality assurance, there is the necessity for many more sensors. As for the inspection for surface defects, the practical introduction of on-line operations will take some more time.

Speaking about the assorting operations, they have mostly been automated in the latest equipment by the special designing of the operation of transferring the material from the lifting magnet or table to the rack. In the assembling operation following the assorting, a method using a rotary device with magnet or a method in which the products are alternately moved up and down have already being put to practical use.

Of the labeling operations, the operation of writing the length and specifications on the label has been automated by the use of an on-line computer, thereby tracking the actual sawing records and comparing them with inspection results and specifications given by the order.

4.4.6 Bars and Wire Rods

(1) General

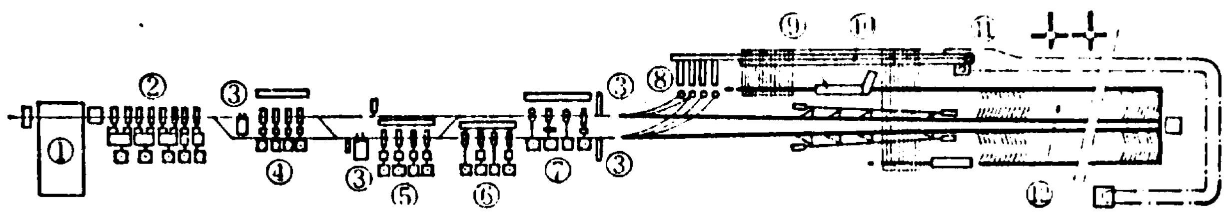
Application technologies for bars and wire rods vary in advances according to the purposes for which they are used. The general trends for bars and wire rods can be summarized as follows.

Bars - Mini mills for reinforcing bars
- Controlled rolling and controlled cooling techniques

Wire Pods - High-speed rolling mills
- Controlled rolling and controlled cooling techniques

Common for both - Measuring instruments for quality assurance
New rolling processes and equipment

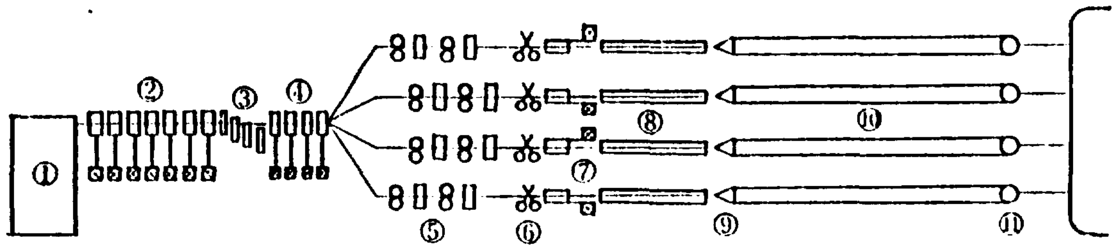
Typical most up-to-date bar and wire rod rolling mills are illustrated in Fig. 4.4.20, Fig. 4.4.21 and Fig. 4.4.22. Fig. 4.4.23 through 25 show the changes in the operating characteristics in these years.



1 Reheating furnace
2 ıghing train
3 Rotary shear
4 First intermediate train
5 Second intermediate train
6 Finishing train A
7 Finishing train B
8 Reels
9 Cold shear gauge
10 Cold shear
11 Hook conveyer
12 Cooling bed

Source: ISIJ

Fig. 4.4.20 Tandem Type Small Bar Mill

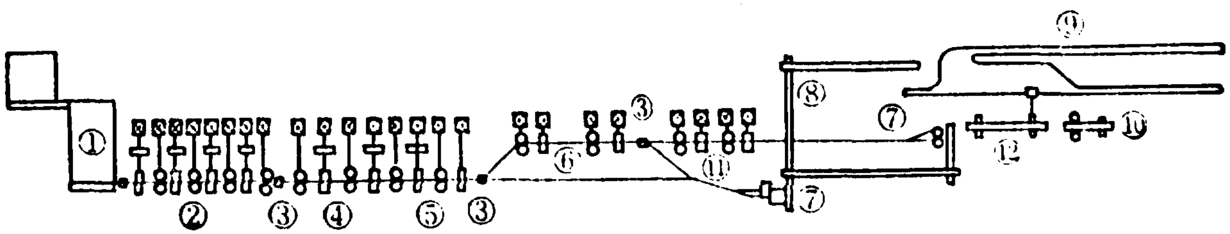


1 Reheating furnace
2 Roughing train
3 Rotary crop shear
4 First intermediate train
5 Second intermediate train (V-H arrangement)
6 Crop shear
7 Finishing block mills (10 stands)
8 Water cooling zone
9 Laying head
10 Forced air cooling zone
11 Loop collector

(8, 9, 10: Controlled cooling facilities)

Source: ISIJ

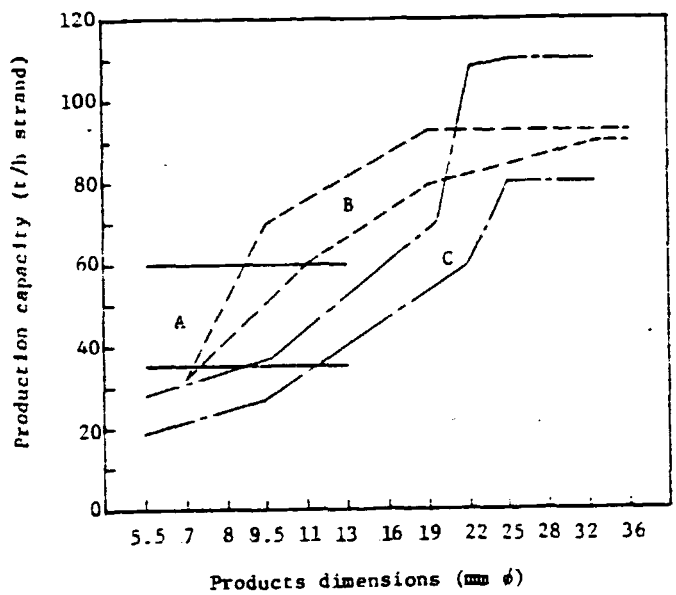
Fig. 4.4.21 Tandem Type Wire Rod Mill for Fine Size



1	Reheating furnace	5	No. 1 finishing train	9	Hook conveyer
2	Roughing train	6	No. 2 finishing train	10	Piler
3	Flying shear	7	Reels	11	No. 3 finishing train
4	Intermediate train	8	Chain conveyer	12	Automatic binding machine

Source: ISIJ

Fig. 4.4.22 Tandem Type Wire Rod Mill for Coarse Size



Note:

A: Multiple strand block mill
(exclusively for fine size)

B: Single strand continuous mill
(for coarse size)

C: Multiple strand continuous mill
(for both fine and coarse sizes)

Source: ISIJ

Fig. 4.4.23 Product Dimensions and Production Capacity

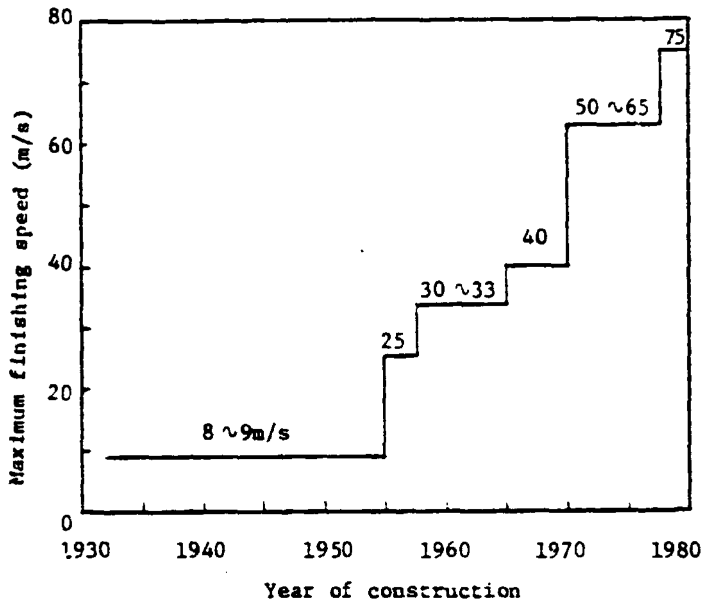
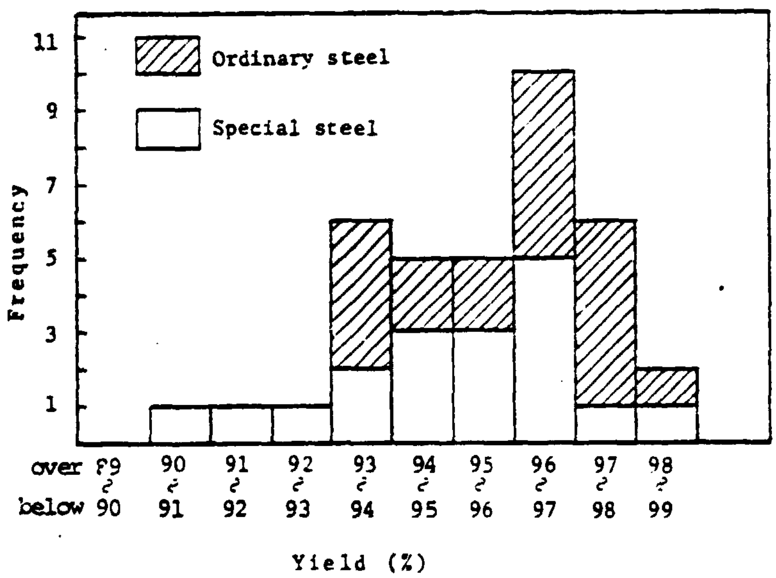


Fig. 4.4.24 Changes in Wire Rod Finishing Mills Speed



Source: ISIJ

Fig. 4.4.25 Yield at Bar Mill

With such developments as the foundation, the main features of the latest wire rod and bar production technologies may be summarized as follows:

(a) Controlled rolling and various other control techniques for the production bars and wire rods.

(b) Advances in inspection technology (progress made in measurirg instruments for quality assurance)

(c) Advances in hot direct rolling and other techniques associated mainly with concrete reinforcing bar rolling mills

(d) Advances in new rolling methods and equipment

(e) Advances in quality improvement techniques

(2) Controlled rolling and controlled cooling technologies

Unlike sheets and shapes, wire rods are rarely used as they are rolled and are usually first heat-treated and drawn and then cold-worked to become the final product. The heat treatment mentioned here is what is called "patenting", that is, a treatment of high-carbon steel wire rods to be made into springs, PC steel wires, wire ropes and the like by improving the mechanical properties, thereby to obtain better drawability.

Previously, this heat treatment was carried out in the patenting furnace installed independently from the rolling line. A new method called "direct patenting" has been developed, in which the same quality as obtained by the use of the patenting furnace can be obtained by the rolling line with the use of the sensible heat of wire rod by properly controlling the cooling speed.

The direct patenting methods now in use are as follows:

(i) Stelmor method
(ii) Vertically descending method
(iii) Fluidized bed method
(iv) Boiling water bath method

Table 4.4.5 shows a comparison of these methods.

Table 4.4.5 Comparison of Different Methods of Direct Patenting

Method		Main coolant	Characteristics of rod quality treated
Stelmor method	The wire rods which are layed on the moving conveyor one upon another in a non-concentric manner from the laying head are uniformly cooled by forced air.	Forced air	Mechanical properties equal to or better than those which are produced by air patenting. Good drawability. Little scale loss.
Vertically descending method	Coiled wire rods are uniformly cooled while being held at equal intervals on the vertically descending conveyor.	Forced air	Mechanical properties equal to those which are produced by air patenting. Good drawability. Little scale loss.
Fluidized bed method	Spiral wire rod is uniformly cooled continuously in a fluidized bed.	Sand	Mechanical properties equal to or better than those which are produced by air patenting. Good drawability. Very little scale loss.
Boiling water bath method	The wire rod from the coiler falls into the bath filled with hot water so that it may be cooled uniformly.	Hot water	Applicable to large-size wire rods. Good drawability. Very little scale loss.

The wire rods which have been directly patented have fine pearlite microstructure uniform along the whole length of the coil and therefore have better drawability and mechanical properties as good as or better than the similar properties obtained by air patenting treatment. Compared with lead patenting treatment which produces the highest level of quality, the direct patenting systems are still inferior in strength and quality variations and at the present time they are still not good enough to totally replace such lead patenting systems.

Recently there has been developed the equipment aimed at the direct annealing of medium carbon steels and low-alloy steels in addition to high carbon steels and it is already been put to practical use.

This is the controlled rolling technique, that is, a technique by which the temperature and rolling conditions during the hot rolling of steel materials are strictly controlled, thereby to greatly improved the mechanical properties and structure the steel materials as they are rolled.

(3) Advances in inspection techniques (Advances in measuring instruments for quality assurance)

(a) Inspection of semifinished products

As for the semi-finished products for bars and wire rods, square billets are commonly used. The quality of finished bars and wire rods is so much influenced by the quality of the semi-finished product from which they are made that the inspection and conditioning are important processes for the assurance of quality of the finished products. In the case of wire rods, the whole length inspection of the wire rod after having been wound into a coil is very difficult from the standpoint of reliability and cost and therefore the inspection of billets assumes a great importance in the external and internal quality assurance. As for bars, how to assure the quality of billets is also a very important key point in attempting the rationalization of the inspection and conditioning processes for the finished products which take so much manpower.

The previous billet inspection and conditioning were labour-intensive operations depending largely on manpower. In recent years, however, the manufacturers make vigorous efforts such as the automation of inspection operations and the integration of inspection and conditioning processes into a continuous line, to establish assurance of high quality and productivity.

(i) Surface Defects Inspection of Billets

For the inspection of surface defects of billets, visual inspection and fluorescent magnetic particle detection method have been commonly used. Since around 1960, various automatic defect detection methods have begun to be developed and nowadays there are many types of such nondestructive defect detectors are in practical use. The nondestructive defect detection methods can be broadly divided into the following two types:

a) The method in which the billet is magnetized and fluorescent of colouring magnetic particles are attached to the defective surface so that the pattern of the magnetic particles is detected and evaluated by suitable methods.

b) The method in which the billet is magnetized and the magnetic flux which leaks from the defective part is directly detected and evaluated by suitable methods.

These automatic defect detection methods enable the qualitative judgement of defects, thus permitting the inspections of billets suited for the required quality of the finished products. This is a great achievement for the sake of quality assurance. On the other hand, automation has greatly contributed to the enhancement of productivity and there is a trend to the further increased use of automatic defect detection equipment in the future.

(ii) Internal Defect of Inspection of Billets

Previously, every billet was subjected to ultrasonic defect inspection manually performed for the detection of internal defects, which was a very lowly efficient operation. Due to the customers' demands for higher quality and greater diversity in recent years, there has been increased demand for the ability to carry out inspections for internal defects in large quantities and yet with great accuracy. As a result intensive efforts have been devoted to the development of continuous and automatic ultrasonic defect detection equipment. Such defect detectors capable of revealing internal defects at such a rapid rate of 30 m/min are already integrated in the actual production lines.

(b) Inspection of Finished Products

(i) Inspection of Wire Rods

As for the inspection of wire rods, it is common practice to make fluorescent magnetic particle defect detection or acid pickling inspection for a certain length of the end of the coil. There has recently been developed and put to practical use a method in which a hot eddy current defect detector is set up after the finishing stand to detect surface defects of the wire rod immediately after being rolled. Although considerably low in defect detection accuracy compared with the previously used ones, this method is used for its advantage that it enables the whole length inspection of the wire rod. This technique is being employed already at many rolling mills mainly for the purpose of preventing the occurrence of large quantities of defective products by early detection of the surface defects and also of checking the qualitative level of the product in process.

With regard to the dimensional measurements, a device which is set up at the exit of the fining mill to make measurements along the entire length of the hot wire rod has been developed and put to practical use. The dimensional measuring device which have so far developed for the most part use non-contact type optical measuring system.

(ii) Inspection of Bars

Bar rolling mills are also making increasing use of the hot eddy current defect detectors and hot dimensional measuring instruments. Attempts are also being made to grasp the product quality level in the early stages of manufacturing process to optimize the inspection and conditioning standards after the finishing process but they have not yet reached the stage of fully practical commercial applications.

Most of the eddy current defect detectors used for the inspection of bars are the probe rotation type which has corrected the shortcomings of the coil type which is not very accurate in the detection of seam cracks.

These systems have excellent defect detecting capabilities. Speaking about the leaked magnetic flux method for instance, it has the same defect detecting ability as the fluorescent magnetic particle method as far as defects deeper than 0.3 mm are concerned. However, the latter method is superior for the detection of defects shallower than 0.2 mm and therefore still in use for the detection of such very shallow defects.

Recently the supersonic defect detection system has begun to be used. In this system automatic supersonic defect detectors are integrated in the automatic surface defect detection line for bars so that the surface and internal defects of the finished bars can be revealed simultaneously in one line. On the other hand, however, there is an opinion that there is no need for the ultrasonic defect detection for the finished product if thoroughgoing inspections are made for the internal defect in the billets. As to whether such a defect detection line will be used widely in the future, it is necessary to watch the trends for the time being.

(4) Technical advances associated mainly with mini-mills for concrete reinforcing bars

In response to the recent increase in demands for concrete reinforcing bars, there is an increasing number of high-productivity mini-mills for making concrete reinforcing bars. This mill consists of three plants - electric furnace, continuous casting and rolling. The finished products range from 9mmø to 41mmø. The billets, from which bars are made range from 110 mmsq to 170 mmsq and those which exceed one tonne in weight are used increasingly.

In some cases the reversing type rolling stands are used in the roughing train to cope with the trend toward larger billets. However, the tandem type rolling with horizontally and vertically arranged stands are likely to become the mainstream. Multi strands rolling is required for rolling small bars in and after the intermediate train and a method of transferring multi strands at one time to the cooling bed is becoming established. Speaking about finishing, a progress is being made in the rationalization of assorting and bundling equipment and development is now under way for the counting device. The continuous cutting of the finished bars to the required length in front of the cooling bed is likely to become one of the tasks to be developed in the future. With regard to the mill as a whole, the energy conservation by the continuous rolling following continuous casting.

At present the following new rolling mill techniques for the production of concrete reinforcing bars are under development.

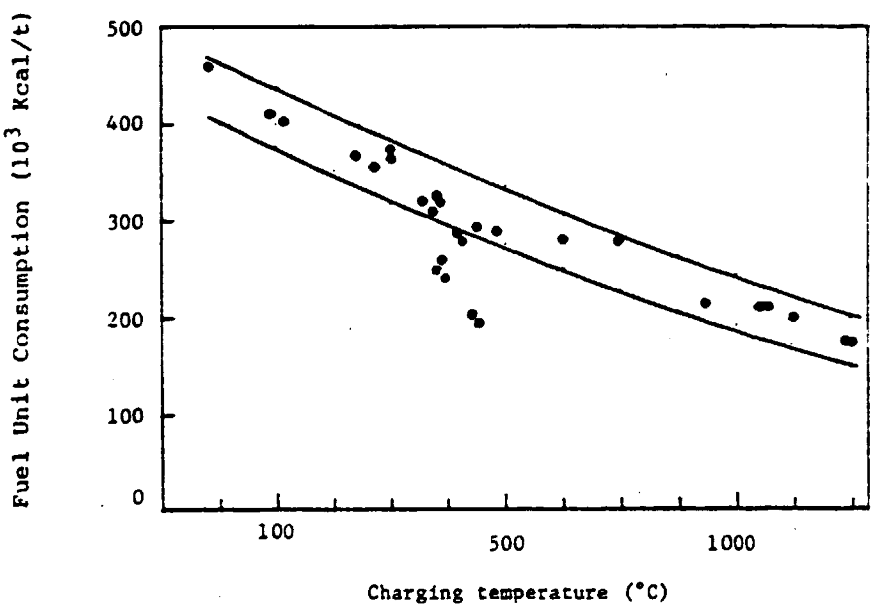
(a) Hot charge and hot direct rolling technology(Fig.4.4.26)

(b) High-productivity rolling techniques such as slit rolling, increased finishing speed (30 m/s), and endless rolling by the use of flash butt welding of billets.

(c) Compactly layouted semi integrated plant

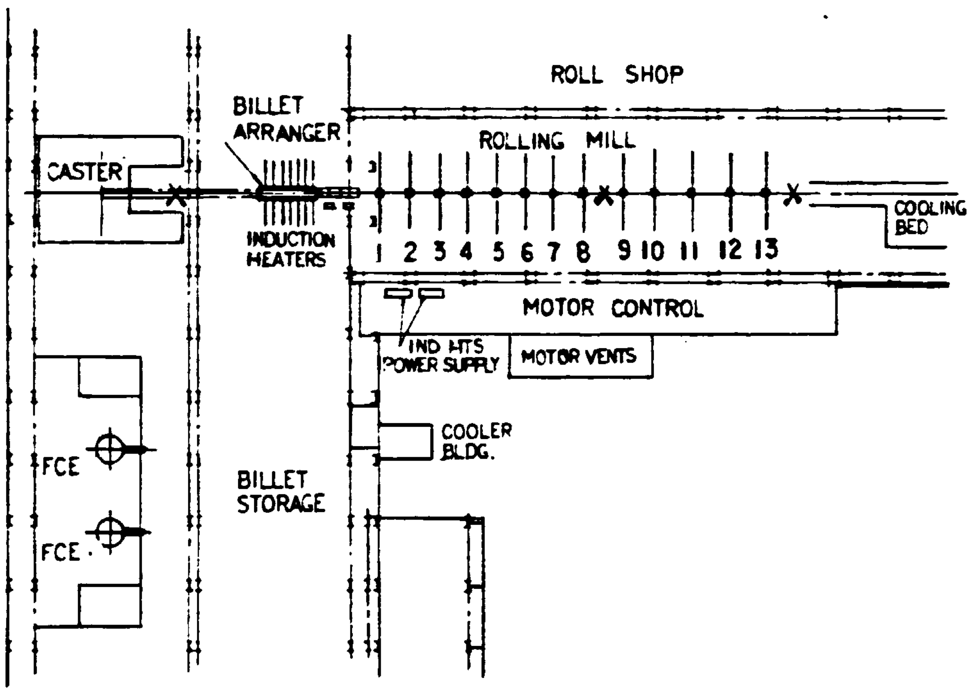
The continuous casting - bar mill direct coupled rolling system is now under development. (Fig. 4.4.27)

It is likely that further advancement will be made for the directly coupled smelting furnace - continuous casting - bar rolling mill system and a progress will be made toward unmanned operations.



Source: ISIJ

Fig. 4.4.26 Charging Temperature and Fuel Fuel Unit Consumption



Source: Nucor Steel (USA)

Fig. 4.4.27 Compactly Layouted Semi Integrated Plant

(5) New rolling methods and equipments

(a) The bar and wire rod rolling has been subjected to various restraints inherent in the conventional groove rolling method. Recently, the following high-reduction rolling methods which surpass the previously used 2-roll groove rolling methods have been developed.

(i) Slit rolling method (The rolled stock is split in the longitudinal direction in front or in the first half of the finishing train.)

(ii) Grooveless rolling method (Billet is rolled by flat passes in the roughing train.)

(iii) Forced rolling method (Billet is mechanically enforced to be bitten into rolls of stand.)

(iv) Endless rolling method (Material is connected after pulled out of the furnace by a flash butt welding machine, and then rolled endlessly). These rolling method will spread as the method rather for relatively low-grade products such as reinforcing bars, conventional wires, etc. than for quality products.

(b) New rolling equipment

(i) High reduction special rolling mill

A high reduction special rolling mill has been developed to cut down the increase in the equipment cost due to enlarged cross sections of materials. But it has only been adopted in a part of the industry owing to its problems in rolling efficiency and life of roll. Main machines of this type are PCRM (Planetary Cross Rolling Mill) wh... can reduce thickness into 1/8 by a single pass, SFM (Swing Forging Machine) which makes continuous forging and can reduce thickness into 1/4, CFM (Continuous Forging Machine), Compact Mill, etc.

Further a rolling mill (prestressed stand) is available in which the roll stands are prestressed by a hydraulic or link structure to increase the rigidity of the stands and improve the size precision.

(ii) A high-speed rolling mill for wire rod

The conventional rolling mills were driven combined with reduction gears and spindles and therefore the vibration of the driving section increased as the speed of rotation was increased so that 40 m/s was the highest limit for the finishing speed.

In order to solve this difficulty, a very compact mill has been developed, in which 8 to 10 rolling stands operate in tandem, alternately tilted 45 degrees to the horizontal in one frame, so that the material may be rolled at a high speed without being twisted.

The main particulars of the principal block mills presently in use are given in Table 4.4.6. Their common characteristics are as follows:

1) The integration of the driving section has enabled high-speed rotations, thereby to obtain the finishing speed so high as 50 to 75 m/s.

2) Space requirements are very small because the mills are so compactly arranged in a single frame.

3) There are less surface defects because of no-twisting rolling.

4) The use of oil film bearings with large load bearing capacity assures high-speed rolling with high dimensional accuracy.

5) The stands are positioned at so short intervals that the cropping of both ends of a coil is very short and consequently yield is so high.

Table 4.4.6 Comparison of Typical Block Mills

	Morgan	M and N	Kocks
System	Two-rolls, non-twisting	Two-rolls, non-twisting	3-rolls, non-twisting
Finishing speed	50-75	50-65	50
Driving device	DC motor common driving	DC motor common driving	AC (or DC) motor common (partly individual) driving
Roll:			
Support	Cantilever support	Cantilever support	Both-ends support
Number of pair of rolls	8-10	8-10	8-13
Roll diameter (mm)	150-200	170-210	290
Number of grooves on roll	1-4	1-2	1
Roll material	Cemented carbide	Cemented carbide	Cemented carbide
Others	High reduction of area is possible with rolls of small diameter. Easy to change rolls. Actual experiences worldwide	High reduction of area is possible with rolls of small diameter. Easy to change rolls.	-

(6) Quality improvement techniques

(a) Precision Rolling:

The demand for greater dimensional accuracy of bars and wire rods has been increasing year after year. As for the springs of automobiles in particular, there is a pronounced trend toward the reduction of cost by the increased dimensional accuracy of the material from which they are made.

Previously, the springs were made mainly through such stage of work as "wire rods → acid pickling → annealing → drawing → surface grinding → finished product (springs)", and such products were made with the accuracy up to tolerance ± 0.10 mm owing to the advances in rolling technology such as the use of precision rolling rolls at the outlet of the finishing stand (a pair of grooved rolls which perform the function of hot roller straightening). The rolling technology made a further progress, thus making it possible to use the processes of "bars → acid pickling → straightening → surface grinding → springs". Recently there are even the signs of using a method in which springs are made directly from the as-rolled wire rods with scale skipping the process of surface grinding. In order to cope with such a situation, further advanced rolling techniques have become necessary.

In order to assure quality for the entire length both in dimensional accuracy and in surface condition without decreasing productivity, the presently used ordinary equipment has nearly reached the limit of its capabilities both technically and economically and therefore there is the necessity for adequate auxiliary equipment.

(b) Coil Weight:

The 1970's saw a dramatic increase in the coil weight owing to the installation of new equipment, which successfully produced coils of 1,000 to 2,000 kg against 80 to 90 kg and 300 to 400 kg in the 1950's and 1960's, respectively, thus greatly contributing to the great increase in productivity and yield for the rod manufacturers and consumers.

In 1981 sixteen rolling mills capable of producing coils over 1,000 kg in weight are in operation in Japan, accounting for about 70% of the total coil production in this country.
Both wire rod manufacturers and consumers will make further efforts to improve the existing facilities and build new ones for the production of large coils. With stabilized and uniform quality large coils are likely to account the majority of wire rod production. Three mills capable of producing coils of 3,000 kg will soon go into operation.

(c) Product Dimensions:

With the expanding uses for wire rods and progress in the wire rod processing techniques, there has arisen the necessity for rolling coarse size and new rolling techniques and equipment have been developed. As a result wire rods which are so large as nearly 50 mm in diameter now can be rolled. The replacement of bars by wire rods as the material for a variety of products has enabled both wire rod manufacturers and consumers to achieve increased productivity and yield.
Wire rods of less than 5.0 mmø and over 50 mmø are likely to be produced to meet the consumers' needs in the future.

(d) Control of the Amount of Scale:

Most of bars and wire rods are put to use after passing through the drawing process. Before the drawing process, the material must be descaled. Descaling was previously achieved by acid pickling. Since several years ago, mechanical descalers have been used. This descaling method has increasing applications for an increased variety of steels and dimensions also from the standpoint of environmental pollution prevention. In the case of acid pickling, the smaller amount scale is desirable in respect of pickling efficiency and yield.

In the case of mechanical descaling, however, it is difficult to mechanically remove the scale unless more than a certain amount of scale is deposited on the surface of the rod. The amount of scale suited for the use of the mechanical descaler is generally said to be over 0.4%, and therefore it is necessary to control the amount of scale during rolling. The amount of scale can be controlled most effectively by properly adjusting the cooling speed during rolling and coiling speed. The use of mechanical descaling is expected to further increase in the future while the acid pickling method still remaining in use. Therefore, it is considered necessary to exercise careful control over the amount of scale to match the purposes for which materials are used.

4.4.7 Steel Pipes

(1) General

Steel pipes can broadly be divided into seamless pipes and welded pipes according to the method of manufacture employed. Table 4.4.7 shows different methods of steel pipe manufacture.

The discussion to follow will pertain to the developments of manufacturing methods for small-, medium- diameter seamless steel pipes, small-diameter forged-welded steel pipes, small-, medium- diameter electric resistance-welded steel pipes, and large-diameter welded steel pipes (UOE method) and their future trends.

Table 4.4.7 Manufacturing Methods of Pipe and Tube

(1) Seamless pipe manufacturing method

Method	Name
Rolling	Mannesmann plug mill
	Mannesmann assel mill
	Mannesmann mandrel mill
Press forming	Ugine-Sejournet
	Erhard push bench

(2) Welded pipe manufacturing method

Method	Name
Forge welding	Continuous forge welding method
Electric resistance welding	Low frequency welding method
	High frequency induction welding method
	High frequency resistance welding method
Electric arc welding	UOE method
	Continuous forging method
	Spiral welding method

(2) Small-, medium- diameter seamless steel pipes

(a) With many high-efficiency mandrel mills having been installed in recent years, the Mannesmann pipe manufacturing method is becoming the mainstream for the production of small-diameter pipes of less than 5-1/2 inches in diameter. The size of plug mills has been increased up to 16 to 17 inches and automation and other equipment rationalization have been rapidly carried out.

Speaking about the various kinds of equipment, the reheating furnaces, of which rotary hearth furnaces are the mainstream, have increased in capacity up to 100 - 150 t/hour and such operations as combustion control and charging and discharging of material are now computer-controlled. The control of the process of heating the material is of extreme importance since it is closely related to eccentricity and defects.

With the increased main motor capacity, increased size of rolls and the use of disk guide, Mannesmann piersers have increased in the piercing speed so that along with the use of mandrel bar circulation they are going to make a great contribution to the enhancement of productivity.

The press piercing mill (P.P.M.) by which continuously cast rectangular blooms can be directly pierced has been developed to provide so much reduction of costs of rods. Since this type of piercing mill can handle square blooms which are more advantageous than round ones from the standpoint of continuous casting techniques, it produces various merits such as stabilized product quality.

In the plug mill rolling, multi-calibers rolls with, long-barrel were commonly used in the past. The new equipment all use single caliber rolls for their such advantages that the rolls can be changed quickly, dimensional accuracy is increased by the increased rigidity of the mill, and the mill guides are so much simplified. Advances have been made in the theory and technology for linking medium-diameter plug mills in a continuous line and 13-3/8" multi-stand plug mills (M.P.M.) with semi-floated mandrel bars have been developed to rapidly attract attention for its outstanding performance in respect of product quality and operating efficiency.

The mandrel method is used mainly for the mass production of oil well pipes and linepipes and now constitute the mainstream for the production of small-diameter pipes. These most up-to-date mills are very much automated and speeded up and are able to handle pipes greater in diameter and in length not only by the improved equipment technology but also the advancement of mechanics of plasticity relating to the groove rolling of pipes.

By using thus produced pipes, the stretch reducers which are used for the reducing of small-diameter pipes, along with the increased number of stands and increased motor capacity, are now working to their full capabilities.

As for the sizers for rolling medium-diameter pipes, there have been achieved various developments such as the use of the three-roll system to improve the roundness, control of roll gaps during rolling, and the device by which the outside diameter of the pipe can be measured hot.

(b) The press forming method, since its piercing process is basically a compression forming, has developed for making pipes from such highly alloyed steels as stainless steels which have higher deformation resistance. Of the pipe manufacturing methods of this type, the Ugine-Sejournet process using glass as a lubricant, along with the extended use of highly alloyed steels and nonferrous alloys, has made a great progress to become a well-established method for the production of highly alloyed steel pipes. In the meantime the finished pipes have become larger in diameter and the pipe rolling mills have become more efficient, making rapid progress in the construction of larger presses over 3,000 tonnes. The rotary or sliding system has been used for the press containers in order to increase the extrusion pitch, thus making it possible to extrude 100 to 120 pipes per hour. Owing to the technological developments related to tools and glass lubricant, the extrusion rate has been increased to enable the extrusion of pipes as long as 40 meters. Improvements have been made in the extrusion techniques for such complex-shaped products as gilled tubes and section steel and also for the materials previously difficult to work, for which there are steadily increasing needs, thus enabling highly stabilized mass production of such products.

(c) Future trends

What is required of seamless steel tubes is probably to reach the limits of improvements in the quality characteristics for high-grade steel pipes capable of withstanding increasingly severe operation conditions in the future. Seamless tubes will enjoy increased demand in the areas in which they surpass welded pipes in cost performance. In order to realize such a situation, the seamless steel tube manufacturing techniques will make rapid stride in progress and the main streams will be firstly the full-scale use of continuous cast material and rationalization of pretreatment operations, secondly the developments of hot and cold rolling methods to match the purposes for which the steel pipes are used and the increases in size and speed and automation of the equipment used in the respective methods, thirdly further improvement of the quality assurance systems, and forthly the extensive introduction of computers. As for the hot pipe rolling, the Mandrel mill method will come to stay for the production small-diameter pipes and advances will be made toward increased length and size in the future. For the production of medium-diameter pipes, continuous rolling such as multi-stand plug mills will undoubtedly make further advancement. The application of Mannesmann process to the production of pipes from highly alloyed steels is also an important task to be accomplished in the futue. The extrusion methods will proceed in the direction of handling materials of high grade, mainly stainless steels.

(3) Welded steel pipes

(a) Small-diameter forge-welded steel pipes

In the forge-welded steel pipe making method, a steel strip is rapidly heated up to the forge-welding temperature and formed into a tubular shape and then the edges are welded by forging. The most up-to-date forge-welded pipe mill consists of 14 stands and the maximum delivery speed of 635 m/min. Until several years ago, slit rimmed steel sheet had been used for making forged-welded pipes. Recently, however, owing to the advances in the continuous casting technology, there has been increasing use of continuous cast killed steel. Along with the increasing size of steel ingots, the coils have increaed in size from about 20 tonnes to about 40 tonnes, thus greatly contributing to the increase in productivity and yield. Recently the world's first plant having a computer-controlled system went into operation. This control system covers the operations from the acceptance of material to the finishing line and performs mainly forge-welding temperature control, wall thickness control and cutting length control and also has such functions as production technical data logging, tabulation of inspection results and so forth. This plant is now operating in good condition.

The greatest problem involved in the forge-welded pipe plant is the fact that the combustion efficiency of the reheating furnace is low. The thermal efficiency is still low even in the latest reheating furnace which has a preheating zone utilizing exhaust gasses. All the manufacturers are making vigorous efforts to decrease the fuel consumption per unit of product. It would be imperative for them to develop a revolutionary low-temperature operation method if they are to survive.

The tasks to be accomplished in the future will be to move into the field of materials by taking advantage of the possibility of making thick-walled small-diameter pipes as compared with the electric-resistance welded pipes and to expand the applications to high-grade piping.

(b) Small- and medium-diameter electric-resistance welded pipes

The electric-resistance welding of pipes has recently shifted mostly from the low frequency welding method to the high frequency welding method. Beginning with this changeover, great strides have been made in this field of welding technology. First of all, productivity has been greatly increased by the increases in the weight of a strip coil and entry equipment, extended use of post-annealers, improvements in the cut-off machines and also in finishing and inspection facilities. The range of the manufacturable dimensions of these types of pipes have been greatly extended owing to the advances made in pipe manufacturing techniques, especially pipe forming techniques. Nowadays electric-resistance welded pipes can be made up to 28" in outside diameter and 16 mm in wall thickness.

The electric-resistance welding technology now can be used to make pipes not only from low-carbon steels but also from medium-carbon steels and low alloy steels. The quality of electric-resistance welded pipes has been greatly improved largely due to the advances in steel-making technology and the progress of controlled rolling technology. That is to say that the progress of desulfurization techniques such as the desulfurization of molten iron has resulted in the noticeable decrease in the sulfur content of steel and the advancement of vacuum degassing technology has assured material with a higher degree of cleanability to provide a higher reliability of the weld. The establishment of controllled rolling technology for the hot strip mills has made it possible to provide a high toughness as required for the line pipes to be used in the very cold districts.

Speaking about quality assurance, in the mills for making electric-resistance welded pipes of diameter below 7", the introduction of the rotary contact type ultrasonic flaw detectors has enabled high-precision and high-efficiency detection of flaws. The mills for making medium diameter electric-resistance welded pipes of diameter over 7" now use ultrasonic flaw detectors on both inner and outer faces to obtain a higher quality assurance accuracy for high-grade products. With the increased mill productivity, the eddy current flaw detectors as high-efficiency inspection facility, has been widely used particularly in the mills for making electric-resistance welded pipes of small diameter. Recently it is becoming common practice to incorporate such flaw detectors in the pipe mills, thereby to control the mill operations.

Owing to the advancement of such manufacturing techniques, the applications of electric-resistance welded pipes have greatly extended to be used for high-grade line pipes, oil well pipes, high-grade boiler tubes, and mechanical structural pipes. This tendency is likely to be further accelerated from now on.

(c) Large-diameter arc-welded pipes

In recent years the properties which are required of large-diameter arc-welded pipes have become increasingly severe due to the increased demands for this type of pipes in such applications as oil and gas well pipes in very cold districts, pipelines to be laid on the deep sea-beds, and marine structures. There is a pronounced tendency of this type of pipes to become greater in diameter and in wall thickness and to be required to have higher low-temperature touchness, resistance to corrosion and dimensional accuracy. In order to meet such requirements, the large-diameter arc-welded pipe manufacturing technology has made a great progress in recent years.

Speaking about the large-diameter arc-welded steel pipes made by the VOE method in particular, the press forming techniques have been improved and developed and the press capacity has been increased to cope with the trend to larger diameter and thicker wall of pipes. At present it is possible to make pipes of this type up to 64" in outside diameter and 1.5" in wall thickness. In order to increase the pipe making speed, it is necessary to increase the welding speed and for this purpose the number of electrodes has been increased to speed up the welding operation. In recent years, furthermore, the low-temperature toughness of the welds and heat-affected areas are so often required for the line pipes in the very cold districts that extensive research has been made for the welding methods and materials to meet such requirements.

As for non-destructive inspections, ultrasonic flaw detection and X-radiography are commonly used in combination. The latest ultrasonic flaw detectors have very high accuracy of performance. There are flaw detectors of this kind having more than eight probes, which play a very important role in the establishment of quality assurance systems.

With regard to the manufacture of material for large-diameter arc-welded pipes, the specially severe requirements for low-temperature toughness have been met by the advancement of steel-making techniques such as desulfurizing and vacuum degassing treatment and the improvement of the shape of inclusions and also by the application of controlled rolling techniques in the manufacture of heavy plates and hot coils.

The problems to be solved in the future will be the development of hydrogen sulfide cracking-resistant large-diameter arc welded steel pipes capable of withstanding much more severe environmental conditions and proper counter-measures against unstable ductile fracture in gas pipelines. The development of clad steel pipes will be pushed forward as a solution to the former problem. The latter is a phenomenon that when there occurred an accident to a pipe-line the internal pressure would not easily decrease because of the very large compression ratio of the gas being transported and therefore the fracture propagates in spite of its being ductile fracture. Research efforts are already being made on this problem in many countries.

From the viewpoint of forming technology, the tendency of pipes of this type toward thicker walls will be further accelerated in the future.

If the development of a technique for making pipes of thickness up to 3" is successfully carried out, they will have greatly increased applications such as marine structures like platforms.

4.4.8 Surface Treated Steel Sheet

Surface treated steel sheets are represented by galvanized steel sheet, tin plate and tin free steel sheet. In the following sections, technological progresses and future trends will be discussed in this field.

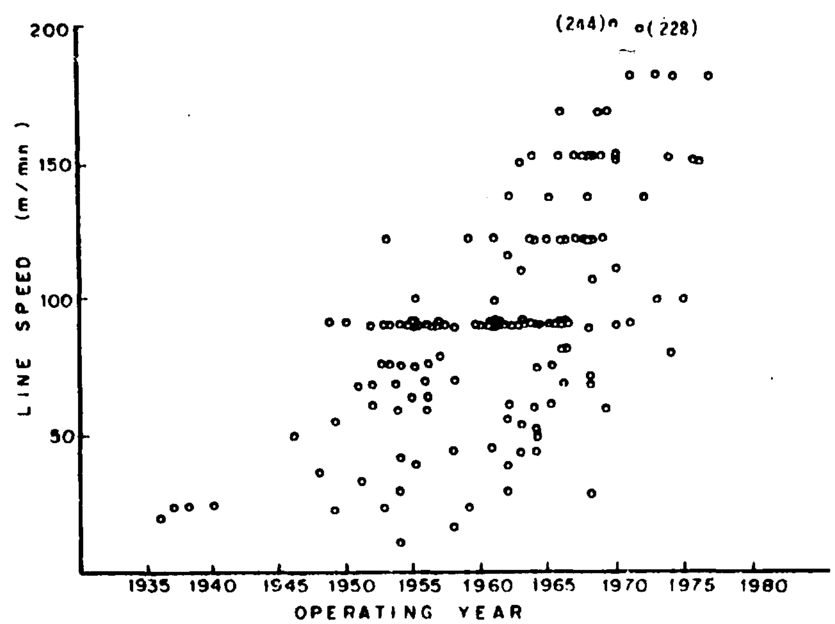
(1) Hot dipping type galvanizing

(a) Outline

Since the introduction of the modern surface treatment process brought about by the development of strip mill, a number of revolutional technological developments have been made. Especially after 1960, each surface treatment line has increased treatment speed along with the progress of peripheral technologies, and other new features such as automation have been realized.

Line speed up leads to a higher productivity and means an indirect saving of energy. More positive energy saving has been brought about through the adoption of various automation technologies.

Automation technologies are very important, needless to say, as a means to stabilize operation and quality under high speed operation.



Source: ISIJ

Fig. 4.4.28 Trend of Speed Up in Hot Dipping Type Galvanizing Line

Such remarkable progress of speed up, energy saving and automation in hot dipping type galvanizing operation has been supported by the following technologies:

(i) Convertion from roll wiping to gas wiping,

(ii) Convertion from oxidizing furnace to non-oxidizing furnace and from horizontal furnace to vertical furnace,

(iii) Presetting, automatic data logging and optimum automatic control of processes by computer,

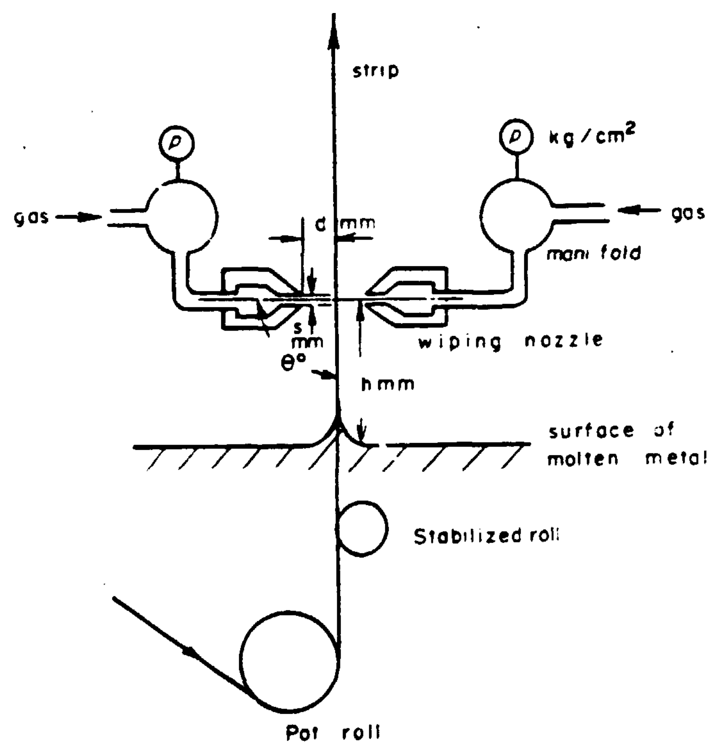
(iv) Compact line and concentration of operation control system,

(v) Unmanned automatic operation and remote control, and

(vi) Increased coil weight and reduced defects in coils.

(b) Wiping process

The major problem of the roll wiping method is said to be in a limited line speed. To solve this problem, the gas wiping method has been introduced.



Source: ISIJ

Fig. 4.4.29 Gas Wiping Mechanism

Gas wiping has the following merits comparing with roll wiping.

(i) Factors to determine zinc accumulation are clearly known.

They are precise and can be reproduced. They can be automatically and/or remotely controlled.

(ii) Zinc accumulation can be controlled in a wide range, and a minimum of 15 to 20 g/cm^2 on one side is possible.

(iii) Higher line speed can be accommodated.

Prompt reaction to changes in material size or zinc accumulation is possible.

(iv) An independent control is possible for each side of strip, and thus different thickness plating can be done precisely, which can be repeated.

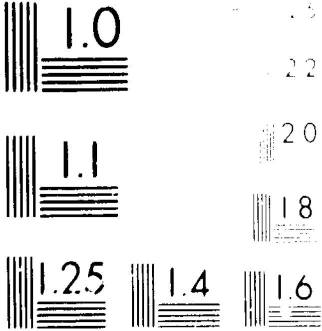
It is true that the gas wiping process has overcome one obstruct for higher speed and has made a great contribution to line speed up to realize a constant line speed of 150 to 200 m/min. In order to further raise speed, such problems as (a) zinc splash, (b) noise from nozzles and

(c) difficulty in zinc low accumulation have to be solved.

(c) Progress of furnace system

As it was a necessity to make furnaces larger in order to get a higher speed with the Sendzimir process, it was an important task for raising line speed to develop small furnaces of higher efficiency. One progress in this field has been the development of a non-oxidizing furnace. In a non-oxidizing furnace, strips are directly heated with a premixing burner. In so doing, the combustion air ratio is precisely controlled. Strip surface is gas-cleaned so that about 5% excess inflammable substances will remain in the products formed as a result of combustion at around 1,300°C. At the same time, surface oxidization is suppressed tc minimum.

With this non-oxidizing furnace, it is possible to reduce heating time to less than half comparing with an oxidizing furnace as it is possible to raise temperature without heavy oxidization as shown in Fig. 4.4.30.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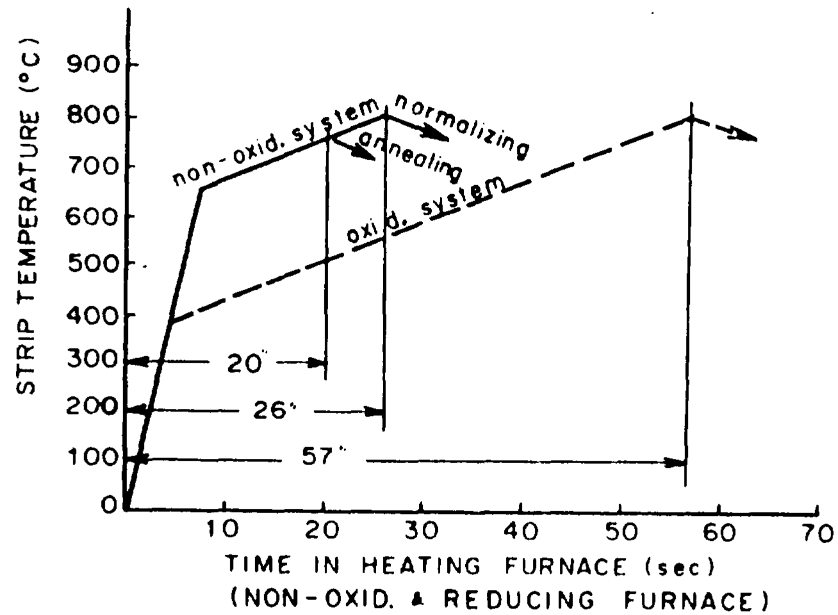


Source: ISIJ

Fig. 4.4.30 Comparison of Heating Cycle between Oxidizing and Non-Oxidizing Furnaces

(2) Electrolytic galvanizing

(a) Outline

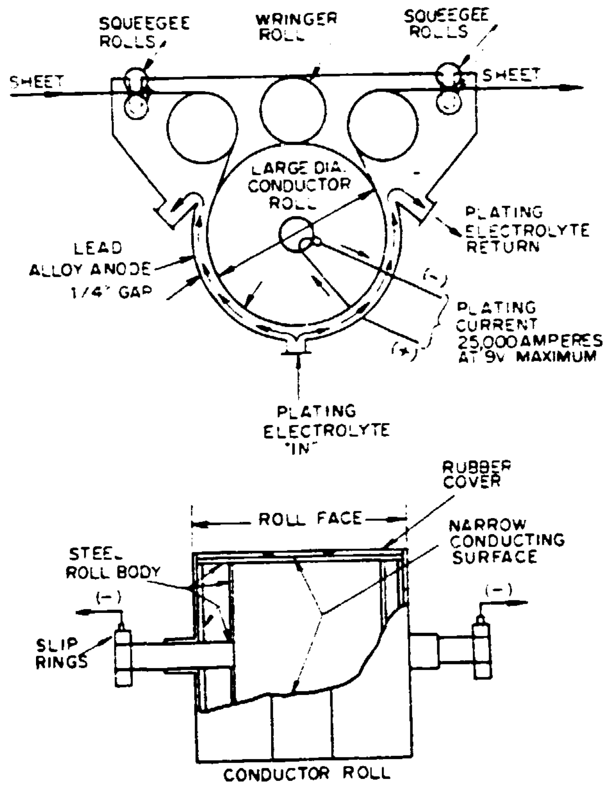
When electrolytic galvanizing was first introduced in U.S.A., zinc was flash-coated only at the thickness of about 3 g/cm^3 on one side most as a base for phosphate-treated steel sheet to be painted. Today, there are increased demands for electrolytic galvanized sheets as anti-corrosion steel sheets as substitutes for hot dipping type galvanized sheets, and such sheets have a zinc layer of about 30 to 50 g/cm^2 on each side. Automotive one-side plated sheets with a layer of 50 to 100 g/cm^2 are demanded today. With such thickness, line speed is naturally low. Therefore, today's important technological task is to find a means to raise the critical current density (Maximum current density at which electrode reaction is effected at 100% current efficiency.)

Past electrolytic galvanizing lines were relatively small with the line speed of less than 100 m/min. After 1972, however, 150 m/min. lines were introduced. In 1976, U.S. Steel Gary started the operation of its 210 m/min. line.

As one method to raise the critical current density which will contribute to raise line speed, it is effective to increase the flow of electrolyte on the electrode surface by causing a forced convection, assuming the bath composition to be constant.

(b) Radial cell process

This process has been developed by U.S. Steel as a means to efficiently produce one-side electrolytic galvanized steel sheets. Its concept is shwon in Fig. 4.4.31. A line adopting this process started operation in 1976.



Source: ISIJ

Fig. 4.4.31 Outline of Radial Cell Process

(3) Electrolytic tin plating

(a) Outline

The first commercial electrolytic tin plating line was constructed at U.S. Steel Gary in 1937. Since then, electrolytic tin plating lines steadily increased to almost completely take over by 1955 the commonly used hot dipping type tin plating method.

Basically, there are three types of electrolytic tin plating lines in terms of electrolyte used and line type. They are the Ferrostan, Halogen and Alkali methods. Comparing these three types, it may be said that the Alkali method is excellent in product quality, but has some productivity problems whereas the Halogen method is excellent in productivity, but has some quality problems. On the other hand, the Ferrostan method is said to come between the other two processes with respect to both quality and productivity, featuring the merits of the two other methods. Also, results at U.S. Steel have supported the Ferrostan method to spread it worldwide. Today, the Ferrostan method is said to account for at least 73% of the world tin plating capacity (118 lines as of 1976.) No Alkali method lines have been constructed since 1970 as this method is not desirable in productivity and operationality. Halogen method lines are popular mainly in U.S.A. to account for about 20% of the world capacity. They are expected to continue to be used as their quality is improved.

As a result of steady Research & Development Works on quality and facility, the Ferrostan method is today almost comparable to the Alkali method in terms of quality and also to the Halogen method in terms of productivity. Therefore, this method is expected to maintain its main-stream status.

Fig. 4.4.32 shows the relationship between the year of operation commencement and line speed for electrolytic tin plating lines in the world. With the Halogen method, high speed lines were realized at an early stage because they used high current density and horizontal pass, the maximum speed being 660 m/min. Meanwhile, the Ferrostan method improved line speed after 1960 and a line speed of 450 to 600 m/min. became common. In 1973, the world fastest line, 700 m/min., was constructed at Usinor/Mardyck.

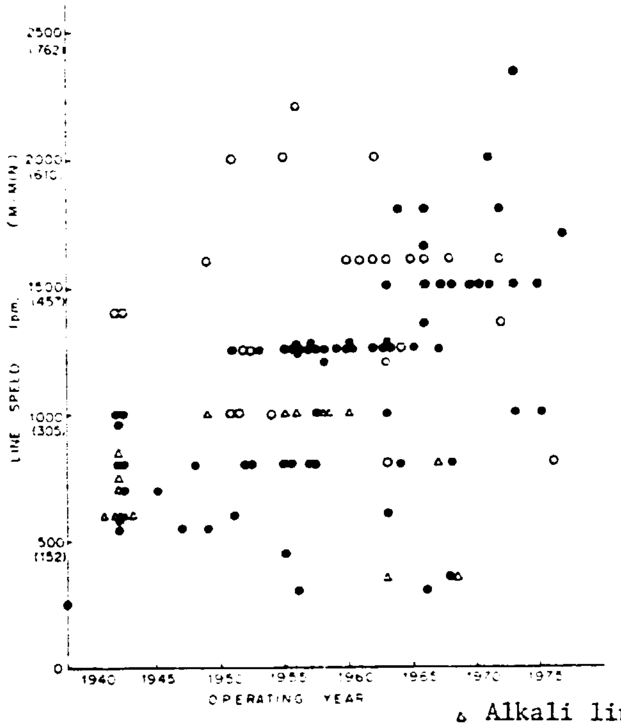
Such improvement in electric tin plating has been brought about under the following backgrounds:

(i) Improvement of plating process,

(ii) Improvement of reflow section - changes in melt system, reflow automatic control, etc.,

(iii) Improvement of accessory sections - improvement of pretreatment, oil application facilities, etc., and

(iv) Introduction of process computer.



△ Alkali line
○ Halogen line
● Ferrostan line

Source: ISIJ

Fig. 4.4.32 Trend of Increasing Electrolytic Tin Plating Line Speed

(b) Improvement of plating process

One requirement in increasing the line speed of electrolytic tin plating is to develop an electrolyte which will have a higher current density without sacrificing plating gloss and electrode efficiency. The development of Alkali bath to Ferrostan bath and then Halogen bath was a progress, during the early stage of electrolytic tin plating, from the standpoint of current density. From 1954, the Fluoborate bath ($Sn(BO_2FO_2)_2$) which was capable of further raising current density was put into commercial use. As allowable current density range of this process is very wide, from 10 to 50 A/dm^2 for instance, plating is excellent. German Rasselstein AG/Andernach No. 11 line is a line with the line speed of 600 m/min., adopting this process.

Another problem related to a higher line speed is the taking-out of the electrolyte by strips. Both the Halogen and Ferrostan methods have been experiencing this problem. Various modifications such as tank and roll structure have been effected, but a perfect solution has not be found yet. For instance, Usinor/Mardyck No. 1 line's consumption of electrolyte is so large at the maximum speed of 700 m/min. that the line cannot be operated continuously for long time.

(c) Improvement of reflow section

In the reflow section, the electrolytic precipitated Sn is remelted to create a beautiful metal gloss and at the same time to form a proper alloy layer in order to improve the anti-corrosion characteristic of each product. The melting method has been changed from the earliest oil melting to the gas melting method. From the 1940's, conduction heating was adopted. This is a method to supply electricity to strips through a conductor roll and higher the line speed, more electricity is required to melt tin. At a speed higher than 500 m/min., operation causes arc spots. This was a great limitation of the process in terms of speed. During the 1960's, high frequency induction heating was developed. This process enabled non-contact rapid heating to completely clear speed limitation. In actual applications, a combination of conduction heating and high frequency induction heating is commonly used to establish a proper heating cycle to generate an alloy layer which has an excellent anti-corrosion characteristic.

(d) Improvement of accessory section

As for the pretreatments including oil removing and acid bathing, old dipping methods have been all replaced by electrolytic methods, energy saving measures such as the automation of solution control are making progress.

The progress of oil application devices may be represented by the commercialization of electro-static oiler. The oil to be used has been changed from palm oil to cotton oil and DOS. Comparing with the past emulsion system, the electrostatic system has been much improved both in quality and oil application speed.

(e) Introduction of computer

The most noticeable change in electrolytic tin plating lines has been the introduction of computers as seen in other surface treatment lines. Today's tin plating lines operate at considerably higher speed than other lines, and thus can enjoy the merits of computerization more than other lines. Already six lines have reported some introduction of computers.

In the States, U.S. Steel Pittsburg, Kaiser Steel Fontana and Jones & Laughlin Aliquippa are each equipped with Honeywell 412 computers. Also Nippon Kokan Fukuyama, Nippon Steel Yahata and BSC Velindre have reported to have introduced computers.

Process computers are used to perform the following functions in electrolytic tin plating operation:

(i) Strip tracking - uses coil welding paints as unit signals with presetting, data collection and process control considered as individual units.

(ii) Presetting - puts in production specifications and automatically changes the conditions of each section by means of unit signals tracked.

(iii) Process optimum control - selects plating tanks, automatically controls plating current and other processes.

(iv) Data logging - records and totalizes monitoring data, line stops, product length, records current, speed, etc.

(f) Double reduced tin plate

Whereas conventional base steels are rolled down to the product thickness of tin plate in the cold rolling process, and their thickness change is very slight in the skin-pass rolling process, double reduced tin plate receives cold rolling work, using rolling mill lubricant, of the reduction 20 to 50% in the process corresponding to skin-pass rolling to be made into the product thickness. By increasing the reduction rate of the second rolling, it is possible to produce thin tin plate with better mechanical properties. Double reduced tin plate has a thickness of two-thirds to half of that of conventional tin plate.

(g) Future of tin plate

Tin plate has a long history as a material for making containers. In the course of the long history, continuous efforts have been made to reduce can's cost through reduction in thickness by means of the adoption of electrolytic-plating and continuous annealing processes and through further reduction in thickness by the development of double reduced tin plate. With the considerable growth of tin-free steel sheet developed more than ten years ago for soft drink can, the status of tin plate as a material for can is said to have changed. Also, appearance of aluminum, plastic and glass cans is expected to have an influence upon the future of tin plate.

Research and Development works on tin plate Drawn & Ironed (DI) can have been conducted to compete against aluminum DI can, and tin plate DI cans have been already introduced to the market. Future tasks should be to improve surface characteristics of tin plate, uniformity and cleanness of base sheet in order to meet the requirements of such new technologies.

(4) Tin-free steel sheet

Tin free steel sheet (TFS) refers to "steel sheet with no tin to replace tin plate".

There are many types of steel sheets using no tin, but only those steel sheets which have been developed to replace tin plate are called tin-free steel sheet. Today, tin-free steel sheets refer to those steel sheets with the inner layer of metal chrome and the thin outer layer of chrome hydration oxide.

Tin-free steel had initially limited applications only in fields other than food cans because of difficulty in jointing of body parts. Owing to the development of the Miraseam process which uses nyron and adhesive for jointing of body section and the Conoweld process of the forge-welded type, use of tin-free steel has been rapidly increasing in the fields of beer and soft drink cans.

(a) Tin-free steel production process

As base steel sheets for tin-free steel, rimmed, capped or continuously cast steels are used as in the case of tin plate. In the processes prior to the electrolytic chromate treatment (or chrome plating) line, a base steel is treated in the same manner as in the case of tin plate production. Tin free steel, however, has a very thin surface film and its film is easily influenced by base steel conditions. In the tin free steel production process there are one step and two-step processes, both of which utilize the treatment of ferrostan line in tin plating. This line can be used also for tin plate production. Tin-free steel production facilities, however, differ from tin plate production facilities mainly in i) lining materials of the electrolytic tank, ii) use of acid-resistant material for rolls, iii) use of non-soluble anode and iv) non-existence of fused part.

(b) Corrosion resistance of tin-free steel

Tin-free steel is usually used with surface painted. Thus, tin-free steel without painting is required to be rust free during transportation and storing and to be usable in applications of cans to contain organic substances other than those for foods.

When it is coated, it demonstrates excellent corrosion-resistance owing to the good cohesion between chrome hydration oxide and coated film, but it does not have such a function of preventing iron from solving as tin plate has. Therefore, unless coating defect is zero or it is used in combination with non-coated tin plate when filling acid food in a coated tin-free steel can, there is a risk of hydrog n gas expansion or holes occurring.

(c) Future of tin-free steel

Tin-free steel has achieved a rapid growth owing to its excellent characteristics and relatively cheap cost comparing with tin plate. As for use in the field of food can which has been the biggest target since its introduction, a rapid progress has been achieved in applications for beer and soft drink cans owing to the development of jointed cans and efforts to make cans lighter through the development of double reduced materials. In the field of food cans, however, tin-free steel free behind tin plate because of problems of a considerable improvement of soldering can production line and of retort treatment. In the fields of beer and soft drink cans, aluminum DI, tin plate DI and glass containers are competing both in price and quality. Especially with respect to quality, a considerable room for making efforts is left in relation with can making process. In the field of food cans, deep drawn two-piece cans are already being to some extent and a considerable growth is expected.

Possibility of manufacturing of tin-free steel in Pakistan is discussed at Appendix to 4-1.

4.5 Energy Saving Techniques

4.5.1 General

Consumption of energy in a BF integrated works is about 4.0-4.5 million kcal/t-pig iron mainly for the pretreatment and melting reduction of iron ores in the pig iron making process, about 200,000-300,000 kcal/t-crude steel for refining and making crude steel in the steel making process and 1.5 million kcal/t-crude steel for heating and rolling in the rolling and surface treatment processes.

The flow of energies in the ironworks is such that coal which is one of the primary energies is put to dry distillation in a coke oven, and cokes for the use of blast furnace and coke-oven gas (COG) are produced. The cokes reducingly melt the ore in the blast furnace and blast furnace gas (BFG) is produced. In pigiron making process a subproduct gas (COG) is generated while it is refined in the converter. These subproduct gases are separately or mixedly used as the fuel for the coke oven, blast furnace and other various heating furnaces together with the primary purchased heavy oil. Further they are used for generating steam in boilers and electricity in the power plant. Steam is used for general heating purposes, and electric power, for driving rolling mills, generating oxygen and supplying industrial water.

Since, in a BF integrated works, energy in various forms enters every process and operates it as mentioned above, the energy saving techniques in the integrated works have the character of a very extensive production technique or a total technique which includes from improving the energy unit cost for a single simple operation or the yield rate in a process, to omitting a part of the iron and steel making processes from the standpoint of stable manufacture operations or the whole integrated works, conversion of energy sources, and improving energy efficiency in the total ironworks.

The energy saving measures promoted by the iron and steel industry are divided into the so-called operational efforts to improve the operation techniques, to strengthen the operation control and to make other various improvements, and measures such as remodelling the equipments and installation of new energy saving facilities.

4.5.2 Improvement on Operational Techniques

The first step to saving energy is avoiding wastes in the work and adopting the methods to effectively use the equipments.

So far mainly pursued are the optimization of the charged material distribution in blast furnace, improvement on the quality of charged raw material and operation of hot stove in the iron making process, the improvement of the recovery rate of converter gas and shortening of the track time in the steel making and blooming processes, the improvement of combustion control and heat pattern in the reheating furnaces and that of the fuel unit consumption by enforcing the hot charge, etc., in the rolling process.

4.5.3 Remodelling the Equipments and Installation of New Facilities

(1) Pig iron making process

Power generation by the blast furnace top pressure (25-30 kWh/T) was prevented from the practical use at an early stage because of its low investment effects. But many power plants of this type have been constructed since 1978 as the turbine efficiency was improved, and the equipment costs were relatively lowered and the energy costs soared. They are presently constructed mainly on large-sized high-pressure blast furnaces, but will also spread to low-pressure ones in future.

(2) Steelmaking process

The continuous casting facilities make 150,000-250,000 kcal/t energy consumption saved. So the pervasion ratio of that facilities in Japan and 32 advanced countries has increased from 17% and 10% in 1972 to 52% and 26% in 1979 respectively according to IISI. These facilities have also a large effect on the production system of the integrated works. Their further installation is planned.

The recovery of converter gas is improved to some extent through the reinforcement of gas holders, improvement of the recovery technique and further of Wöbb Index control and other utilization techniques.

(3) Rolling process

The measures for improving thermal efficiency of the reheating furnace include the increase of furnace length, strengthening the insulation, remodelling of the furnace including the use of roof burners, the control of the furnace temperature pattern, control of waste O_2 gas, and lowering the soaking temperature by high-speed rolling.

On the other hand, the ratio of hot direct rolling which can do without the reheating furnace is increasing by the establishment of improved casting techniques and hot defects detection techniques.

The cold rolling process is taking the measures for reducing the steam unit consumption for pickling, adopting a continuous batch type annealing and providing a recuperator at the annealing furnace.

For saving electric power, the on-off system to operate the motors for combustion air, dust collection blower and cooling water pump according to the necessary load on them, the control of revolutional frequency of motors and the measures for improving various power-factors have become popular.

Energy Saving Techniques in Future

Since the 2nd oil crisis, the establishment of techniques to cut down the necessary oil energy has been strongly called for, in addition to the improvement of all energy consumption efficiency, in the research and development of the energy saving techniques.

The research and development of all coke operation and the techniques to blow in fine coal or coal slurry are planned to cut down the volume of heavy oil blown into the blast furnace. They are the iron and steel making technique themselves, and it is important to improve the total iron and steelmaking techniques including the raw material problem, which leads to the problem of the sintering ratio and hot metal ratio, product quality, yield rate and the whole production processes.

The energy problem is expected to be hotter and hotter in future. The countermeasures from a short or middle range view, such as wider use of the measures so far taken, and those from a middle or long range view, such as the security of fuels, mainly coal, and less dependency on oil and electric energies through the development of energy saving techniques must steadily be promoted.

5. CONDITIONS AND POSSIBILITY CONCERNING INTRODUCTION OF MODERN IRON AND STEELMAKING TECHNOLOGY INTO PAKISTAN

5.1 General Conditions of Iron and Steel Industry

(1) Role of the steel industry

The iron and steel industry has been playing a very important role as a basic industry in devleoped countries. By promptly meeting the quantitative and qualitative needs of steel consuming industries, and by properly dealing with natural resource and energy problems, the industry has been playing a role of the driving force to raise the nation's industrial structure in developed countries.

On the other hand, most developing countries have been regarding the iron and steel industry as a symbol of industrialization of the country, and planning to develop it as a national policy, and the development of the iron and steel industry will:-

- improve not only self-sufficiency of iron and steel, but also
- accelerate employment,
- save foreign exchanges, and
- promote the development of steel consuming and supporting industries.

Thus, considering that it will be beneficial for a developing country to develop the iron and steel industry as a national policy even if its products will be more expensive than imported ones during the early stage of the development, the developing country will have been planning to develop its own iron and steel industry.

However, a modern iron and steel industry will:-

1) require an enormous amount of construction funds as minimum economical capacity limits have become so large,

2) need to secure a long-term stable supply of raw materials and energy sources. Depending on the relative difficulty to secure them, the iron- and steelmaking process will be determined, and

3) require high standard techniques and skillings to operate such integrated iron- and steelmaking process as a system, and the national economy to have reached a relatively high development stage.

In view of the above consideration, the iron and steel industry in Pakistan, does not possess these conditions to take itself off.

Therefore, there are various economical and technical factors to be considered in the iron and steel industry.

Of these, iron- and steelmaking process, site of steelworks and size of plant are most significant.

(2) Iron- and steelmaking processes

There are, as described before, many routes for the modern iron- and steelmaking process. For making mild steel products on a mass-production base, the following three routes can be considered.

1) Blast furnace - basic oxygen furnace operation, i.e. integrated iron- and steelmaking (BF/BOF route).

2) Direct reduction furnace - electric arc furnace - subsequent metallurgical operation (DR/EAF route).

3) All steel scrap melting in an electric are furance - subsequent operation (SS/EAF route).

(a) BF/BOF route

This route is generally suited to a large-scale production. Therefore, the recently constructed integrated iron and steel mills adopting this route are provided with the production capacity of 3 million to 10 million tonnes per year. Because of its large scale, the route has shown a very high productivity and great economic efficiency.

The blast furnace ironmaking process requires high-quality coke, so that it is a prerequisite to secure coking coal as its raw material, and also to install ancillary equipment and facilities such as coke ovens. Nowadays this route will not use any other energy sources than coal as a main reducing agent. It will be, therefore, difficult for this route to conduct the diversification of energy sources. In addition, it is required to install pre-treatment equipment for the principal raw material, i.e. iron ore fines. As clearly seen from above, the route involves a large scale together with the requirement for relevant equipment and facilities, hence the route may call for a vast sum of the initial investment.

From a standpoint of plant operation, the route involves a great difficulty for the blast furnace to flexibly adjust the pig iron producing rate to be compatible to a series of subsequent processes. Nevertheless, when the blast furnace may be blown out for any reason, a lengthy period of time and a huge sum of expense are to be necessitated before it is blown in again.

Therefore, this route prevails generally in developed countries.

(b) DR/EAF route

In a direct reduction furnace iron ores (pellets and/or lump) are reduced in their solid state, and the resultant DRI will be charged into an electric arc furnace. Thus it is possible to flexibly adjust the running production rate. The DR furnace can provide a lower rate operation, and even it is stopped of its operation, it requires only a very short period of time before it resumes its operation. Hence, high flexibility is provided by the furnace. But where the purity of DRI may be of lower grade, the material would consume a great deal of power at the subsequent processing stage by the electric arc furnace. It is a general practice to use the high-grade iron ores with 66% or higher content of Fe.

For reducing agents, natural gas or solid fuel is generally used. Availability of cheaper raw materials and fuels is the prerequisite. The investment cost for the DR/EAF route is said to be lower by approximately 25% than the BF/BOF route. In the case of the molten steelmaking cost, the former has some reports that the cost is lower than that of the latter. In general, the operation cost is always subject to the costs of power, gas and raw materials.

(c) SS/EAF route

The key-point is the supply of material, i.e. steel scrap. Where the steel scrap is unavailable in the domestic market, its only source must be the imports.

However, scrap is generally subjected to fluctuation of market price to a great extent, in that its supply is always far from stable. It is, of course, desirable that the cost of electric power is maintained low.

Recently, this process is being looked at again to replace the open-furnace process or less efficient blast furnaces of old type, for instance, in U.S.A. because this route is characterized by smaller energy consumption per tonne of steel product, and capital cost and size of equipment.

Although it is not easy to perfectly foresee future energy conditions, various research and development works are being carried out in order to diversify energy sources for iron- and steelmaking including the production of coke from steam coal, injection of pulverized coal or tar into blast furnaces, use of steam coal in direct reduction. Even if energy sources are diversified and the continuous production process is developed, there will be no basic changes in the three routes above-mentioned during the coming 20 to 30 years, even if there will be some variations.

Whatever an adopting route may be, various factors including demand of steel will be taken into consideration, and the factor of energy and raw materials will occupy an important role in the consideration.

If a country which has no raw materials for iron- and steelmaking decides to construct a modern integrated steelworks, it will have to construct a steelworks at seashore provided with a port which is accommodated large ships. Modern steelworks in Japan and/or in Europe are good examples. It is clearly more economical to produce iron and steel at seashore than to produce iron and steel after transporting raw materials to an inland point where even the demand of steel exists.

For countries with rich iron ore and energy resources, it is common to construct a steelworks close to energy resources such as natural gas or coal than close to ore resources. Needless to say, the location for steelworks will be eventually determined in view of the existing infrastructure, transportation and places where products are demanded.

Raw material conditions as mentioned, will have a great impact upon the selection of a steelmaking process and the determination of site of a steelworks.

(3) Techno-economical capacity limits

Table 5.1.1 shows techno-economical capacity limits for a number of process steps and plants.

The techno-economical capacity is defined as an approximation of what could be considered, under normal circumstances, the lowest technically and/or economically viable layout capacity for a given plant or plant configuration.

This type of data are referred for their comparative rather than their absolute value, and they may also serve as a kind of fixed point to which the further train of thought can be related.

In context with techno-economical capacity limits the general principle of the economy of scale would be referred as shown in Fig. 5.1.1.

The point is that one cannot as yet take any appreciable advantage of the economy of scale while operating near or at the techno-economical capacity limit which is reflected in an operating point towards the left end of the economy of scale line.

Table 5.1.1 Techno-Economical Capacity Limits

(Unit: 1,000 tonnes/y)

Process Step	Type of Plant	Techno-Econo. Cap. Limit	Modern Capacity Range
Ironmaking	Blast Furnace	1,000	3,000 - 6,000
	Direct Reduction Furnace	900	400 - 600
Steelmaking and Casting	EAF + Billet Cast	120	400 - 800
	BOF + Slab Caster	1,000	2,000 - 3,000
Steel Rolling	Rod & Wire Mill	100	300 - 600
Long Products	Heavy Section Mill	300	300 - 1,300
	Cold Strip Mill	200	200 - 1,500
Steel Rolling	Plate Mill	500	500 - 2,500
Flat Products	Hot Strip Mill	1,000	2,000 - 4,500
	Galvanizing Line	100	100 - 400
Processing Plant	Tinning Line	150	200 - 500

Source: JISF

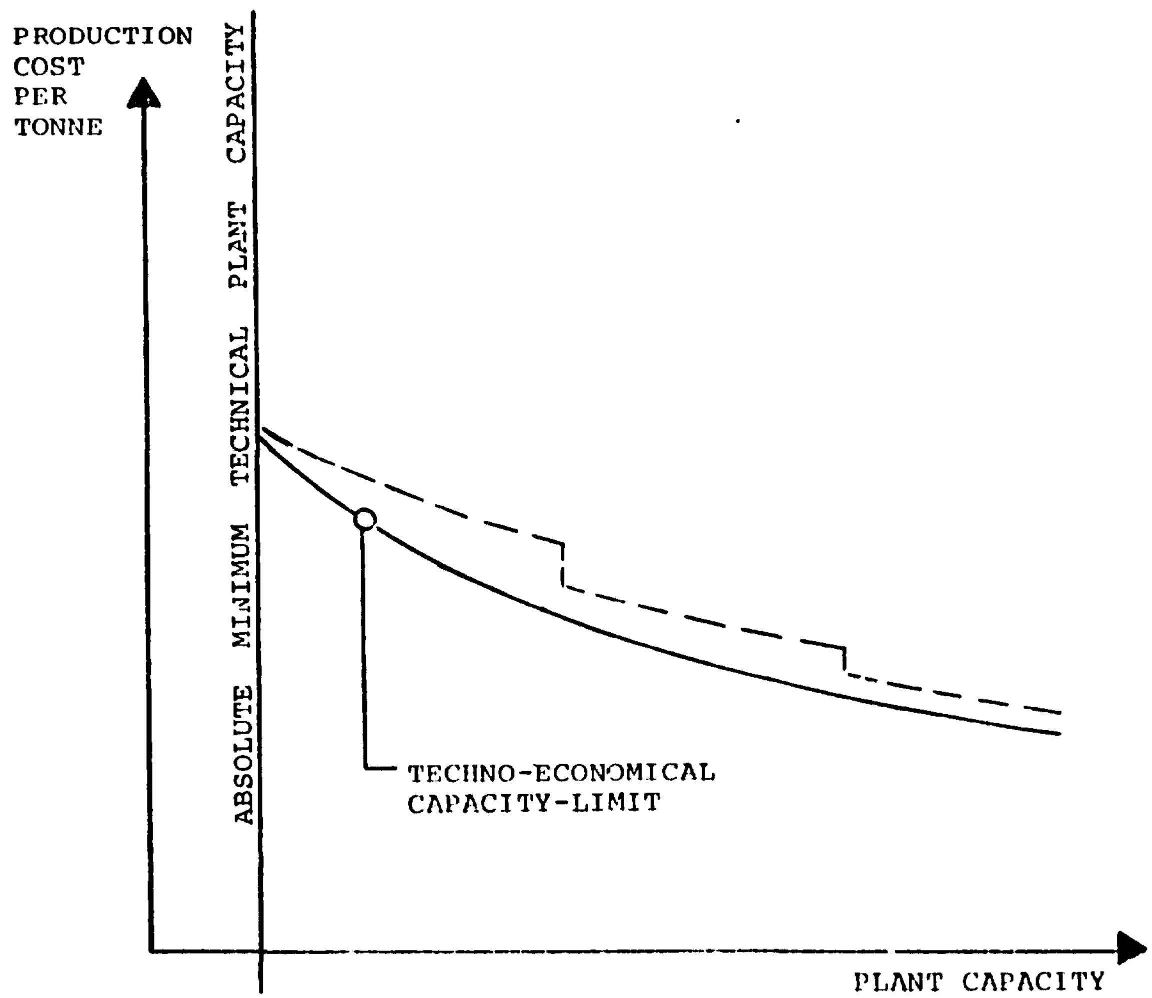


Fig. 5.1.1

Principle of Economy of Scale

Source: ISF

Relating the above to national steel development will show the following more clearly:

With regard to long products (or non-flat products), techno-economical capacity limits will hardly be a real criteria even for smaller countries, and domestic consumption alone will, in most cases, allow to take reasonable advantage of the economy of scale.

With regard to flat products, however, techno-economical capacity limits as well as low economy of scale may well present a problem for countries of smaller size and/or young industrial development.

5.2 Possibility Concerning Introduction of Modern Iron and Steelmaking Technology into Pakistan

As mentioned in Chapter 2, Pakistan has virtually no indigenous iron ores available at present. Domestic coking coal accounts for only 6% supply of consumption in Pakistan Steel. Meanwhile, steam coal is known to be deposited in Pakistan, but much cannot be expected both in terms of quantity and quality at present. Although it has some natural gas, there is apparently no excess production of natural gas to be used in steelmaking as it is fully loaded with industries. In order to use natural gas for steelmaking, Pakistan will have to replace gas for burning use with steam coal. Otherwise, it will have to develop new technologies to use steam coal for steelmaking.

Pakistanis iron and steel industry has to secure a stable supply of raw materials for steelmaking for economic stability, as it has to almost entirely depend on imports for both iron ores and coking coal for the time being. The world deposits of iron ores and coking coal are said to be sufficient to support the world steel industry for more than 100 years, but it should be remembered that natural resources are limited and known ones will be eventually totally consumed.

Meanwhile, indigenous raw materials should be utilized in future as a basic material policy of Pakistan. However as it will put in a great deal of work and time for the exploration them, the realization seems to need a long period of time from economical and technical points of view. Suitable strategies for indigenous raw materials will be discussed in Supplement.

As mentioned in 2.2.4 (5), it may be necessary to consider channels dredging at port Qasim as for reducing freight costs.

The proportion of the raw materials and energy costs to the total costs of producing steel is quite high, and those costs are said to account for more than half of the total costs of producing steel in countries which depend on imported raw materials and energy costs. From the standpoint of cost competitiveness, the development of production technologies means to reduce raw materials and energy consumption. In the blast furnace — converter process, such measures as ore pretreatment, production of high quality coke, blast furnace high pressure operation and oxygen enrichment have been taken to reduce fuel rates, to raise the efficiency of both hot-blast stove and re-heating furance and thus to save energy. At the same time, wastes such as dust, mill scale and waste acid have been minimized and also have been recovered in order to raise yield in ironmaking and rolling processes. Such measures are naturally expected to be taken in Pakistan Steel.

The steel industry enjoyed the merits of mass production through the operation of larger facilities prior to the first oil crisis in 1973. Following the oil crisis, however, such scale merits have been reduced and equipment costs have been raised to change the past direction of going larger. It may be said all research and development works to improve production processes and also to improve facilities are all oriented towards resource and energy savings.

Pakinstan Steel is expected to start commissioning in around 1984-85. Pakistani iron and steel industry is ready to introduce most advanced facilities and production technologies. Future iron- and steelmaking operation will be formed as a total system, not as a grouping of each individual process. In other words, there will be one-heat process, continuous process, etc. For example, continuous casting and hot rolling may be connected or a continuous cold rolling may be realized. These are the targets which advanced countries are hoping to achieve by 1990.

Therefore, even if these technologies are developed in advanced countries, their introduction will be after 2000 into Pakistan, in view of the accumulation of technologies and skillings. Fig. 5.2.1 shows a comparison of current process and possible process in indirect ironmaking route, and shows technologies which are likely to be introduced into iron- and steelmaking processes.

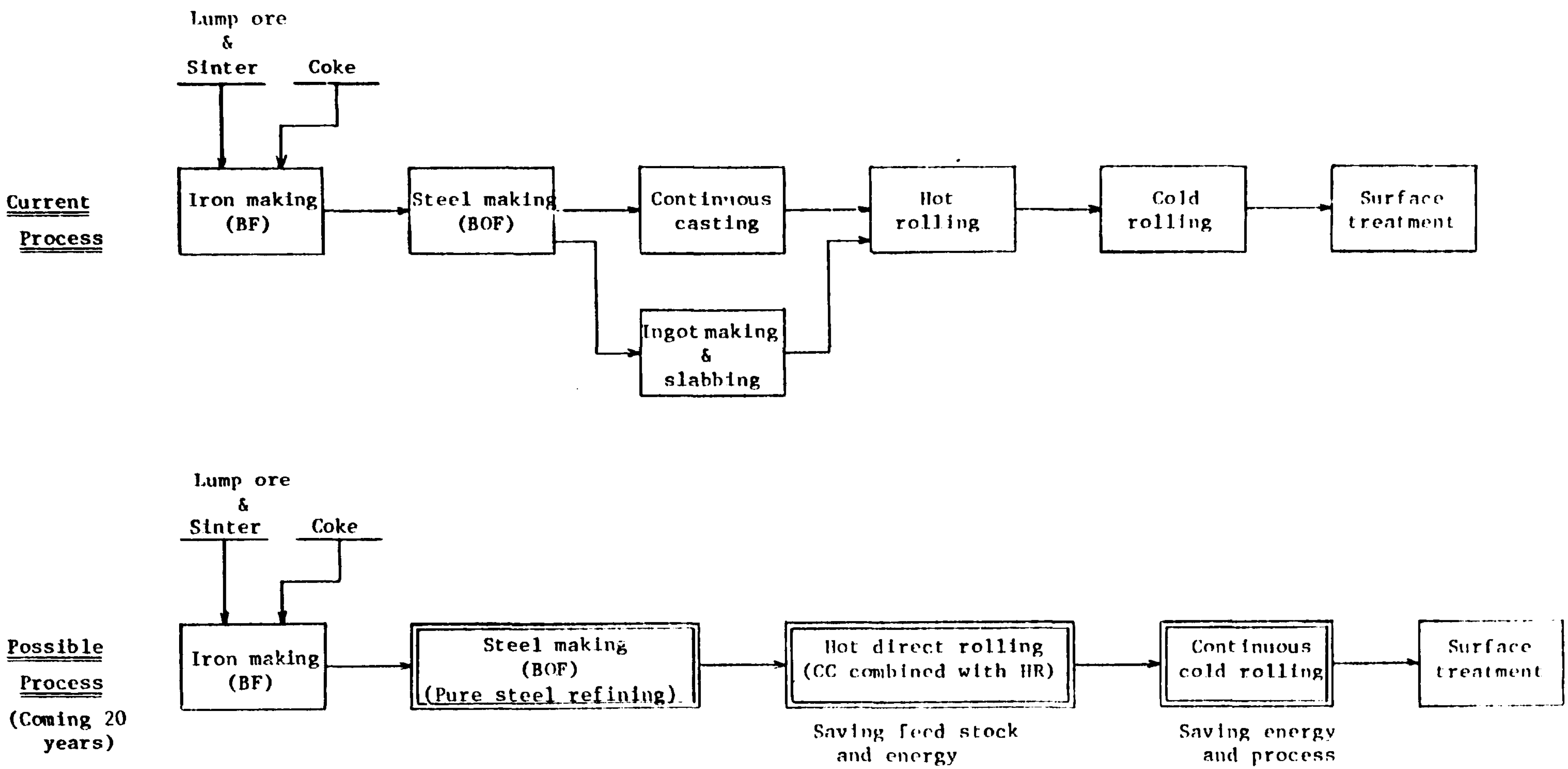


Fig. 5.2.1 A Comparison of Current Process and Possible Process in Indirect Ironmaking Route

As for another iron- and steelmaking process, cost minimization and energy saving are demanded in the process of ingot making from DRI and/or scrap. With respect to any requirement, a solution cannot be found in any single process such as DR furnace, EAF or continuous casting process. The solution must be found in a total system. Otherwise, there will be no future for each process. Therefcre, some technological assistances are needed during the initial stage when such a process is applied, but as Pakistan has a basis for the production of non-flat products, their production with this process is expected to progress relatively smoothly.

Fig. 5.2.2 also shows a future DR based integrated steelmaking process. DRI has a merit of being made into high quality steel with less quality fluctuation if it is produced from stable quality iron sources and under controlled conditions, though it contains less metallic iron comparing with scrap. Imported scrap tends to have fluctuated prices due to speculative deals, but DRI involves no speculative elements even if ore and other raw materials have cost rising as shown in Fig. 4.2.9, and thus long term planning is possible with DRI. Therefore, there are strong needs for DRI in Pakistan. If a stable supply of raw materials and energy source is secured, DRI is likely to be realized soon.

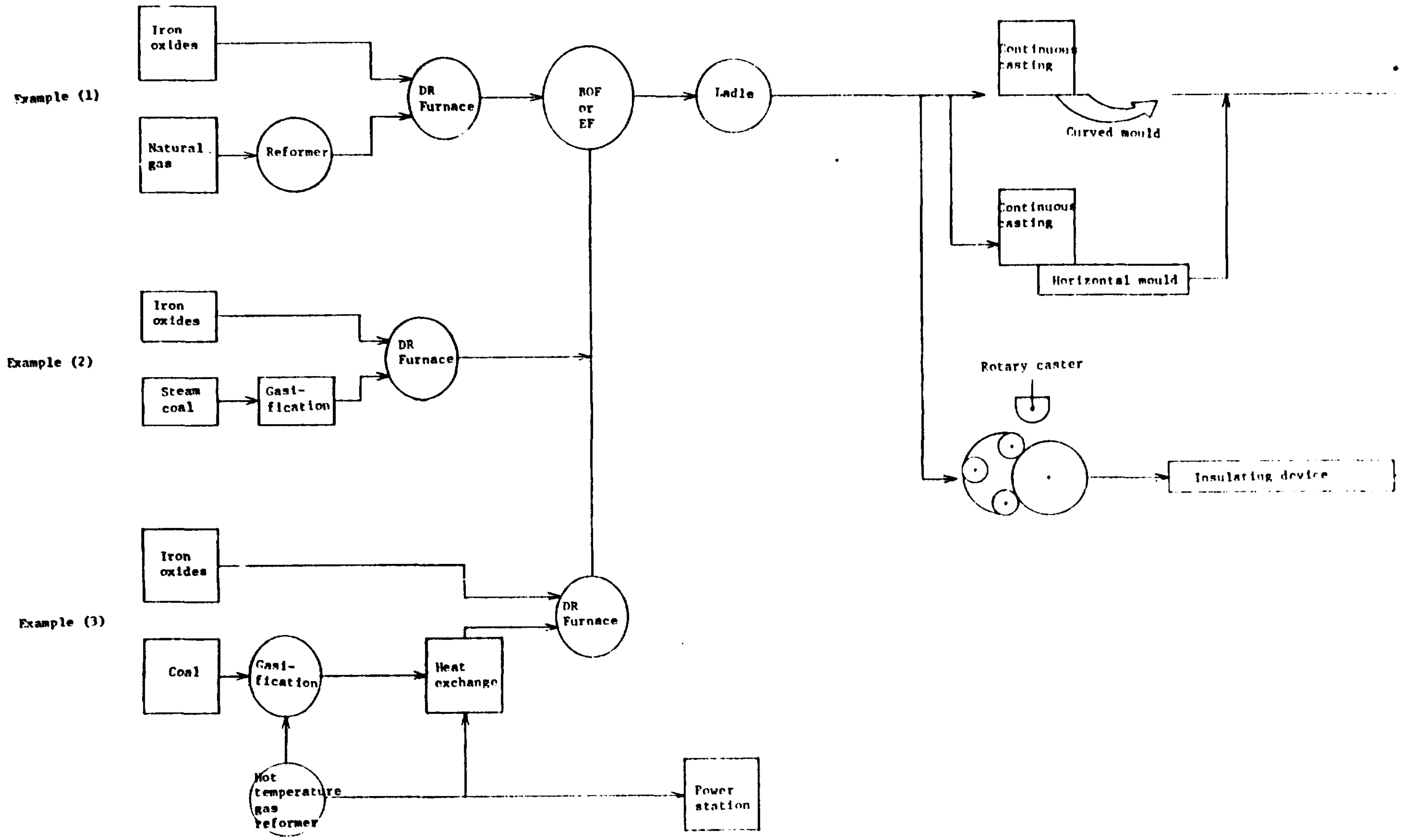


Fig.5.2.2. Possible Iron - and Steelmaking Process in Direct Reduction Route for Coming 20 Years

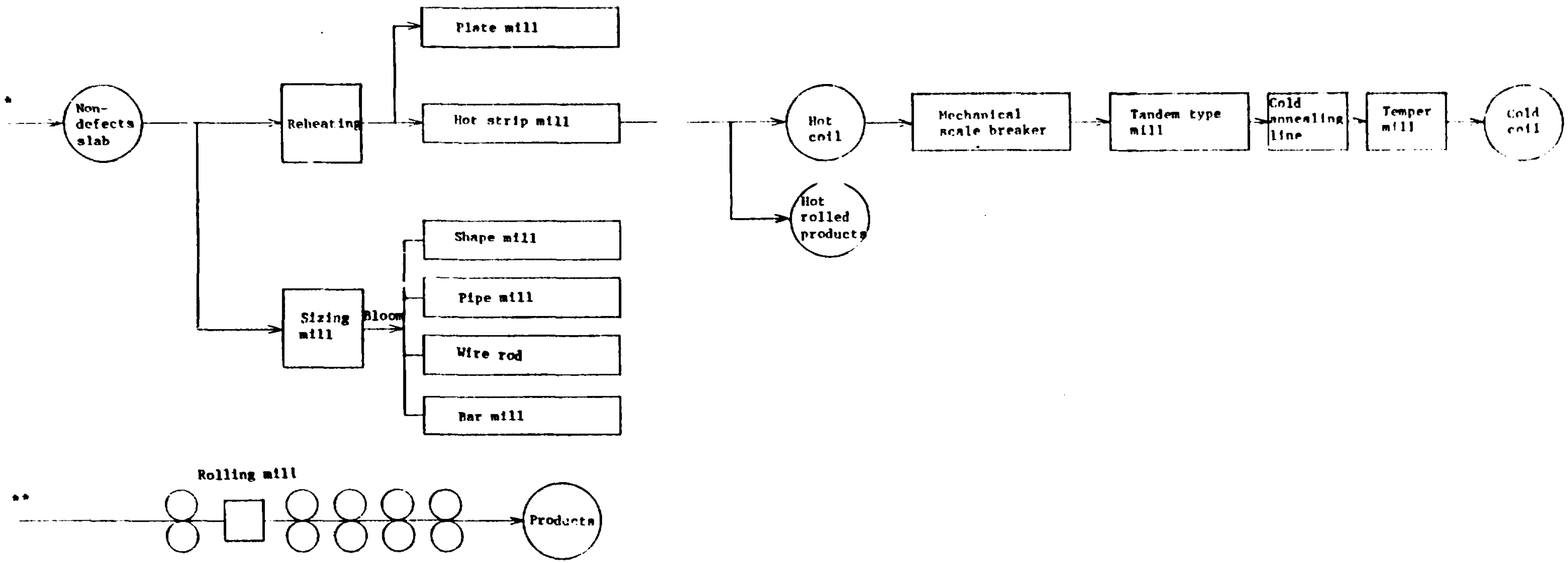


Fig.5.2.2. Continued

5.3 Projection of Pakistani Iron and Steel Industry up to the Year 2000

5.3.1 General

In studying the prosepcts for the development of iron- and steelmaking technology in Pakistan, the trends of iron and steel products in the market, i.e. the kind, quality, demand quantity and prices of products re-quaired in the market, will play an important role. However it is almost impossible to forecast these factors accurately over a period of about 20 years. Especially the forecasts for the latter 10 years have much room for errors.

It is generally said that a project requires about five years from its decision to commissioning, and another about five years to reach the stage of full operation. Therefore it may be possible to make the forecasts on some limited items of a master plan with a 20-year period over the initial 10 years, but it is very difficult to do it over the second 10 years.

When the Pakistani iron and steel industry is examine based on the above viewpoint, the iron and steel production facilities in Pakistan are generally 20-30 years behind the world's modern facilities in the design criteria. Since Pakistan has some grounding of the manufacturing techniques for steel bars and small-size sections, it may reach the present world level in these fields in the 20 years to come.

It is the first attempt in Pakistan to manufacture iron and steel, mainly flat products by the choice of BF/BOF process. This process must function as a single system from the up-stream to the down-stream equipment.

Therefore about 10 years may be enough for Pakistan Steel to master the manufacturing techniques in each field, but it will take another 10 years, i.e. totally 20 years to operate a single coherent system of iron- and steelmaking in high efficiency.

Only heating and melting, or heating and rolling the feed stocks procured from somewhere have so far been responded the purposes of the Pakistani iron and steel industry. But when they want to operate the above modern equipment as a coherent system, they should introduce the industrial engineering process and make the process and quality control.
Pakistan - not only it. iron and steel industry but also all the industries – is considerably behind other countries in this respect.
For these reasons including this point, it will take Pakistan Steel a lot of time to make efficient operation of the modern iron and steel production equipment.

5.3.2 Prospects for the existing melters and re-rollers

It is estimated that the existing steelmaking plants in Pakistan are equal to the Japanese steelmaking industry about 30 years ago in the scale of melting and ingotmaking equipment, the unit costs of productivity, electric power, electrode and refractories, and the levels of actual operation techniques, except for some manufacturers who have introduced continuous casting process.

In the 1st half of 1980's, the use of oxygen gas, the water cooling of the furnace wall and roof and the feeding of auxiliary materials using a small-sized changer will occur in EAF with a mroe than 5-tonne capacity, while the continuous casting process will be adopted in some works. These will not be made to improve the productivity and yield,and reduce the unit cost, but will be made only following other works' steps. No idea of industrial engineering seems to lie in these movements.

In the latter half of 1980's,the increase in EAF transformer capacity and the introduction of an oxygen fuel burner will be introduced into EAF's with a mroe than 10-tonne capacity, provided that the conditions of electric power are improved.

In melting facilities with a less than 5-tonne capacity, on the other hand, the consolidation or abandonment of them may be discussed as the limit of scale merits has been reached.

In 1990's, the consolidation or abandonment of 5-tonne class furnaces will be done though it will much depend upon the demand of steel, and the construction of high-performance steelmaking plants equipped with a 40 to 70-tonne class UHF EAF and a billet continuous casting machine will be considered.

In the latter half of 1990's, the unit costs of productivity, yield, electric power, electrode and refractories will approximate to the levels of those in the same-scale steelmaking plants at present in the world. Further the Pakistani industrial standards and their quality standards will be established, and crude steel shall be produced according to the standards. Some small-sized EAF's and IF's will be used for manufacturing the special steel or for melting cast iron in place of cupolas.

As for rolling technology in the present Pakistani industry, there is virtually no standards or specifications for chemical composition and physical strength of steel, except for twisted ribbed bars (Tor steel) and some steel products with specified customers.
It can go so far as to say that any rolled products can be sold only if they are low in price, no matter

what chemical composition or physical propeties they may have. Under these circumstances, the supply of cheaper raw materials and the simple operation rather than the cost reduction through technical improvements on the rolling process tend to be pursued. No large technical improvements can be expected in Pakistan on the whole,though some efforts to improve the efficiency and yield will be made in individual mills. The rolling operations by the tong working system of old and small-sized 3Hi type mills will still continue in future.

It will be the quality of bar and section required in the market that innovates in such technical trends. Namely, the investments on new rolling mills or the remodelling of the old will be made mainly by the major manufacturers within a payable scale, and technical improvements will follow them, when the time has come when the warranty of chemical and physical properties of the products become necessary or when the demand for steel products with the stringent standards of shape, size, length and straightness has so increased that it is difficult or commercially not feasible to manufacture them by the existing 3Hi type mills. This will progress in the way that the tong rolling operations by the old 3Hi mills are replaced and driven out by the introduction of 2Hi continuous mills with the tandem alignment. This progress will be remarkable in the field of small-sized steel bars up to 50mm in diameter where the technical and economic effects of the continuous type mills are easier to appear. On the other hand, this will make the 3Hi mill rolling method concentrate in the field of mild steel bars and lead to the separation of the special steel rolling industry from the mild steel rolling industry.

Although depending upon the market conditions, the introduction of these 2Hi continuous type high-speed steel bar mills will begin from the latter half of 1980's, judging from that the introduction of such modern equipment is now limited only in PECO, Ittefaq Foundry, and Metropolitan Steel, that the standardization has been made for twisted ribbed bars as mentioned previously and that the quality of the steel which is imported into Pakistan.

This continuous type high-speed mill will facilitate improving the adjustment technique of reheating furnace, rolling, mill guide device and electrical operation. In the case of Japan, the transfer from the old 3Hi mills to 2Hi continuous steel bar mills which had begun from about 1960 required about 15 years to reach the stage of invention of a high-speed and large-sized mill. In the field of section, the wide flange beam of which manufacture started with that of the conventional 3Hi and 2Hi rolling mills in the latter half of 1950's led to the introduction of universal mills about 5 years later and took over the leading part in large-sized section rolling operations about 10 years further later.

In the field of wire rod rolling, the repeater type continuous rolling which had begun in 1955 marked an epock in the conventional manual tong rolling history, and considerably improved the rolling speed, coil unit weight and product quality. It also led to the invention of the present high-speed mill about 10 years later.

These developments in Japan are needless to say not always applicable to Pakistan. However, it will be proper to forecast that the manufacturing techniques for bars and sections in Pakistan will reach the present Japanese level by the year 2000, provided that the market is active and the down-stream conditions can promote such technical developments, considering the Pakistani experience of rolling bars and sections cultivated and accumulated by the rolling operations, though manual, using 3Hi rolling mills; the circumstances where such perfect high-efficiency equipment and operation techniques can immediately be imported, if wanted, because they are already existing today unlike Japan in those days, and that the modern continuous operation of iron- and steelmaking is going to start in Pakistan Steel.

5.3.3 Prospects for Pakistan Steel

Its equipment level is almost equal to the Japanese level in 1960's and its operation technique is almost none. It is possible to introduce new techniques and equipment at a rapid tempo, but it will take considerably time to reach the stable operation conditions because much experiences must be accumulated in order to obtain high operation techniques.

The 1980's is a period for the training to master the existing facilities. Therefore, there will be some technical introductions necessary for stable operations, but there will be no introduction of new technologies and new equipment during this period.

In the 1st half of 1990's, the operation will fairly become stable and the output approximate to the nominal capacity will be able to be obtained, provided that the demand is enough. Further, in the technical aspect, improvements on the productivity of the existing facilities and decrease in the unit costs will be made rather than the introduction of new technologies and equipment.

Meanwhile, a process computer system will be introduced.

In the latter half of 1990's, the operation will become almost completely stable; the doubling plan will be discussed; new technical introductions will be planned, and on the other hand, the stricter process and quality controls will be required to meet the demands for higher quality products.

Fig. 5.3.1 shows possible processes into Pakistan Steel in the future.

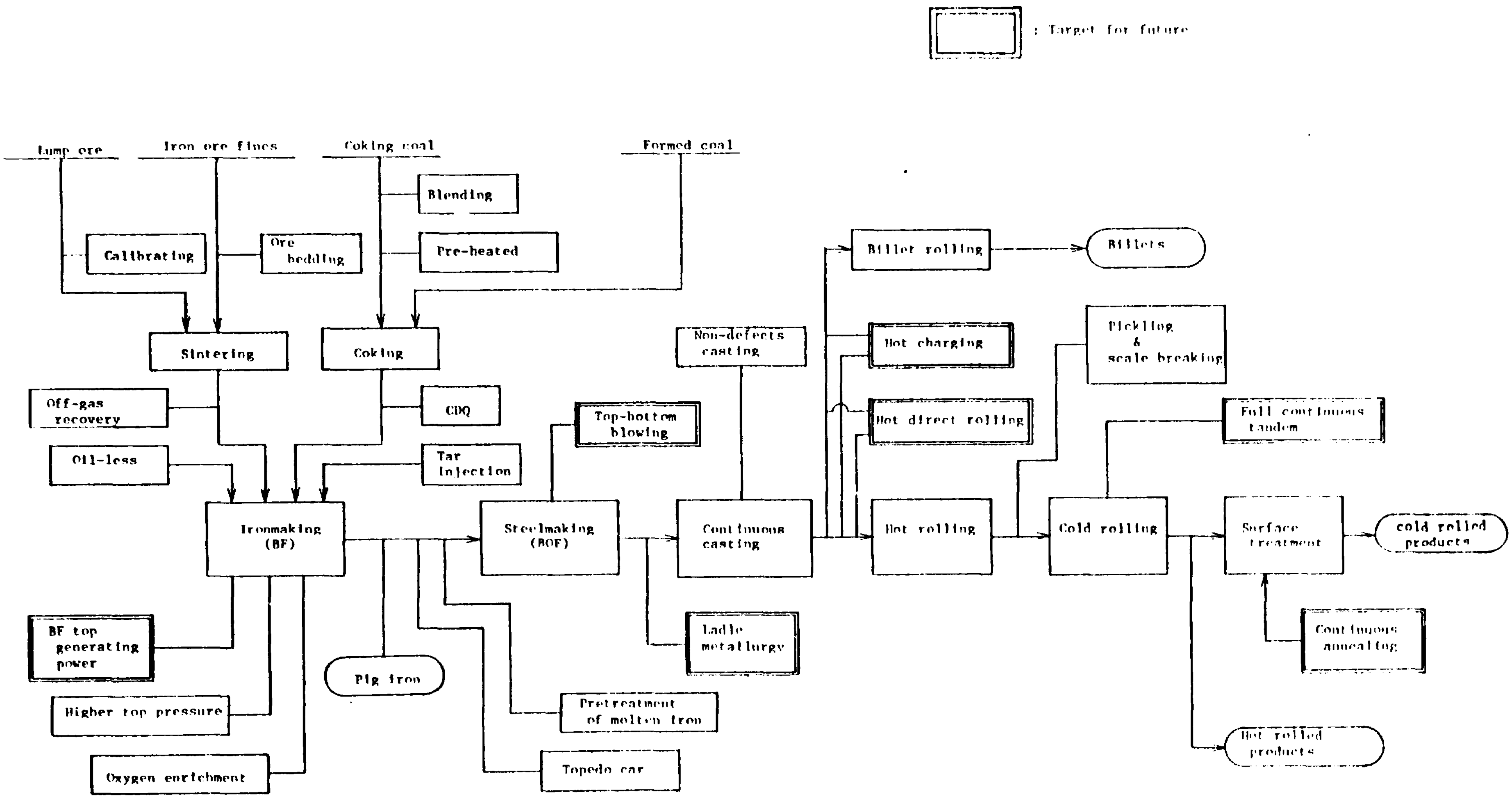


Fig. 5.3.1 Possible Processings into Pakistan Steel (for Coming 20 Years)

6. PROSPECTIVE PROJECT STUDY

In the preceding chapter, we have assessed applicable advanced technologies to the steel industry in Pakistan from among the modern iron and steel production technologies in the world described in Chapter 4. In Chapter 3, we forecasted the future demand for steel products in Pakistan up to the year 2010.

By various kinds of criterion, namely technology, economics, demand and so on, we assess and select possible future projects, which we call future possibility of new installation of production unit. In these Projects, some of them are alternative and may not allow to exist the other, and others are non-competitive with each other and can coexist. In this chapter, that classification, alternative or coexistent, will be put aside, and prospective Projects shall mainly be determined.

6.1 Screening of Project

6.1.1 Projects for Raw Materials and Semi-finished Products

(1) Pelletizing Plant

Currently, there are no demands at all for oxide pellets in Pakistan. When Pakistan Steel, currently under construction, starts the operation, oxide pellet can be used as a burden for its BF. However, the price of pellets for their iron content is relatively high as compared with lump ore or sinter. In general, pellets are playing the role of buffer as adjustment of chemistry of raw materials or additional input of pretreated iron ore to increase iron production.

The ratio of sinter to ore in Pakistan Steel remains at 65% to 35%, and only 10% of whole burden (approx. 150,000 tonnes/year) can be replaced by pellets as a part of lump ore.

As for DR pellets, there is no DR plant in Pakistan now, but there is a possibility of DR plant in future, which is described later. Even in such a case, demands will remain at around 1.8 million tonnes/year at maximum in or around 1995.

Considering the economical size and location of a pelletizing plant, only a pessimistic conclusion will have to be drawn. About the size of the plant, it was once said that the minimum economical scale of production would be 2 million tonnes/year. In recent years, however, it is said to be 3-4 million tonnes/year. In recent years, however, it is said to be 3-4 million tonnes/year because of increased fuel cost and popularity of large-size facilities.

As to the plant location, 1) in the vicinity of a iron ore sources for pellets, 2) an area where energy cost is low in order to reduce soaring fuel expenses, 3) an area where a large consumer for pellets lies, these three points are considered as the likeliest locations. In Pakistan, none of the areas will meet these requirements for the time being, therefore a pessimistic view has come out.

(2) DR plant

As described in Chapter 2, CURRENT SITUATION OF PAKISTAN STEEL INDUSTRY, the existing ingot makers in Pakistan are fully (100%) dependent on scrap, the raw material. There are various opinions on the future supply and demand for steel scrap in the world, a part of which was already described in Chapter 5. In particular, majority of the opinions is pessimistic on the scrap supply in the future.

Some of those worries have already proved to be true in Pakistan. The existing ingot makers are unable to fully utilize their installed capacity and their utilization ratio of capacity remains at around 64%. This is mainly because they cannot secure stable supply of steel scrap. There are variable reasons for the unstable supply of steel scrap. Complex formalities required for foreign exchange allocation, and acquisition of import licenses, political restrictions and so on. And it is also principal reason that steel scrap itself is fluctuating in the supply quantity and price in the market.

The best way to settle these problems associated with materials is import or production of DRI. However, there has not been established any route through which stable supply of DRI can be provided. Also there is no guarantee for long-term stable supply of DRI at reasonable price.

Accordingly, the best way is to set up a DR plant and to make best use of natural gas which is fortunately available in Pakistan and which price is rather cheap. Based on this conclusion, we have taken up as Project to set up a DR plant for supplying its products to ingot makers.

(3) Ingot/billet production

Ingot/billet demands are calculated from the figures listed on Table 6.1.3, which is the forecast of future production of rolling mills. Meanwhile, we made a forecast of ingot/billet production capacity for the next 20 years. Looking into individual business, we notice that some of them will have to shut down their plants because of the aging facilities, and withdraw or drop out from their businesses, while some others may replace their facilities by new machinery and equipment or introduce up-to-date steel mills, and realize expansion of their production capacity. Additionally new-comers may create their capacities. Factors leading to increase or decrease of production capacity are complex and intermingled together.

In our estimate, we assumed that the existing production capacity will be maintained as a whole although there may be changes among individual businesses. However, we are anticipating gradual increase due to technological improvements and minor investment for their equipment.

On the contrary, as to these production capacity of ingot/billet, their demands are estimated at a little bit lower level than that, because these demands were assumed without increase of rolling mill facilities.

In dividing the demands into Pakistan Steel, ingot makers, shipbreaking and re-rollable scrap, we kept in mind Pakistan Steel's billet manufacturing capacity of 380,000 tonnes per year. We estimated figures as a model case by paying attention to the supply capacity of shipbreaking industry and existing ingot makers and to the significance of existence and sound future development of those industries. The results are shown in Table 6.1.1.

Table 6.1.1 Supply and Demand of Ingot/Billet for Non-flat Products

Year	1979-80	1984-85	1989-90	1999-2000
Demand	642	734	980	988
Supply Capacity:				
Pakistan Steel	-	380	380	380
Ingot maker	512	555	584	642
Re-rollable scrap (including shipbreaking)	250	250	250	250
Total	762	1,180	1,214	1,272
Supply:				
Pakistan Steel	-	240	380	380
Ingot maker	362	344	350	358
Re-rollable scrap (including ship-breaking)	175	150	250	250
Total	537	734	980	988

From the above table, when Pakistan Steel starts supplying billets, the ingot/billet market will be oversupplied. It means that there is no need to newly install facilities with an objective to supply only the billet in Pakistan.

6.1.2 Projects for Final Products

(1) Demand projection

Actual demand for steel products in Pakistan are revailed by conducting a fact-finding survey spending over a month in the field, and future demand up to the year 2000 are forecasted by the most sophisticated method for steel demand projection. The results are described in detail in Chapter 3. Its summary is showed in Table 6.1.2.

Table 6.1.2 Current and Future Demand of Steel Products in Pakistan

(Unit: 1000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Non-flat products:				
Bars	381	505	688	1,265
Wire rods,wires	39	53	73	139
Sections	206	280	387	717
Rails	39	51	68	122
Seamless pipes	2	3	7	17
Total	667	892	1,223	2,260
Flat products:				
Plates	21	32	56	130
Hot rolled sheets	153	214	306	591
Cold rolled sheets	131	188	274	539
G.I.	52	76	116	230
Tinned	77	116	181	370
Other coated	-	2	2	9
Welded pipes	51	73	106	217
Total	485	701	1,041	2,086
Grand Total	1,152	1,593	2,264	4,346

(2) Supply and balance projection

(a) Non-flat products

The main products of domestic supply of non-flat products in Pakistan are reinforcing bars, and next comes medium and small sized sections. These two product categories account for nearly 100% of domestic production of non-flat products.

In terms of production facilities, approximately 700 units of rolling mills are the suppliers of these products. As described in Chapter 2, most of these are miniature-size businesses. It is said that some of them are manufacturing steel products without any "business licenses", and that 200 units of them are out of business, and that a number of businesses are operated by relatives or family members alone. That is why it is difficult to get the actual situation of their business.

In these circumstances, the domestic output for 1980 is estimated at 609,000 tonnes from the side of material supply, hearing the opinion of the Pakistan Re-rolling Mills' Association officials and paying visits to some of the semi-integrated mills and re-rollers, and through reports on relevant surveys and studies.

For the future projection on output, we set up the following assumptions.

Various obstacles that may obstruct full utilization of production capacity are removed under an implemented policy, and production is determined only by the principles of the market economy. One of the difficulties is the fluctuation in price of re-rollable scraps and billets, and another is financial problem.

We made a forecast of rolling mill production capacity for the next 20 years. Looking into individual business, we notice that some of them will have to shut down their plants because of the aging facilities, and withdraw or drop out from their businesses, while some others may replace their facilities by new machinery and equipment or introduce up-to-date steel mills and realize expansion of their production capacity. Additionally new comers may create their capacities. Factors leading to increase or decrease of production capacity are complex and intermingled together.

In our estimate, we assumed that the existing production capacity will be maintained as a whole, although there may be changes among individual business. However, we are anticipating gradual increase due to technological improvements and minor investment for their equipment.

In other words, we did not include introduction of large scale new plants in the forecasted production capacity. Instead, we picked them up as future Projects in order to balance supply and demand.

The production capacity and projected production under the said prerequisite are shown in Table 6.1.3.

Table 6.1.3 Non-flat Supply and Demand Projection

(unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	667	892	1,223	2,260
Production Capacity:				
Pakistan Steel	-	120	120	120
Existing rolling mills	820	861	902	919
Total	820	981	1,022	1,039
Supply:				
Pakistan Steel	-	100	120	120
Existing rolling mills	574	668	902	919
Total	574	768	1,022	1,039
Balance	93	124	201	1,221

The reason why 1984-85 supply is less than the production capacity is because the demand in that year includes wire rods, rails and seamless pipes that cannot be produced at the existing production facilities, and they are excluded.

Considering Project for the future, we have to pay attention to these product categories included in the balance.

Included in the balance in 1989-90 are wire rods & wire (73,000 tonnes), rails (68,000 tonnes) and seamless pipes (7,000 tonnes), and each of them is quite small in quantity from that of the economic scale of rolling mills. Therefore, we can hardly take these up as Projects of single rolling mill in this context.

Only bar and section can be regarded as a production unit for non-flat production. During the 1993-94, bar/section supply shortage will reach 500,000 tonnes per year. Of this amount, 120,000 tonnes/year can be replaced with formed sections that will be supplied by Pakistan Steel, and yet there will be 380,000 tonnes shortage. Further in 1997-98, it is expected that over 800,000 tonnes will be in short.

To compensate for this much shortage, some sorts of new Projects have to be worked out. The followings are picked up at random as possible Projects:

1. Re-rolling mill for bars/sections
2. EAF semi-integrated steel works
3. DR integrated steel works
4. Down stream of Pakistan Steel

It is decided not to take up EAF semi-integrated steel works because of the long term instability of scrap supply, tightness of the market and unreliability of DRI stable purchase, as previously mentioned.

Also we did not hold positive stance in setting up bar section mill as Pakistan Steel's downstream. The majour reason for that is Pakistan Steel has a rolling capacity twice as much as that of its steel-making capacity. Therefore, Pakistan Steel should first utilize its own capacity and should not expand its rolling capacity before utilizing its existing capacity.

The second reason is that Pakistan Steel will soon have strong influence in the market of steel products. Therefore, from the view point of national economy, it should not be allowed for Pakistan Steel to launch an area where already many private businesses are growing, and drive them away from that area. It may be necessary to put limits on areas of state coorporation, and promote to grow up the vitality of private businesses.

Accordingly, even if Pakistan Steel gets involved in non-flat production activities, it should probably remain as a billet supplier.

As a conclusion drawn from non-flat product area, the folowings are taken up as Projects:

1. Bar-section re-rolling mill
2. DR integrated steel mill
3. Pakistan Steel billet supply

As for DR module it is generally considered more profitable from the techno-economical viewpoint to employ a larger module for instance, 600,000 t/y in consideration of the above-mentioned DR plant for DRI which substitutes for scrap.

The selection of the module is discussed in detail in Appendix to 6-2 and summarised as follows:

To adopt a 600,000 t/y module only for the exclusive purpose of supplying the ingot makers with DRI, the substitute for scraps, will be unreasonable not only from the viewpoint of demand volume as mentioned above, and also in view of the existence of shipbreaking industry and domestic scrap generation.

In view of the capacity of rolling mill it is inappropriate to make the scale of the DR integrated steel works for production of bar/section 600,000 t/y.

Combining the above two plans, a compromise plan is formed. That includes a 600,000 t/y module DR plant for selling 200,000 t/y of DRI to the outside and for inside manufacturing 400,000 t/y of bar/section. As an inplementation of installation following three cases can be considered:

1) to delay the start of whole production till 1993-94 when the demand for bar/section will grow enough.

2) To hasten a construction of the whole DR integrated steel works sacrificing its low efficient operation for several years from the start-up, and

3) First of all to install only a 600,000 t/y DR plant enduring its low efficient operation, and the installation of the downstream is postponed until the demand for bar/section has grown enough.

Out of them, the third case is expected to have the least loss and then it is compared with a case where each 400,000 t/y DR module is installed for production of DRI for sale and for the integrated steel works. As a result, we have concluded that the latter 400,000 t/y module is superior and recommendable.

(b) Flat products

As for the production of flat products in Pakistan up to now, there are only hoops in a small quantity, which were re-rolled from shipbreaking scrap, and almost no other products. If Pakistan Steel, currently under construction, starts up, it will supply most of the demands.

In forecasting Pakistan Steel production, we made a projection on its start-up learning curve by referring to examples of start-up operation of BF integrated steel works in advanced countries and developing countries. The learning curve and product mix for start-up are described in detail in Appendix to 6-1. The effective capacity of Pakistan Steel is assumed as 1,050,000 tonnes/year, setting up the rate of effective production capacity to nominal capacity as 95.5%, which is the same of Japanese result as the most ideal case. Those rates of the main steelmaking countries are shown in Table 6.1.4.

Table 6.1.4 Rate of Effective Production Capacity to Nominal Capacity

Germany (GFR)	91.3 %
France	86.7
Italy	86.3
United Kingdom	82.1
Spain	95.9
U.S.A.	97.2
Canada	95.3
Australia	97.8
Japan	95.5
Argentina	67.8
Mexico	65.6
Venezuela	79.0
Latin America, Total	82.0
India	79.8
Korea (ROK)	92.3
Taiwan	89.7
Asia, Total (excl. Japan)	79.9
Egypt	46.5
Middle East, Total	59.3
Developing Countries, Total	79.6

Note: The concept of effective steel manufacturing capacity:

In estimating the worldwide steel production capacity, definition of capacity is the most important thing. At present, various steel-related international organizations and steel economists are estimating the effective capacity of the global and specific individual areas. However, their concepts of capacity are different. Here, effective steel production capacity was estimated by means of capacity

utilization ratio (* peak cut coefficient) of the year in which highest balance of supply and demand was experienced multiplied by the nominal capacity. In this method, all the restrictive factors have been taken into consideration, which factors are associated with raw material procurement, labor supply and demand, iron-making and rolling processes, market trend and environmental restrictions.
* Peak cut coefficient: It means the maximum utilization ratio in the year when there were heaviest demands.

The quantities of ... de steel thus calculated is allocated to billet and slab up to year 2000 to find out the supply and demand balance of flat products.

The quantity of billet supply by Pakistan Steel is 380,000 tonnes/year of maximum production, and the remainder as slab production quantity. Allocating the slabs to individual flat products, high value-added products are given first priority from a viewpoint of facilities utilization and sales maximization. Table 6.1.5 shows the results.

Table 6.1.5 Supply and Demand Projection of Flat Products

(unit: 1,000 tonnes)

	1979-80	1984-85	1989-90	1999-2000
Demand	485	701	1,041	2,086
Supply	-	470	623	623
Balance	485	231	418	1,463

However, by the year 1985-86 and 1986-87, the flat product market would not be well developed, and produced crude steel could not be fully consumed on the planned product mix basis, if the start-up production is satisfactory. Therefore, it is necessary to export the products or introduce new production facilities. This is a pressing problem and an important issue, and yet its significance is a little different from the future plans described in this chapter. For this reason, details of this issue are described separately in Appendix to 6-1.

(c) Expansion of Pakistan Steel

In considering the expansion of production capacity of flat products we should not forget that a hot strip mill of 1.8 million tonnes/year capacity will soon be installed in Pakistan Steel.

The capacity utilization of this mill will be around 40% at the stage of 1,100,000 tonnes of crude steel per year, and at the time of expansion, maximum utilization of it will be the most essential problem to be tackled with for Pakistan Steel. As to the size of expanding the production capacity of Pakistan Steel, doubling 2 million tonnes/year on a crude steel basis is most recommendable for the following reasons.

1) In the Pakistan Steel's original plan, layout is designed aiming at producing 2 million tonnes of crude steel per year.

2) As the second step from BF 1033 m^3 when having a 1.1 million tonnes per year production capacity, a larger BF of 1700-2000 m^3 scale is most appropriate.

3) To meet the capacity of the hot strip mill which is currently under construction.

In consideration of doubling Pakistan Steel from the view point of realizing the substantial production capacity of flat product, it is expected that the demand will nearly double in 1995-1997 period.

Generally considered possibility of Pakistan Steel expansion is as follows:

1) Product mix - rolling mill
   a) Considering utilization of the hot strip mill with only flat products in mind.
   b) Incorporating bar section into the project, and giving up utilization of hot strip mill to some extent in order to realize doubling earlier.

2) Iron-making and steel-making
   a) On a BF/BOF basis
      Just following the basic processes of the facilities which is now under construction.
   b) On a DR/EAF basis
      Connecting additional DR/EAF to the BF/BOF base which is under construction.

When contemplating on doubling the production capacity with only flat products in mind, what will happen to product mix will be as shown in Table 6.1.6.

Table 6.1.6 Possible Expansion (1) of Pakistan Steel

(Unit: 1000 tonnes/year)

		Demand (96-97)	Supply (96-97) Existing Plant	Expanded Plant	Increment
Product mix					
Plates		108	-	-	-
Hot rolled sheets		506	260	450	+190
Cold rolled sheets		459	90	390	+300
Galvanized sheets		195	100	180	+ 80
Tinned plates and sheets		313	-	250	+250
Other coated		7	-	-	-
Welded pipes		184	*(20)	*(160)	*(+140)
Flat total		1,668	470	1,430	+960
Formed sections		-	120	120	-
Billets		-	380	380	-
Steel products total		-	970	1,930	+960
Cast iron		-	135	135	-
Cokes		-	215	215	-
Facilities					
Slab CC	Production		(650)	(1,700)	(+1,075)
	Capacity		825	1,700	+875
Bloom CC	Production		(400)	(400)	(-)
	Capacity		480	480	-
Billet mill	Production		(380)	(380)	(-)
	Capacity		380	380	-
Hot rolled mill	Production		(620)	(1,625)	(+1,005)
	Capacity		1,800	1,800	-
Cold rolled mill	Production		(200)	(830)	(+630)
	Capacity		200	830	+630

* mark indicates hot rolled coil or sheet supply to the existing pipe makers

Without limiting Pakistan Steel's product mix to flat products alone, the time of doubling its capacity 2 or 3 years earlier than listed in the above.

In this case, however, Pakistan Steel should not get away from the prerequisite that it is to fully utilize the hot strip mill. And it will pose a big problem if Pakistan Steel enter into the non-flat products in such a scale as to drive away other businesses in this field.

Therefore, a rolling mill should be set up separately from Pakistan Steel, regardless of whether by an existing business or a new comer, and Pakistan Steel should remain the billet supplier in non-flat field. For the category of non-flat products, it should concentrate other than reinforcing bars. For the annual production, we put the conceivable least amount which is 200,000 tonnes/year. The Table 6.1.7 shows the second plan.

Table 6.1.7 Possible Expansion (2) of Pakistan Steel

(Unit: 1000 tonnes/year)

		Demand (94-95)	Supply (94-95) Existing Plant	Expanded Plant	Increment
Prduct mix					
Plates		93	-	-	-
Hot rolled sheets		449	260	450	+190
Cold rolled sheets		406	90	330	+240
Galvanized sheets		173	100	100	-
Tinned plates and sheets		276	-	230	+230
Other coated		5	-	-	-
Welded pipes		162	*(20)	*(140)	*(+120)
Flat total		1,564	470	1,250	+780
Formed sections		-	120	120	-
Billets		-	380	580	+200
Steel products total		-	970	1,950	+980
Cast iron		-	135	125	-
Cokes		-	215	215	-
Facilities					
Slab CC	Production		(650)	(1,500)	(+850)
	Capacity		825	1,500	+675
Bloom CC	Production		(400)	((400)	(-)
	Capacity		480	480	-
Billet mill	Production		(380)	(380)	(-)
	Capacity		380	380	-
Billet CC	Production		(-)	(200)	(+200)
	Capacity		-	200	+200
Hot rolled mill	Production		(620)	(1,440)	(+820)
	Capacity		1,800	1,800	-
Cold rolled mill	Production		(200)	(470)	(+270)
	Capacity		200	500	+300

* mark indicates hot rolled coil or sheet supply to the existing pipe makers

Already Pakistan has more than ten manufacturers of welded pipes and tubes. Although the self-sufficient rate of pipe and tube has not been so high, they have obtained certain result up to now.

Taking the significance of their existance into consideration, no pipe and tube manufacturing facilities are not introduced for the expansion of Pakistan Steel in both possible cases (1) and (2). It is recommended to employ the policy bringing up these existing pipe and tube manufacturers to meet future demand and to consume the hot rolled coil of Pakistan Steel.

As for the iron and steelmaking route for the expansion of Pakistan Steel, DR-EAF route is not employed by the following reasons:

1) A.1.1 million tonnes per year BF integrated steel plant with built-in potential for expansion to 2 million tonnes per year.
2) Complecated layout.
3) Different tap to tap time between BOF and EAF.
4) Natural gas consumption.
5) Power consumption.
6) Coal back in premier role

These reasons are discussed in detail in Appendix to 6-3.

6.2 Selection of Site

With a large proportion of raw material cost in the iron and steelmaking cost, the iron and steel industry does handle so large quantities of bulk materials that it is called by another name of the raw material transport industry. Various factors must be considered for selecting the site of the industry, but the point will be focussed to whether the industry should be located according to the raw material conditions or at product consuming places.

In the second half of this Chapter, five prospective projects are proposed. Of them Project A is intended to supply the existing ingot/billet makers with DRI. This quarters of the ingot/billet makers are located at Punjab area, about a quarter of them at Sind area and some at other areas. The material for DRI is high-grade iron oxides (iron ores pellets and/or lump iron ore). As already mentioned, no high-grade iron oxide has been found in Pakistan by the surveys so far made. And it remains unclear when low-grade ores begin to be used after beneficiation for DRI, because of their quality, quantity and occurrence. Therefore it is inevitable to use the imported ores in Project A. A study will be made about whether Project A should be located according to the raw material conditions or at a consuming product place.

Proposed site	:	Sind or Punjab
Landed price of iron oxide at Port Qasim	:	US$50.00/tonne
Transportation cost of iron oxide	:	US$5.00/tonne (Port Qasim to Sind)
do	:	US$20.00/tonne (Port Qasim to Punjab)
Unit rate of iron oxide per tonne·DRI	:	1.5 t of iron oxide/t.DRI

Accordingly,

Unit cost of iron oxide per tonne·DRI	:	US$(50+5) x 1.5 = 82.5/t.DRI (at Sind)
do	:	US$(50+20) x 1.5 = 105.0/t.DRI (at Punjab)

Let the DRI price be 92% of the scrap price at the proposed site in Sind or Punjab.

Landed price of scrap at Port Qasim	:	US$150.00/tonne
Transportation cost of scrap	:	US$8.00/tonne (Port Qasim to Sind)
do	:	US$30.00/tonne (Port Qasim to Punjab)

Accordingly,

Ex works price of DRI per tonne (at Sind)	:	US$ (150+8) x 0.92 - 8 = 137.36/t (for Sind)
		US$ (150+30) x 0.92 - 30 = 135.60/t (for Punjab)
do (at Punjab)	:	US$ (150+8) x 0.92 - 30 = 115.36/t (for Sind)
		US$ (150+3) x 0.92 - 8 = 157.60/t (for Punjab)
Sales quantity for Sind	:	100,000 tonne/year
Sales quantity for Punjab	:	300,000 tonne/year
Sales revenue at Sind	:	US$137.36 x 100 thous tonnes/ year (for Sind)
do	:	US$135.60 x 300 thous tonnes/ year (for Punjab)
Sales revenue at Punjab	:	US$115.36 x 100 thous tonne/ year (for Sind)
do	:	US$157.60 x 300 thous tonne/ (for Punjab)
Average ex work price of DRI per tonne	:	US$133.54 (at Sind) US$137.04 (at Punjab)

Here,

Balance after deduction of iron oxide price	:	US$(133.54 - 82.5) = 51.04/t.DRI (at Sind)
do	:	US$(137.04 - 105.0) = 32.04/t.DRI (at Punjab)

But no tax is considered in both sites. The conditions and price of utilities, manpower and natural gas were found not very different between the two sites, and therefore handled as the same.

A surplus of about US$15.00/DRI tonne is left for Sind after the transport cost of iron ores were deducted.

From the above, the proposed site at Sind is more favourable for Project A, provided that the imported materials are used.

In Project B, the site is more favourable when it is nearer the Port Qasim as shown in the case of Project A, because the main material is DRI. Project C is also more favourable if it is located adjacent to Pakistan Steel, because it is the project where billets will be supplied from Pakistan Steel.

As for Projects D-1 and D-2, the enlargement of Pakistan Steel is of course conceivable. The survey of demand for flat products has found no need to install another factory than Pakistan Steel.

Pipri, Landi and S.I.T.E. which were candidate sites at Sind were examined and Pipri was found the best as it was the closest to Port Qasim, unloading port of raw materials. The Landi and S.I.T.E. site are too small to allow the construction of modern steelworks.

Therefore all the five Projects are based on the conditions of construction at seashore in Pipri.

In Projects A and B, the home-produced iron ores are priced at less than US$53.00/t ore at Punjab on the site. If high-grade pellets or lump ore with more than 66% of iron content are supplied, the site will be selected according to the raw material conditions rather than at a consuming product place, i.e. it will be selected at Punjab.

The comparison and examination of the sites were made based on an economic study of raw materials availability, in which no state policy was taken into consideration.

6.3 Prospective Projects

6.3.1 Summary

6.1, Introduction, reviewed the supply and demand situation of steel products in Pakistan up to the year 2000, and screened new project possibilities to compensate for the short of supply. Through further acceleration of the idea, the detail of Projects are described hereafter. We define Projects that are worth taking up from among individual possibilities of new facility installation in future iron and steel industry. The outlines of the taken-up Projects are provided in Table 6.3.1.

Table 6.3.1 Summary of Projects

Projects	Name	Basic Concept	Main Facilities (Additional only)	Product Mix (Additional only) 1,000 tonnes/year	
A	400,000 t.p.a. DR Plant	DRI supply as an alternative of scrap to existing ingot makers	. DR	. DRI	400
B	400,000 t.p.a. DR integrated	Effective dealing with new demand of non-flat products. Utilization of natural resources (Natural gas).	. DR . EAF . Billet CC . Bar-section mill	. Bar/Section	380
C	400,000 t.p.a. Rolling mill	Effective dealing with new demand of non-flat products. Utilization of existing supply capacity of ingot/billet.	. Bar-section mill	. Bar/Section	400
D-1	Pakistan Steel doubling for flat products	Effective dealing with new demands for flat products. Utilization of existing hot rolling mill.	. Sinter plant . Coke oven . BF . BOF . Slab CC . Cold rolling mill . Galvanizing line . Tinning Line	. Hot rolled sheets . HRS for welded pipes . Cold rolled sheets . Galvanized sheets . Tinned plates and sheets	190 140 300 80 250
D-2	Pakistan Steel doubling for flat and non-flat products	Effective dealing with new demands for flat procucts and billet for non-flat products.	. Sinter plant . Coke oven . BF . BOF . Slab CC . Billet CC . Cold rolling mill . Tinning line . Galvanizing line	. Billets 150 mm sq. . Hot rolled sheets . HRS for welded pipes . Cold rolled sheets . Tinned plates and sheets	200 120 140 270 250

6.3.2 Project A (400,000 tonnes/year DR Plant)

(1) Basic Concept

Considering the future growth of steel industry in Pakistan, what we should be very careful about is the fact that steel industry is already in existence in Pakistan. Therefore, the point is how further development and growth of these existing ingot makers and re-rollers can be realized. This is what one should think first.

To help them grow up, stable supply of scrap should be secured by those ingot makers, because the biggest reason for low utilization ratio is the unstable supply of scrap. To cope with this situation, it is quite reasonable to introduce DRI base operation which is less affected by the market situation.

It is possible to think of import of DRI from overseas suppliers. Up to now, there have been no cases of long-term distribution. Even if that is realized, it would be too risky to depend on a single source of supply, but if one is talking about two or more different supply sources, it would become less realistic.

Fortunately, Pakistan has abundant natural gas resources that can be used as reducing agent. Currently, natural gas is mostly used as a fuel which is said less effective way of consuming. Heat energy for domestic consumption should be replaced by coal, and good quality energy like natural gas should be used more effectively as chemical material and reducing agent in the steel industry.

On the basis of such a basic concept, we have taken up DR plant as one project. As to its operation scale, we have calculated 400 thousand tonnes/year on the basis of approx. 350 to 360 thousand tonnes/year of the current EAF production level. From the view-point of demand, it should be constructed as soon as possible. In selecting process of DR plant, the shaft furnace process is selected using natural gas instead of gassified coal as reducing agent, because a coal-based DR has no established technology for it as described in Chapter 5.

(2) Raw Material Plan

Iron oxides:

pellets	(67.5% Fe)	536,000 t/y
lump	(66% Fe)	60,000 t/y

Pellets will be imported from North Europe (Sweden, Norway) and South America (Brazil, Peru and Chile). (When a new DR pellet project is operated in India and Bahrain, both countries will be considered as possible suppliers.) As for lump, high quality ores from India and Australia are planned.

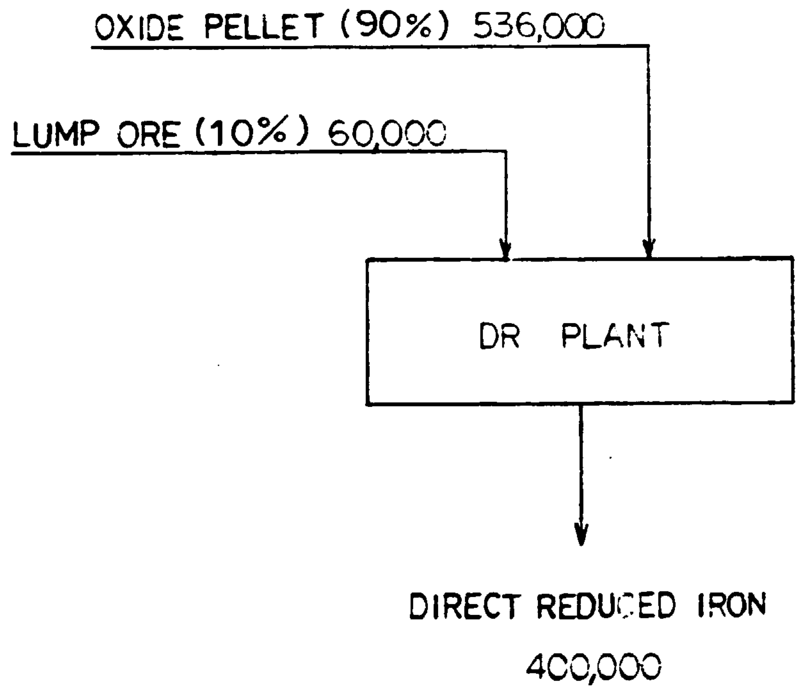
Natural gas: 185 million N m^3/y

Expected to be supplied from the existing network.

To put the plan into a concrete form, it will be necessary to review oil, gas and coal through a general energy plan.

Material balance is shown in Fig. 6.3.1.

Fig. 6.3.1 MATERIAL BALANCE PROJECT A



UNIT : ANNUAL TONNES

(3) Main Facilities

The main facilities of this Project consist of a direct reduction furnace which will produce 400,000 tonnes of reduced iron per year and its accessories. The Project assumes to utilize the existing raw material handling facilities.

A production capacity of 400,000 tonnes/year is an economically ideal size, representing the size of a typical reduction furnace. There are many reduction processes of which the most commonly used shaft furnace process has been adopted.

In order to produce DRI as products, a briquetting machine is equipped.

(a) Direct reduction furnace facilities

Production: 400,000 tonnes of DRI per year

Product : DRI of 92.5% metallization

Type : Shaft furnace process

(i) Direct reduction furnace: 1 set

Reducing capacity: normal - 52 tonnes/hour

maximum - 62 tonnes/hour

(ii) Top gas scrubber: 1 set

Direct water cooling type

Gas flow: 116,000 N m^3/hour

(iii) Cooling zone scrubber: 1 set

Direct water cooling type

Gas flow: 54,800 N m^3/hour

(iv) Reformer: 1 set

Vertical tube filled with catalyst

Upward gas stream type

(v) Material handling and transportation: 1 set

(vi) Briquetting machine: 1 set

(4) Plant construction plan

For the construction of direct reduction facilities, a total of about 36 months are required from the commencement of engineering works to the production of facilities to site preparation to ground works to equipment installation works.

(5) Manpower Requirement

(i) Worker for production and staff for administration are needed. The following staff will be required when the plant starts operation:

Production:	280 persons
Administration:	10 persons
Total:	290 persons

Out of 280 persons for production, about half will be general workers to handle materials. For the operation of the direct reduction furnace, a total of 60 persons will be needed as direct workers.

(ii) As a direct reduction furnace represents a new steel making process and is close to a chemical plant, some in-plant training will be generally needed prior to the commencement of operation. This training will require at least six months, and therefore should be started one year before the commencement of operation.

Trainees, around one-sixths of total workers, will be composed of workers for maintenance and direct operation workers for the reduction furnace.

6.3.3 Project B (400,000 tonnes/year DR Integrated Works)

(1) Basic concept

As mentioned in the last part of 2.2.4, Pakistan Steel, the Pakistan Steel is a steel mill which has enormous production capacity, being rather too big for the steel market in Pakistan. As a result, whether the Pakistan Steel wishes or not, it is quite possible that such a gigantic steel mill monopolizes the steel market.

This is considered a minus factor for development of the steel industry in Pakistan which advocates the free competition principle. Fortunately, that particular steel mill is specializing in flat product manufacturing. In case of integrated steel works for non-flat products or constructing a modern steel works of larger scale, it should be considered that a new company is established away from Pakistan Steel.

From the view point of reducing cost by sharing utilities, maintenance and administration departments, it could be one idea to construct a DR integrated plant inside of Pakistan Steel, because it is logically possible to add a DR/EAF within the framework of a BF/BOF layout.

Besides the above, we do not adopt such a Project for the reason that this will uncessarily make complex the physical distribution, because the basic system is different from each other, facilities that can be shared by both of them are limited, and therefore, this will not provide so many merits but many difficulties instead.

From such a view point, we have taken up as Project a modern DR integrated works in the form of a works completely independent from Pakistan Steel around 1994-95. Non-flat product supplies are expected to be short at that time around 400,000 tonnes per year. As we conducted a collective review on the plant site, some place of Karachi is considered most favourable location, because that place is close to Port Qasim where existing unloading facilities can be utilized. This Project should aim at mass production of steady quality products which are clearly different from the products of existing rolling mills, and should meet the objective of supplying high quality products at lower price.

As the reducing agent for DR, priority use of natural gas should be provided in the sense of its effective use from a national point of view as is the case of Project A.

(2) Raw material plan

Iron oxides:

pellets	(67.5% Fe)	536,000 t/y
lump	(66% Fe)	60,000 t/y

Pellets will be imported from North Europe (Sweden, Norway) and South America (Brazil, Peru, Chile). (India and Bahrain each has a DR pellet plant project, but neither project has been finalized.) As for lump, high quality ores from India and Australia are planned.

Natural gas: 185 million N m^3/year

Natural gas is expected to be supplied from the existing network. At the stage of the realizing in future, it will be necessary to review oil, gas and coal through a general energy plan.

DRI (92.5% M.Fe) 400,000 tonnes/year

DRI will be produced by the shaft furnace system from the above-mentioned iron oxides and natural gas as main raw materials.

Scrap :

Purchase scrap	(95% M.Fe)	50,000 tonnes/year
Return scrap	(100% M.Fe)	35,000 tonnes/year

Scrap will be purchased from domestic sources.

As other raw materials, lime stone, fluorite, ferro-alloy and carborizing agent will be needed. Lime stone, fluorite will be obtained from domestic sources. Ferroalloy will be imported. Carborizing agent will be coal or electrode waste as by-products.

Material balance is shown in Fig. 6.3.2.

(3) Main facilities

The main facilities of this Project 400,000 tonnes/year DR plant will be composed of the following four facilities:

Direct reduction furnace facilities

Electric are furnace steel making facilities

Billet continuous casting facilities

Steel bar/section steel rolling facilities

Of the above facilities, the direct reduction furnace will be the same as the Project A, without briquetting machine.

As for electric arc furnace steel making facilities, the most advanced high efficiency furnace of UHP and ladle metallurgy facilities are adopted. A billet continuously casting machine is a curved mould bending type to take construction costs into consideration. As for billet size, a larger size will be desirable for the stable, high efficiency operation of the continuously casting machine, but in order to avoid a large investment for rolling mill of down stream an economic 150 mm by 150 mm is selected.

The rolling mill is the most advanced one with tandems continuously arranged mainly for steel bar rolling at the speed of 15 m/sec. This mill is capable of producing at a high efficiency both small and medium sections.

(a) Direct reduction furnace

Production: 400,000 tonnes of DRI per year

Product : DRI of 92.5% metallization

Type : Shaft furnace process

(i) Direct reduction furnace: 1 set

Reducing capacity: normal - 52 tonnes/hour

maximum - 62 tonnes/hour

(ii) Top gas scrubber: 1 set

Direct water cooling type

Gas flow: 116,000 N m^3/hour

(iii) Cooling zone scrubber: 1 set

Direct water cooling type

Gas flow: 54,800 N m^3/hour

(iv) Reformer: 1 set

Vertical tube filled with catalyst

Upward gas stream type

(v) Material handling and transportation: 1 set

(b) Electric arc furnace steel making facilities

Production : 421,000 tonnes of molten steel/year

Tap to tap time: 160 minutes

(i) UHP electric arc furnace: 2 sets

Capacity : 70 tonnes/heat

Electrode dia.: 508 mm

(ii) Transformer for furnace: 1 set

Capacity: 37 MVA

(iii) Raw material handling equipment: 1 set

(iv) Additives handling equipment: 1 set

(v) Molten steel handling equipment: 1 set

(vi) Dust collecting facilities: 1 set

(vii) Cranes: 1 set

Ladle handling use: 120/35 tonnes/year

(viii) Ladle metallurgy facilities

(c) Billet continuous casting facilities

Production: 400,000 tonnes/year

Products : 150 mm sq. billets, 3 to 6 m

(i) Molten steel handling equipment: 1 set

Tundish, tundish car, etc.

(ii) Continuous casting machine: 2 sets

Curved mould bending type

Billet size: 150 mm sq.

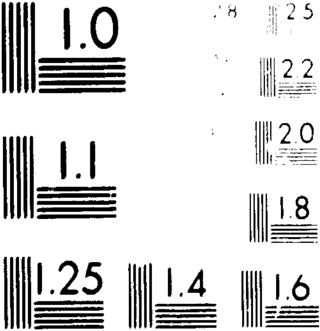
Number of strands: 4 strands

Mould oscillation mechanism, secondary cooling equipment, etc.

(iii) Discharging equipment: 1 set

Billet shear, roller table, cooling bed, etc.

(iv) Product handling equipment: 1 set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1.8
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1.4
1.6

(d) Bar and section rolling facilities

Production: 380,000 tonnes/year

Products : 12ø - 60ø steel bars, deformed steel bars, and shaped steel products of corresponding sizes

(i) Reheating furnace: 1 set

Capacity: 80 tonnes/hour

Type: Pusher type

(ii) Rolling mill: 1 set

Layout: Tandem type continuous mill

Train: Roughing, intermediate and finishing trains

Type of stand: 2 Hi closed type

Rolling speed: 14 m/sec.

(iii) Cropping and shearing equipment: 1 set

(iv) Cooling bed: 1 set

Type: Rake type

(v) Bar and section finishing facilities: 1 set

(vi) Material and product handling equipment: 1 set

(e) Plant Supporting Facilities

(i) Electric power receiving and distributing facilities

(ii) Utility facilities

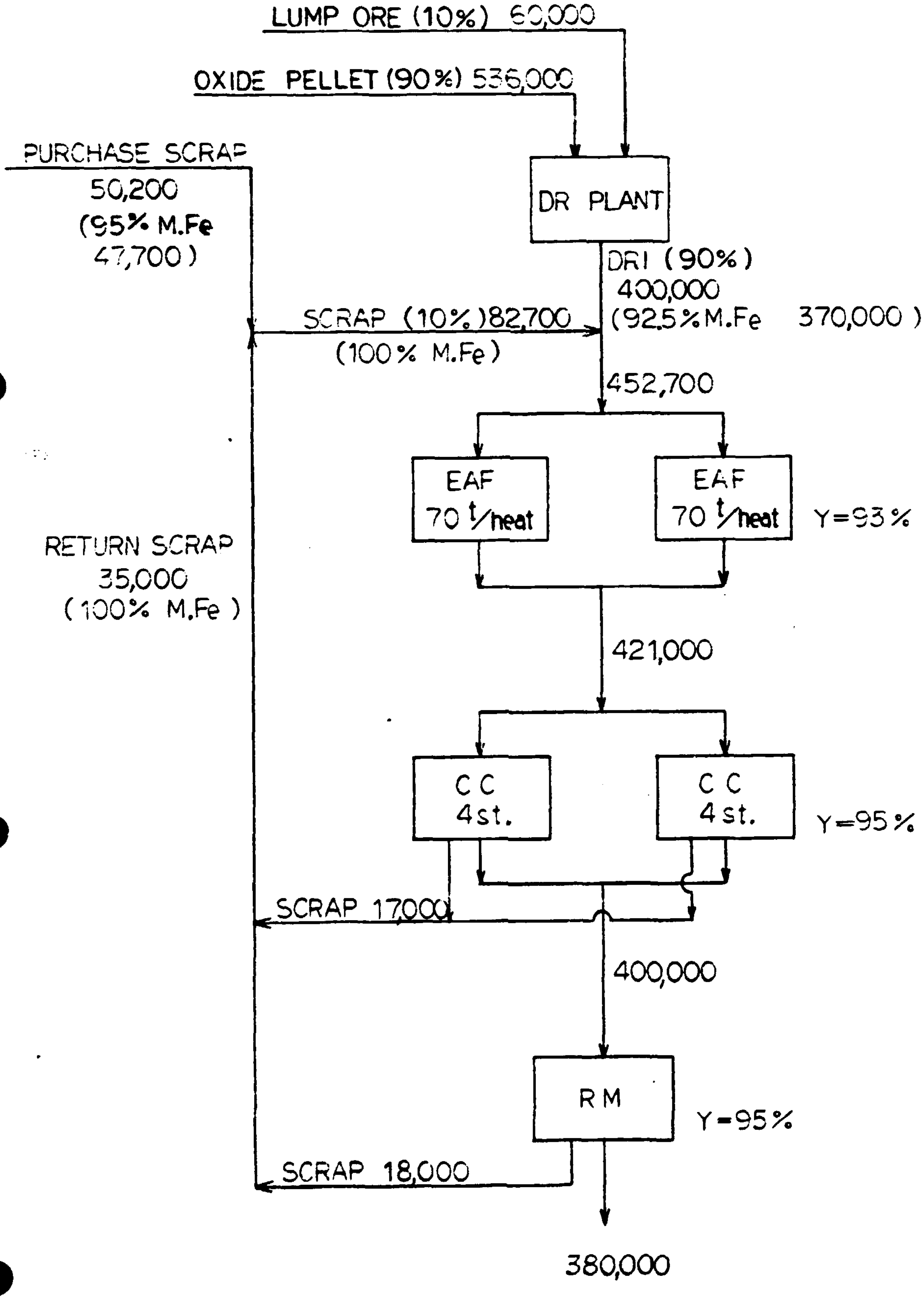
(iii) Inspection and laboratory

(iv) Maintenance shop, etc.

(4) Plant construction schedule

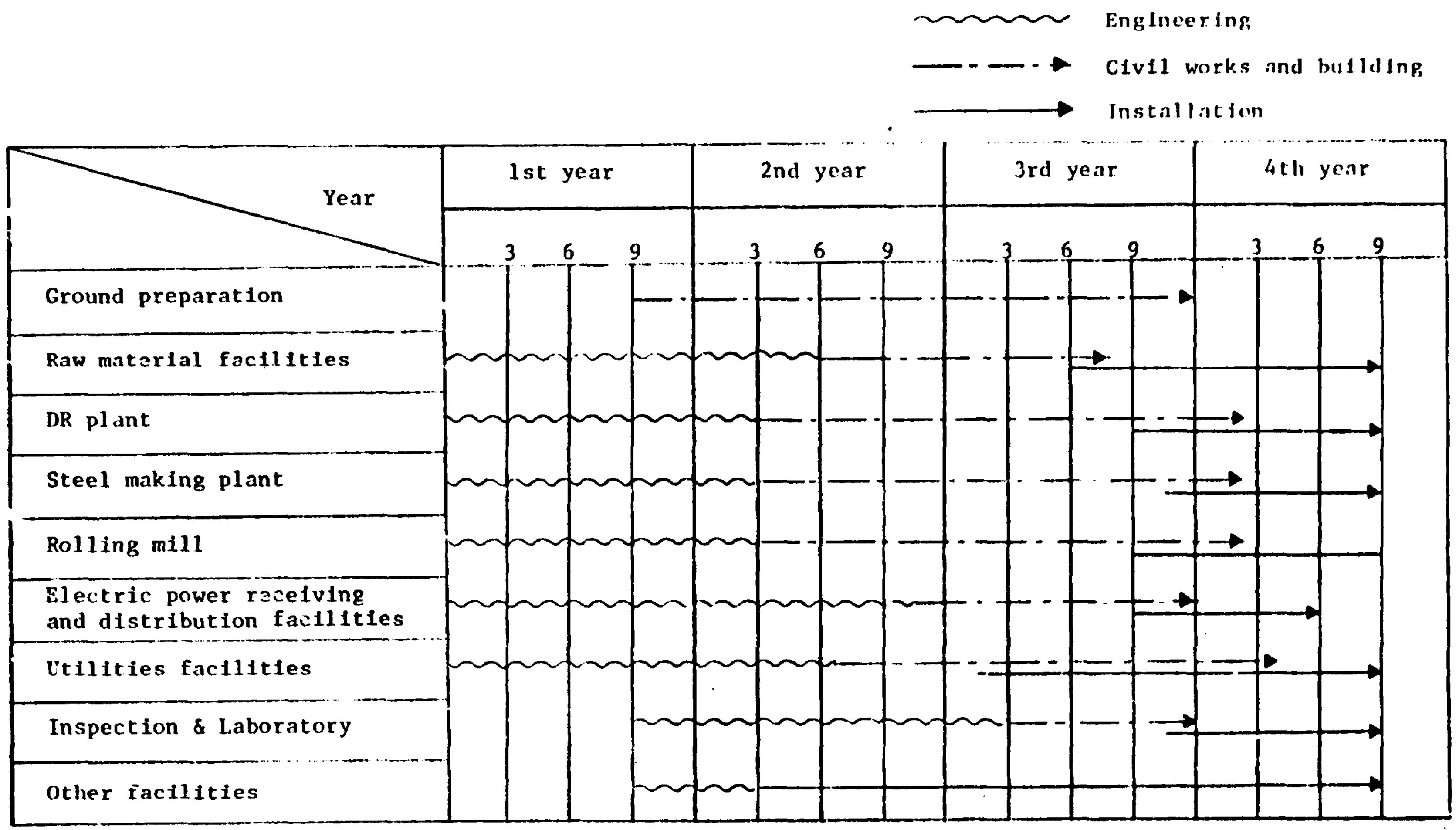
The plant construction schedule is as shown in Table 6.3.2. As seen from the table, the period from the commencement of engineering to the commissioning of the plant is expected to be about four years.

Fig. 6.3.2 MATERIAL BALANCE PROJECT B



UNIT : ANNUAL TONNES

Table 6.3.2 Construction Schedule of Project B



(5) Manpower requirement

(i) This DR integrated steel works requires the following manpower for operation:

Production:	1,440 persons
Administration:	160 persons
Total:	1,600 persons

(ii) About 200 persons from the direct operation and maintenance should receive in-plant training. In-plant training should start at least one year prior to the start-up.

6.3.4 Project C (400,000 tonnes/year Rolling Mill)

(1) Basic Concept

As it is clear from Table 6.1.1, "Supply and Demand of Ingot/Billet for Non-flat Products", ingot/billet supply constantly exceeds the re-roller's demand quantity, ingot/billet demand, by 200,000 to 300,000 tonnes after Pakistan Steel come into the ingot/billet market.

However, it is rather difficult to calculate the supply capacity of rerollable scrap from shipbreaking. It is possible for shipbreakers to make an extreme change of production quantity according to the demand. Re-rollable scrap is assumed as 250,000 tonnes in Table 6.1.1 from shipbreaking and some other sources. It is possible to expect over 300,000 tonnes per year.

In Project D-2 which will be described later, 200,000 tonnes/year billet supply is expected after doubling Pakistan Steel's capacity. As their downstream, this project shall be considered.

In this case, however, it is not recommended to install a rolling mill in the plant site of the Pakistan Steel. Instead, it is the prerequisite that some of the re-rollers or new-comer invest in the newly projected plant, because these re-rollers have grown up already to certain standards as private business. On the basis of such conditions, looking into non-flat products and the market, it is appeared that 400,000 tonnes will be short after 1994-95. To meet the demand, it is inevitable to set a mill capable of manufacturing 400,000 tonnes of bar/sections per year. In Project C, we have taken up a rolling mill producing 400,000 tonnes of products per year.

(2) Raw material plan

The rolling mill will be supplied of billets by either of the following options or the combination of them.

(a) Continuous cast billet produced by Pakistan Steel in Project D-2.

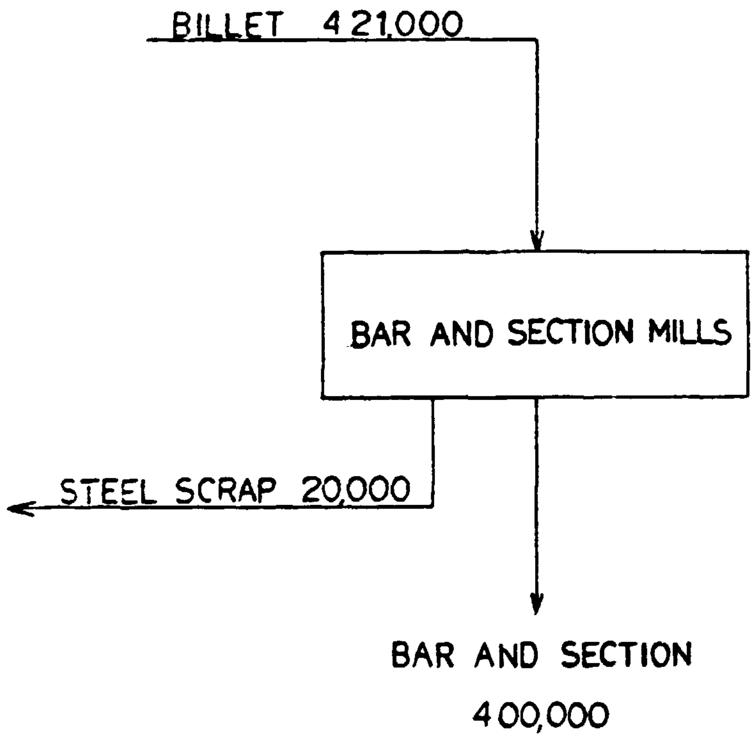
(b) Rolled billets produced at the billet mill of Pakistan Steel.

(c) Continuously cast billets produced by the billet Continuous casters to be constructed by domestic melters.

Also, small ingots could be obtained from melters, but they are not able to compete costwise with the above-mentioned billets.

Material balance is shown in Fig. 6.3.3.

Fig. 6.3.3 MATERIAL BALANCE
PROJECT C



UNIT : ANNUAL TONNES

(3) Majour facilities

The majour production facility under this Project will be a bar and section rolling mill.

The rolling mill will be of a continuous tandem layout. It will have a rolling speed of 14 m/sec. Elements will be 120 to 130 mm sq., taking into consideration the specifications for the continuous casting plant under construction.

Product size will be minimum 12ø. Those less than this minimum size will be made by re-rollers.

(a) Bar and section rolling mill

Production:	400,000 tonnes/year
Products:	12ø - 60ø bars, deformed bars and sections of corresponding sizes
Material:	120 - 130 mm sq. billets

(i) Reheating furnace: 1 set

Capacity: 80 tonnes/hour

Type: Pusher type

(ii) Roller: 1 set

Layout: Tandem type continuous mill

Train: Roughing, intermediate and finishing trains

Type of stand: 2 Hi closed type

Rolling speed: 14 m/sec.

(iii) Cropping and shearing equipment: 1 set

(iv) Cooling bed: 1 set
Rake type

(v) Bar and section finishing facilities: 1 set

(vi) Material and product handling equipment: 1 set

(b) Plant Supporting Facilities

(i) Electric power receiving and distributing facilities

(ii) Utility facilities

(iii) Inspection and laboratory

(iv) Maintenance shop

(4) Construction schedule

This Project covers the construction of only rolling mill and accessary facilities. Thus, construction works will be relatively simple.

Thirty-six months will be needed after the decision to construct the plant to the start-up of operation.

(5) Manpower requirement

For the rolling mill itself, the same number of workers will be needed under this Project as others, but staff will be required to control the entire plant.

Assuming three-shift operation, manpower will be needed as follows:

Production:	260 persons
Administration:	80 persons
Total:	340 persons

In order to operate the plant, about 70 of them should receive in-plant training for about six months one year before the commencement of operation.

6.3.5 Project D-1 (Doubling the Capacity of Pakistan Steel for Flat Products)

(1) Basic Concept

Details of doubling Pakistan Steel for flat products have already been described in 6.1.2 (2), (c).

To utilize fully the capacity of a hot strip mill currently under construction, this Project is aiming to double the steel-making capacity in 1996-97, when domestic demands for flat products are expected to increase significantly. Also, this Project has been worked out with an intention not to have Pakistan Steel launch the field of non-flat products for which considerable gap is anticipated between supply and demand. This is an attempt not to cause any confusion in the market of non-flat products with an advancement of a gigantic mill, Pakistan Steel.

(2) Raw Material Plan

Iron oxides:

lump ore (65% Fe)	465,000 t/y
fine ore (62% Fe)	1,139,000 t/y

Australia, Brazil and India are considered as potential suppliers.

Coking coal: 800,000 t/y

U.S.A., Canada and Australia are considered as potential suppliers. Domestic coking coal will replace imports when it is available.

Limestone/dolomite: 275,000 t/y

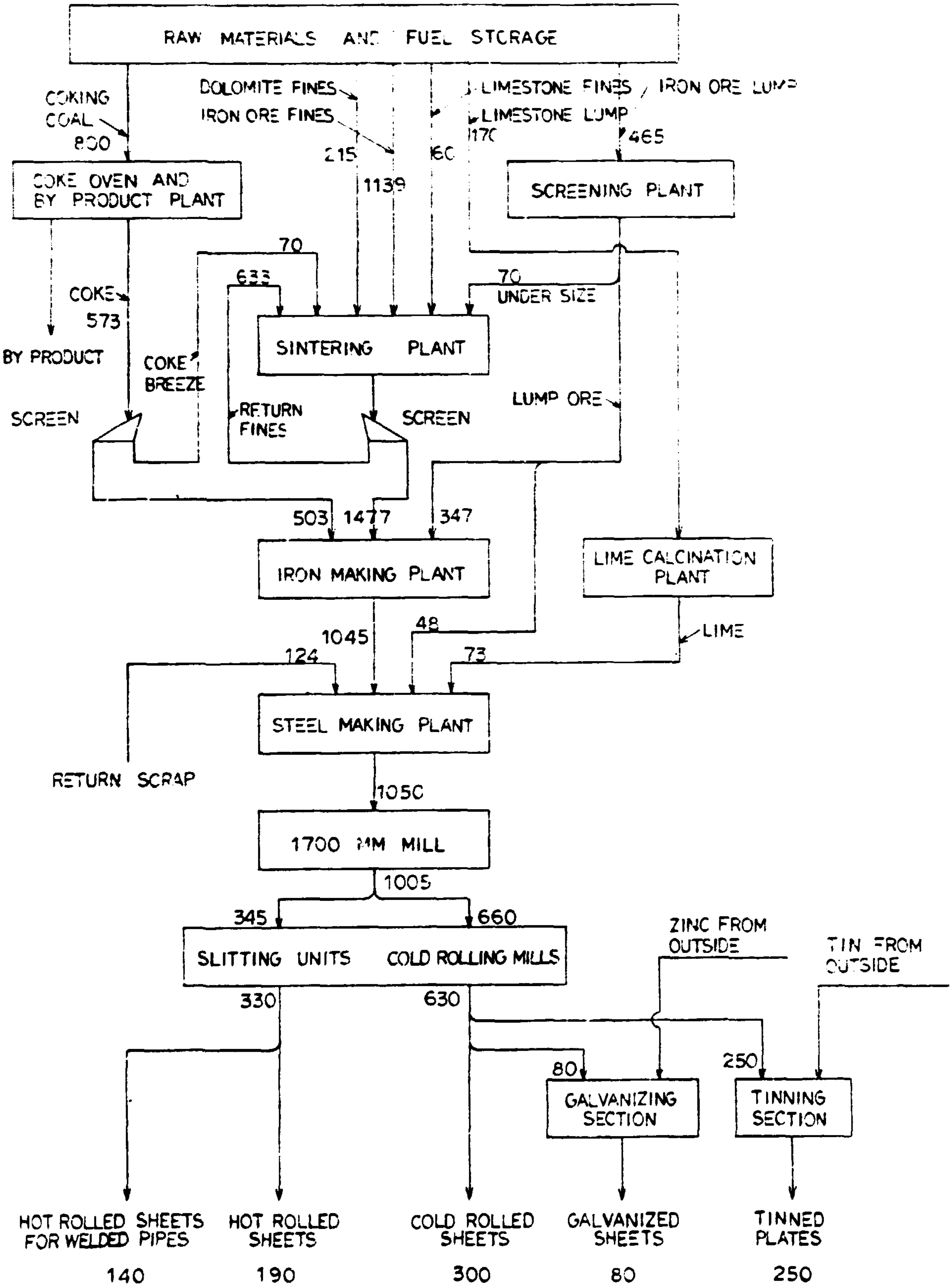
Domestic sources will be utilized.

(Out of the above, 170,000 tonnes/year for burnt lime.)

In addition to the above, fluorite and ferroalloy will be needed. The former will be obtained from domestic suppliers and the latter from foreign suppliers.

Raw materials for plating are planned to be imported. Material balance only for the addition is shown in Fig. 6.3.4.

Fig. 6.3.4 MATERIAL BALANCE
PROJECT B-1



UNIT : ANNUAL THOUSAND TONNES

(3) Majour Facilities

Pakistan Steel's hot strip mill is utilized to the maximum extent. When expanding Pakistan Steel facilities to produce flat products, the following facilities will be needed:

Sintering facilities

Coke ovens

Lime calsining plant

Blast furnace

Converter

Slab continuous casting machine

Cold rolling mill

Galvanizing facilities

Tinning facilities

Among the above facilities, a blast furnace to be constructed will have a capacity equivalent to the combined capacity of the two existing blast furnaces from the viewpoint of economics. It will be operated under ultra-high pressure. This operating technique will be sufficiently learnt with the operation of the existing blast furnaces by the time of the commencement of operation.

A converter will of the same specifications as the existing two converters so that they will be used in turn. As for a slab continuous casting machine, there will be no changes in majour specifications from those for the existing one.

A cold rolling machine will be of a high efficiency tandem type in view of production quantity.

As for galvanizing facilities, an electric type will be adopted as the existing one is of a dipping type, so that either electric or dipping type could be used according to order specifications.

Tinning facilities will be of an electrolytic type.

(a) Sintering facilities

Production: 1,500,000 tonnes/year

(i) Raw material handling facilities: 1 set

(ii) Sintering facilities: 1 set

Production rate: 1.3 tonnes/m^3.hour

Blower capacity: 10,000 m^3/min.

Blower load: 1,600 mmAq.

(iii) Product handling facilities: 1 set

(iv) Water treatment facilities: 1 set

(v) Desulfurization facilities: 1 set

(vi) Dust collecting facilities: 1 set

(b) Coke oven

Production: 573,000 tonnes/year

Products: lumpy coke 88%

coke breeze 12%

Bulk density of changed coal: 0.74 tonnes/m^3

(i) Pretreatment facilities: 1 set

(ii) Oven: 30 sets

Cycle time including soaking time: 18 hours

Effective volume: 30 m^3

(iii) Gas refining facilities: 1 set

(c) Blast furnace

Production: 1,045 tonnes of pig iron per year

Coke ratio: 500 kg/tonne-pig

Ore rate: 1.66 tonnes/tonne-pig

Rate of sinter to ore: 80% : 20%

Oxygen enrichment: 1%

(i) Furnace: 1 set

Inner volume: 1,600 m^3

Furnace top pressure: 1 - 2 kg/cm^2

(ii) Hot stove: 3 sets

Heated air temperature: max. 1,200°C

(iii) Gas scrubbing facilities: 1 set

(iv) Casting bed facilities: 1 set

(v) Dust collecting facilities: 1 set

(vi) Casting machine: 1 set

(d) Lime calsining plant

Production: 73,000 tonnes/year

(i) Lime calsining plant: 1 set

Shaft type

(ii) Product storage silo: 1 set

(iii) Fire quenching facilities: 1 set

(e) Converter

(i) Converter: 1 set

Top and bottom blowing type

Converter capacity: 130 tonnes/heat

Inner volume: 109 m^3

(ii) OG facilities: 1 set

(iii) Additives handling equipment: 1 set

(iv) Cranes: 1 set

(v) Mixers: 1 set

Capacity: 1,300 tonnes

(vi) Ladle metallurgy equipment

Capacity: 130 tonnes

(f) Slab continuous casting facilities

Production: 1,050,000 tonnes of cast slab/year

Slab size: 150 - 200 mm thick

700 - 1,550 mm wide

3 - 6 m long

(i) Continuous casting machine: 1 set

(ii) Tundish and tundish car: 2 sets

(iii) Mould oscillation system: 1 set

(iv) Cast slab handling equipment: 1 set

(g) Cold rolling mill

Production: 630,000 tonnes/year

Product: 0.15 mm - 3.2 mm thick

60 mm - 1,500 mm wide

(i) Pickling facilities: 1 set

Solution: Hydrochloric acid

Type: Continuous type

(ii) Cold rolling machine: 5 sets

4 Hi tandem arrangement

Finishing rolling speed: max. 1,800 m/min.

(iii) Electrolytic cleaning line: 1 set

(iv) Continuous annealing line: 1 set

(v) Tempering rolling machine: 2 sets

4 Hi type

(vi) Shearing and slitting line: 1 set

(h) Electrolytic galvanizing facilities

Production: 80,000 tonnes/year

(Capacity: 100,000 tonnes/year)

Product: 0.3 - 3.2 mm thick

700 - 1,500 mm wide

1 - 4 m long

Galvanizing speed: max. 150 m/min.

(i) Electrolytic cleaning and pickling facilities: 1 set

(ii) Electrolytic galvanizing line: 1 set

Model: Continuous two-side simultaneous plating type

Galvanizing speed: max. 150 m/min.

Zink bath: Six units

(iii) Chemical treatment facilities: 1 set

Nitric-hydrofluoric treatment

(i) Electrolytic Tinning Facilities

Production: 250,000 tonnes/year

Product: 0.15 - 0.6 mm thick

700 - 1,550 mm wide

1 - 4 m long

(i) Pretreatment facilities

(ii) Tinning facilities

Model: Continuous Ferrostan type

Tinning speed: max. 480 m/min.

Tin bath: 20 units

(iii) Chemical treatment facilities

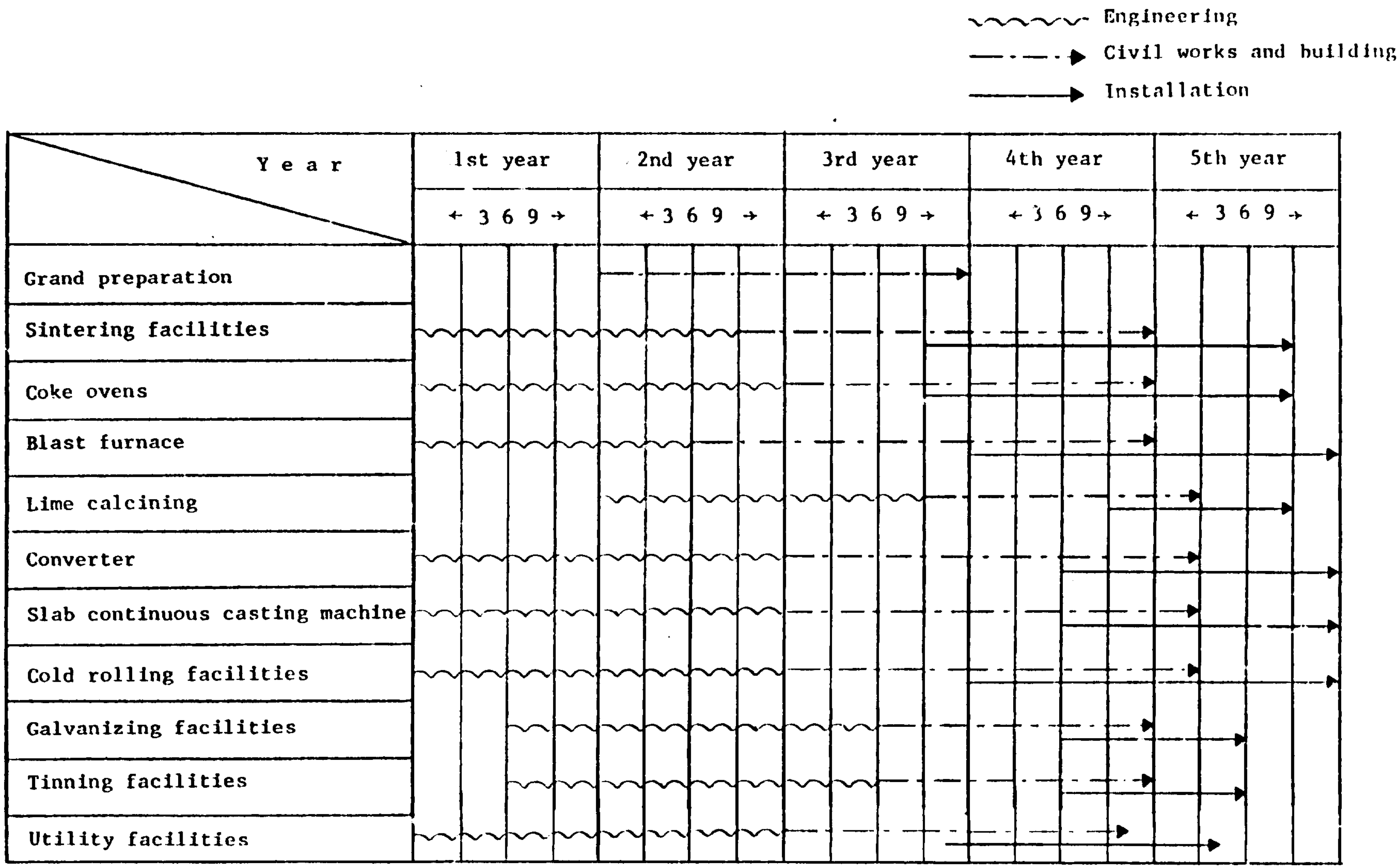
(iv) Oil application facilities

(v) Shearing facilities

(4) Plant construction schedule

The plant construction schedule is shown in Table 6.3.3. Five years will be needed to complete all construction works.

Table 6.3.3 Construction Schedule of Project D-1



(5) Manpower requirement

As this project is a plan to expand the existing facilities of Pakistan Steel, the manpower requirement will mean addition of workers to employed ones for existing plant. A total addition of about 3,000 workers are expected to be required as follows:

Production	:	2,900 persons
Administration	:	100 persons
Total	:	3,000 persons

There will be 27% personnel addition to the existing work force of 15,000 persons.

Out of the above additional work force, about 400 workers should receive training for the operation or maintenance of down-stream facilities, cold rolling facilities, electrolytic galvanizing facilities and tinning facilities. As for up-stream facilities, on-the-job-training using the existing facilities will be sufficient.

6.3.6 Project D-2 (Doubling the Capacity of Pakistan Steel for Flat Products and Billets)

(1) Basic concept

In the Project D-1, possibilities are studied on products for expansion limited to the flat products. As a result, expansion will not be made until the latter part of 1990s, namely, 1996-97.

From our basic stand, however, Pakistan Steel should think only of its expansion in the area of flat products. Because of the anticipated demand increase, the time of expansion will be much delayed. In order to make use of advance investment and build up stable business bases, through best use of accumulated technical know-how, Project D-2 has been worked out for earlier realization of Pakistan Steel expansion.

In this Project, product mix is not limited to the flat products but billets for non-flat products.

Even in this case, however, increase in supply of small billets of around 50 mm sq. to the existing rerollers may result in further confusion in the ingot/billet market. For this reason, Pakistan Steel's billet is set to be large sized 150 mm sq. billet, on the assumption that new rolling mill has been set up to roll these billets.

Project C may become a model for the said new rolling mill.

(2) Raw material plan

Iron oxides:

lump ore (65% Fe)	465,000 t/y
fine ore (62% Fe)	1,139,000 t/y

Australia, Brazil and India are considered as potential suppliers.

Coking coal: 800,000 t/y

U.S.A., Canada and Australia are considered as potential suppliers. Domestic coking coal will replace imports when it is available.

Limestone/dolomite: 275,000 t/y

Domestic sources will be utilized.
(Out of the above, 170,000 tonnes/year for burnt lime.)

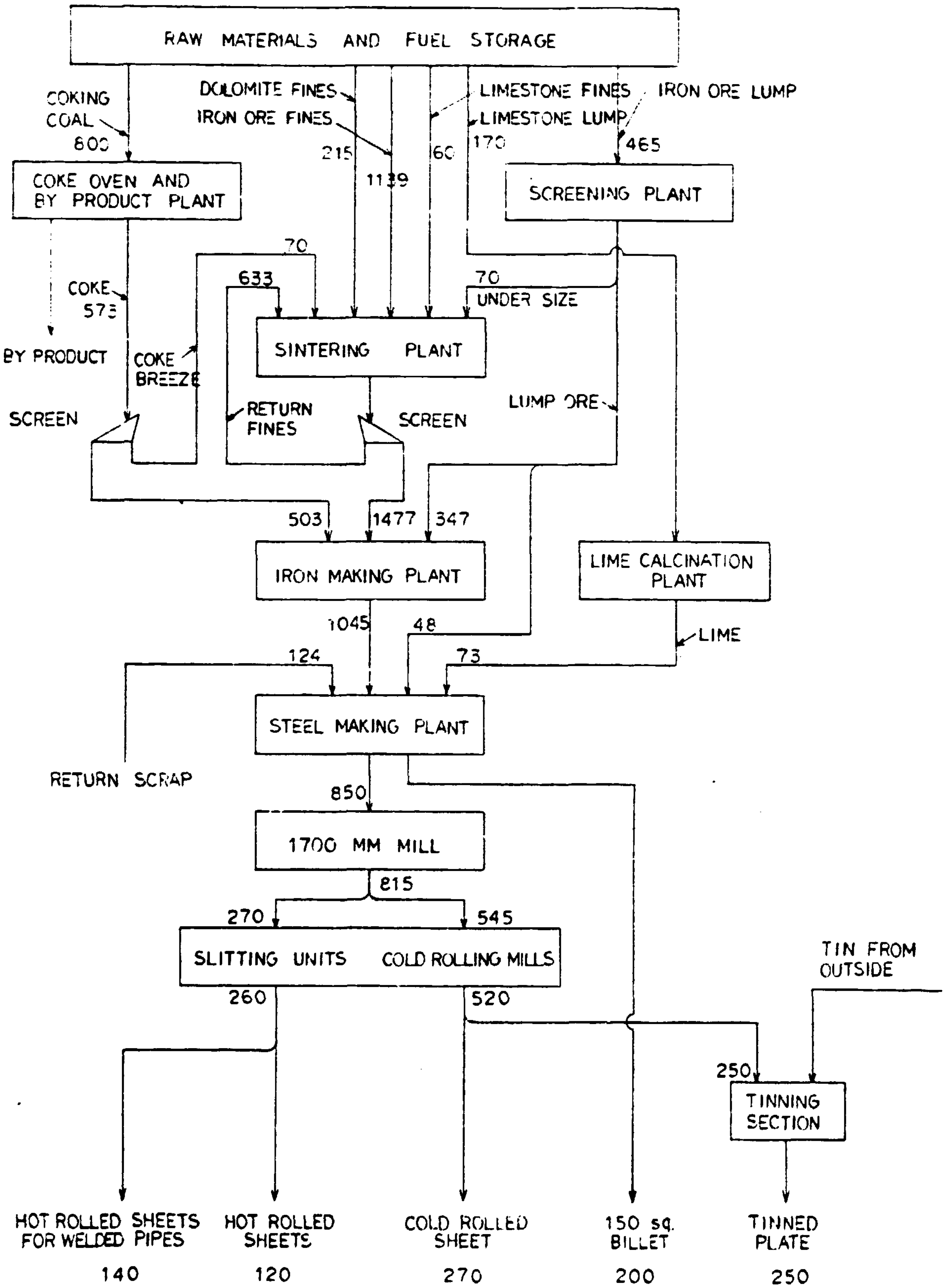
In addition to the above, fluorite and ferroalloy will be needed. The former will be obtained from domestic suppliers and the latter from foreign suppliers.

Raw materials for plating are planned to be imported.

Material balance only for the addition is shown in Fig. 6.3.5.

Fig.6.3.5 MATERIAL BALANCE

PROJECT D-2



UNIT : ANNUAL THOUSAND TONNES

(3) Main facilities

As described in (1) Basic concept, majour facilities which should be added in the expansion of Pakistan Steel to manufacture non-flat products, will be as follows:

Sintering facilities
Coke ovens
Lime calsining plant
Blast furnace
Converter
Slab continuous casting machine
Billet continuous casting machine
Cold rolling mill
Tinning facilities.

Comparing with Project D-1 which aims at only flat products, there are naturally no differences between them, as shown in the material balance sheet , Fig. 6.3.4 and Fig. 6.3.5, as far as up-stream facilities including sintering facilities through converter are concerned.

As for down-stream facilities, billet continuous casting facilities will be newly installed. Additional cold rolling facilities could be smaller, but slab continuous casting machine could be same size. Therefore, it will not be necessary to add galvanizing facilities, and only tinning facilities will be added.

(a) Sintering facilities

Production: 1,500,000 tonnes/year

(i) Raw material handling facilities: 1 set

(ii) Sintering facilities: 1 set

Production: 1.3 tonnes/m^3.hour

Blower capacity: 10,000 m^3/min.

Blower load: 1,600 mmAq

(iii) Product handling facilities: 1 set

(iv) Wate treatment facilities: 1 set

(v) Desulfurization facilities: 1 set

(vi) Dust collecting facilities: 1 set

(b) Coke oven

Production: 573,000 tonnes/year

Products: lumpy coke 88%

coke breeze 12%

Bulk density of charged coal: 0.74 tonnes/m^3

(i) Pretreatment facilities: 1 set

(ii) Oven: 30 sets

Cycle time including soaking time: 18 hours

Effective volume: 30 m^3

(iii) Gas scrubbing facilities: 1 set

(c) Blast Furnace

Production: 1,045 tonnes of pig iron/year

Coke ratio: 500 kg/tonne-pig

Rate of sinter to ore: 80% : 20%

Oxygen enrichment: 1%

(i) Furnace: 1 set

Inner volume: 1,600 m^3

Furnace top pressure: 1 - 2 kg/cm^2

(ii) Hot stove: 3 sets

Heated air temperature: max. 1200°C

(iii) Gas scrubbing facilities: 1 set

(iv) Casting bed facilities: 1 set

(v) Dust collecting facilities: 1 set

(vi) Casting machine: 1 set

(d) Lime calsining plant

Production: 73,000 tonnes/year

(i) Lime calsining plant: 1 set

(ii) Product storing silo: 1 set

Shaft type

(iii) Fire quenching facilities: 1 set

(e) Converter

(i) Converter: 1 set

Top and bottom blowing type

Converter capacity: 130 tonnes/heat

Inner volume: 109 m^3

(ii) OG facilities: 1 set

(iii) Additives handling equipment: 1 set

(iv) Cranes: 1 set

(v) Mixers: 1 set

Capacity: 1,300 tonnes

(vi) Ladle metallurgy equipment

Capacity: 130 tonnes

(f) Slab continuous casting facilities

· Production: 850,000 tonnes of cast slab/year

Slab size: 150 - 200 mm thick

700 - 1,550 mm wide

3 - 6 m long

(i) Continuous casting machine: 1 set

Type: curved mould bending type

Number of strands: 2 strands

(ii) Tundish and tundish car: 2 sets

(iii) Mould oscillation system: 1 set

(iv) Cast slab handling equipment: 1 set

(g) Billet continuous casting facilities

Production: 200,000 tonnes/year

Product: 150 mm sq. x 3 - 6 m long

(i) Molten steel handling equipment: 1 set

Tundish, tundish car, etc.

(ii) Continuous casting machine: 1 set

Curved mould bending type

Billet size: 150 mm sq.

Number of strands: 6 strands

Mould oscillation mechanism

Secondary cooling equipment, etc.

(iii) Discharging equipment: 1 set

Billet shear, roller table, cooling bed, etc.

(iv) Products handling equipment: 1 set

(v) Bundling and shipping equipment: 1 set

(h) Cold rolling facilities

Production: 520,000 tonnes/year

Product: 0.15 - 3.2 mm thick

60 - 1,500 mm wide

(i) Pickling facilities: 1 set

Solution: Hydrochloride acid

Type: Continuous type

(ii) Cold rolling machine: 5 sets

4 Hi tandem arrangement

Finishing rolling speed: max. 1,700 m/min.

(iii) Electrolytic cleaning line: 1 set

(iv) Continuous annealing line: 1 set

(v) Tempering rolling machine: 2 sets

4 Hi type

(vi) Shearing and slitting line: 1 set

(i) Electrolytic Tinning Facilities

Production: 250,000 tonnes/year

Product: 0.15 - 0.6 mm thick

700 - 1,550 mm wide

1 - 4 m long

(i) Pretreatment facilities

(ii) Tinning facilities

Model: Continuous Ferrostan type

Tinning speed: max. 480 m/min.

Tin bath: 20 units

(iii) Chemical treatment facilities

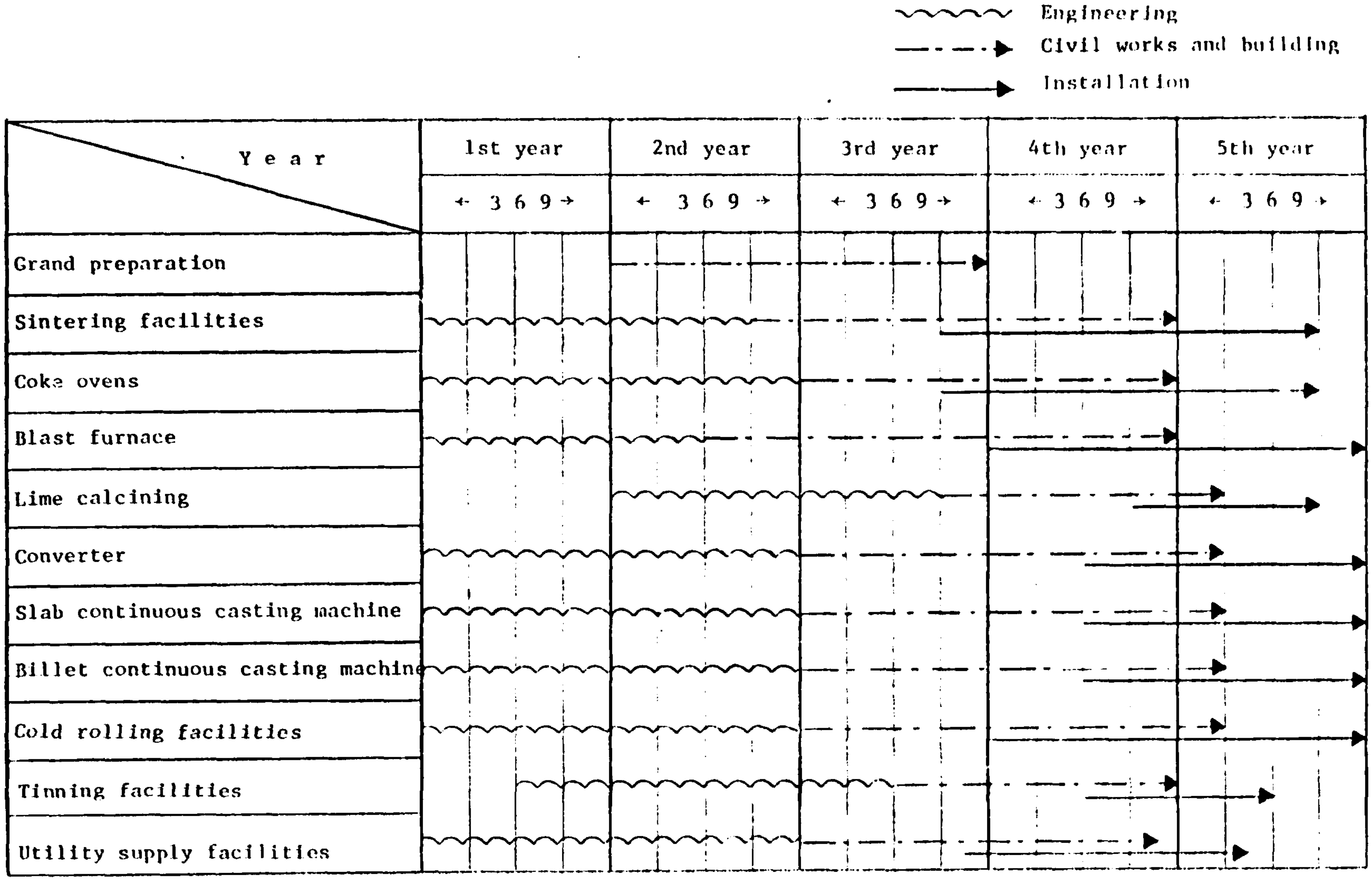
(iv) Oil application facilities

(v) Shearing facilities

(4) Plant construction schedule

The plant construction schedule is shown in Table 6.3.4.

Table 6.3.4 Construction Schedule for Project D-2



(5) Manpower requirement

This Project is also a plan to expand the existing facilities of Pakistan Steel as Project D-1. It will also require some additional workers.

Additional manpower requirement will be as follows:

Production:	2,830 persons
Administration:	100 persons
Total	3,930 persons

A total of 390 workers should receive training for the operation or maintenance of cold rolling or tinning facilities.

7. FINANCIAL AND ECONOMIC EVALUATION OF PROJECTS

In this chapter, the five Projects in Chapter 6 will be evaluated from the standpoint of business management. Such evaluation is called financial evaluation. First each Project will be evaluated if it is feasible as a business enterprise. Then, viewpoints will be turned to the national economy to evaluate if the Project will be valuable or contributable to the national economy. This evaluation is called economic evaluation.

7.1 Financial Evaluation

7.1.1 Assumptions

In evaluating the Project from a financial side, it is inevitable to make some bold assumptions concerning the unknown future. What is the important in making such assumptions is not whether such assumptions are realistic or not, but whether assumptions are balanced between Projects, whether assumptions are not based on some intention and well balanced between assumptions.

Setting up assumptions for this evaluation, we have tried not to differ much from generally accepted thinkings for the same kind of project by adopting assumptions which are as close as possible to those adopted for the evaluation of similar steel projects, while taking the above mentioned into consideration.

We have established the following assumptions for a financial evaluation:

(1) Basic Assumptions for a calculation:

(a) currency in calculation: U.S. dollar.

(b) time of price estimation as of the first half of 1981.

(c) project period: 20 years from the start-up.

(d) price for calculation: constant price, future price changes are not taken into consideration at all.

(e) All taxes and duties except for corporate tax shall not be applied for new Projects like Pakistan Steel which is enjoying the duty exemption for imported machinery and equipment and raw materials.

(2) Detailed assumptions

Detailed assumptions are described in each item.

(3) Changes in price level and constant price

For a financial evaluation, constant price is commonly used as to the all prices such as construction costs, production costs and sales prices. This is not because that future price changes are predicted to be zero, but because of a positive thinking to eliminate any intentional distortion of project evaluation by introducing unknown inflation factors.

If uniform inflation rates are applied to the all factors, future profits can be unreasonably expanded to make it difficult to evaluate the project correctly.

It should be ideal if future price can be predicted for each element. Actually, however, prices are determined by not only inflation rate but also by such factors as market balance and political intervention, so that it is extremely difficult to predict future prices.

Therefore, we have decided against the introduction of future price changes in our evaluation.

In order to realize the Project in future, it is necessary to make detailed studies and to review construction costs which are affected by inflation in advanced countries to a large extent.

7.1.2 Estimation of Construction Costs and Raising of Funds

(1) Assumptions

(i) Direct construction costs are estimated on turn-key basis, and include costs for roads, wiring and piping within the battery area, but not costs for infrastructure outside the battery.

As for harbour facilities, existing facilities will be used and as for other non-existing infrastructure, they are assumed to be installed when these Projects have been realized. In this analysis, costs for such installation is not included, and their costs will be included on fee basis.

(ii) Pre-operational expenses

Pre-operational expenses will include training, technical cooperation and organization expenses and interests during construction.

(iii) Net working capital

The difference between current assets and current debts during the project period is predicted as net working capital which is needed at the final stage of construction period.

(iv) Foreign and domestic currencies

For the calculation of domestic currency requirement, the maximum domestic supply is assumed to be utilized in machinery and equipment, materials and services. As a result, major portion of civil works and building and small portion of facilities are estimated to be domestic supply.

(v) Raising of funds

The portion of domestic currency is assumed to be raised by share capital up to 30 % of total costs excluding net working capital. The remaining 70 % is assumed to be raised by a rather soft long-term loan from abroad in foreign currency portion and from the government in domestic currency portion.

As for the conditions for foreign loan, the interest rate will be 7.75 % per year and the period will be the construction period plus ten years according to the guideline of the OECD. The same conditions will be applied also to the local long-term loan.

Net working capital will be secured through commercial loan which will be obtained at the annual interest rate of 15 % and will be repaid in one year time.

(2) Estimation of construction costs

On the basis of the assumptions mentioned above, construction costs have been estimated as shown in Table 7.1.1.

Table 7.1.1 Construction Cost

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Direct construction cost					
Iron making	67	57	-	315	315
Steel making	-	59	-	171	190
Rolling mill	-	62	78	269	234
Others	-	34	-	104	104
Installation, Civil and Construction	25	195	72	521	487
Total	92	407	150	1,380	1,330
Pre-operational expenses	9	48	12	176	171
Total Construction cost	101	455	162	1,556	1,501
Net working capital	11	32	8	126	124
Total fund reauirement	112	487	170	1,682	1,625
Foreign currencv	70	307	1C1	954	926
Construction cost per annual tonne of crude steel (US$/tonne)	-	1,081	-	1,396	1,346
Contruction cost per annual tonne of products (US$/tonne)	253	1,197	405	1,621	1,532

Only for a reference, comparison tables of construction cost per tonne of crude steel and final products are attached as Appendix to 7-1 including other countries' project which capital cost can be known.

(3) Model of Fund Raising

Fund raising model on the basis of the assumptions mentioned in (1) is shown in Table 7.1.2.

Table 7.1.2 Raising of Fund

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Share capital	30	136	48	467	450
Long term loan	71	319	114	1,089	1,051
Short term loan	11	32	8	126	124
Total	112	487	170	1,682	1,625

7.1.3 Estimation of Sales Revenues and Production Costs

(1) Assumptions

(a) Sales revenues

(i) Sales price

Unit prices are calculated from current market price* deducted with distribution costs as a net price which the new Project could get.

* As discussed in Chapter 3, current market prices are considerably high in comparison with international market prices mainly because of high tariff rates. As raw materials are treated as duty free and sales prices are calculated on the basis of market prices which include duty, the results are likely to look too excellent. This aspect shall be reviewed in Economic Evaluation.

(ii) Sales quantity

Sales quantity is assumed to be equal to production quantity.

(b) Production costs

(i) Variable costs

As for raw materials and utilities, experiences in advanced steel manufacturing countries will be used as reference for estimation. As for raw material purchase prices, actual prices are used as to those raw materials which Pakistan has purchased before and international prices are used as to those raw materials which Pakistan has never purchased.

As for utility purchase prices, existing prices in Pakistan are used.

(ii) Fixed costs

Labour expenses are calculated on the basis of average wages in Pakistan, adding 50 % welfare expenses.

Maintenance and repair charges are calculated with reference to general experiences at modern steel works.

As for depreciation cost, the following method is adopted which is generally applied in Pakistan.

	Building	Machinery
Method	fixed amount	fixed amount
Residual value	10%	10%
Number of years	18 years after start-up	9 years after start-up

Pre-operational expenses are amortized equally over five years after start-up of operation.

(iii) Production Quantity

During first and second years, production will increase gradually to reach a level of full production. In the case of Project C full production can be achieved after a year of start-up.

(2) Estimation of sales revenues

On the basis of the above-mentioned assumptions, sales revenues have been estimated as shown in Table 7.1.3.

Table 7.1.3 Estimate of Sales Revenue

(Unit : 1000 tonnes/year)

Products	Unit Price (US$/tonne)	Sales Quantity Project A	B	C	D-1	D-2
DRI	206	400	-	-	-	-
Bar & Section	621	-	380	400	-	-
Hot rolled sheet	704	-	-	-	330	260
Cold rolled sheet	842	-	-	-	300	270
Tinned plate	965	-	-	-	250	250
Galvanized sheet	935	-	-	-	80	-
Billet	469	-	-	-	-	200
TOTAL						
(1000 tonnes/year) Quantity	-	400	380	400	960	980
(US$ million) Amount	-	82.4	236.0	248.4	801.4	745.4
(US$/tonne) Average unit price	-	206	621	621	834	761

(3) Estimation of production cost

(a) Variable cost

On the basis of the above-mentioned assumptions, variable costs are assumed as Table 7.1.4 and their break-down are shown in Appendix to 7-2.

Table 7.1.4 Estimate of Variable Cost

(Unit: US$ per product tonne)

Project		
A	DRI	103.9
B	Bar & Section	197.5
C	Bar & Section	538.9
D-1	Galvanized Sheet	245.5
D-1 & D-2	Hot Rolled Sheet	210.3
ditto	Cold Rolled Sheet	231.3
ditto	Tinned Plate	361.4
D-2	Billet	193.9

(b) Production costs

In addition to the variable costs in (a), fixed costs including depreciation and amortization cost are estimated.

Table 7.1.5 shows estimated production costs at the fifth year after start-up.

Table 7.1.5 Estimate of Production Cost
(5th year after start-up)

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Production quantity (1000 tonnes)	(400)	(380)	(400)	(960)	(980)
Variable cost (Unit cost US$/t)	(103.9)	(197.5)	(538.9)	(259.1)	(251)
	41.6	75.1	215.6	248.7	246.2
Fixed cost					
Labour cost	0.2	1.2	0.2	2.2	2.2
Maintenance & Repair	1.8	9.0	2.7	30.4	29.3
Depreciation	10.0	44.0	14.0	160.0	155.0
Total	12.0	54.2	16.9	192.6	186.5
Total production cost	53.6	129.3	232.5	441.3	432.7
Production cost/product.t (US$/t)	134.0	340.3	581.3	459.7	441.5

In order to compare the production costs of DR integrated and those of BF integrated, a cost comparison has been performed on liquid steel basis between the two Projects (Project B and Projects D-1, D-2).

Results are shown in Table 7.1.6.

Table 7.1.6 Estimated Production Cost of Liquid Steel

(Unit: US$/tonne)

Project	B	D-1, 2
Variable cost	180.7	179.5
Fixed cost	65.6	84.7
Total	246.3	264.2

7.1.4 Financial Projection

As a financial projection for each Project, projected profit and loss and projected cash flow are shown in Tables 7.1.7 through 7.1.16.

Table 7.1. 7 Projected Profit & Loss for Project A

(unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Sales revenue								
(Quantity, 1000 tonnes)	(200)	(340)	(400)	(400)	(400)	(400)	(400)	(400)
(Unit price US$/tonnes)	(206)	(206)	(206)	(206)	(206)	(206)	(206)	(206)
Amount	41.2	70.0	82.4	82.4	82.4	82.4	82.4	82.4
Production cost								
Variable cost	20.8	35.3	41.6	41.6	41.6	41.6	41.6	41.6
Fixed cost	11.0	12.0	12.0	12.0	12.0	3.0	3.0	2.0
Total	31.8	47.3	53.6	53.6	53.6	44.6	44.6	43.6
Operating income	9.4	22.7	28.8	28.8	28.8	37.8	37.8	38.8
Non-operating expenses								
General adm.	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Financial expenses	7.2	7.3	4.4	3.9	3.3	0.5	-	-
Total	7.4	7.7	4.8	4.3	3.7	0.9	0.4	0.4
Net income before tax	2.0	15.0	24.0	24.5	25.1	36.9	37.4	38.4
Tax	1.1	8.3	13.2	13.5	13.8	20.3	20.6	21.1
Net income after tax	0.9	6.7	10.8	11.0	11.3	16.6	16.8	17.3
Accumulated net income	0.9	7.6	18.4	29.4	40.7	108.4	192.4	277.4

Table 7.1.8 Projected Cash Flow for Project A

(Unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Source of funds								
Cash and deposit (beginning)	-	1.0	2.9	21.6	35.3	107.9	193.2	282.2
Financial resources								
Long-term loan	-	-	-	-	-	-	-	-
Short-term loan	15.0	-	-	-	-	-	-	-
Total	15.0	-	-	-	-	-	-	-
Sales revenue	41.2	70.0	82.4	82.4	82.4	82.4	82.4	82.4
Total	56.2	71.0	85.3	104.0	118.3	190.3	275.6	364.6
Use of funds								
Production cost (excl. dep. & amo. incl. gen. adm.)	23.0	37.7	44.0	44.0	44.0	44.0	44.0	44.0
Repayment								
Long-term loan	7.0	7.0	7.0	7.0	7.0	8.0	-	-
Short-term loan	11.0	15.0	-	-	-	-	-	-
Total	18.0	22.0	7.0	7.0	7.0	8.0	-	-
Financial expenses								
Long-term loan	12.5	5.0	4.4	3.9	3.3	0.5	-	-
Short-term loan	1.7	2.3	-	-	-	-	-	-
Total	14.2	7.3	4.4	3.9	3.3	0.5	-	-
Tax payable	-	1.1	8.3	13.2	13.5	16.1	20.6	42.2
Cash and deposit (end)	1.0	2.9	21.6	35.3	50.5	121.7	211.0	278.4
Total	56.2	71.0	85.3	104.0	118.3	190.3	275.6	364.6

Table 7.1.9 Projected Profit & Loss for Project B

(unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Sales revenue								
(Quantity, 1000 tonnes)	(190)	(323)	(380)	(380)	(380)	(380)	(380)	(380)
(Unit price US$/tonnes)	(621)	(621)	(621)	(621)	(621)	(621)	(621)	(621)
Amount	118.0	200.6	236.0	236.0	236.0	236.0	236.0	236.0
Production cost								
Variable cost	37.5	63.8	75.1	75.1	75.1	75.1	75.1	75.1
Fixed cost	53.2	53.2	54.2	54.2	54.2	17.2	17.2	10.2
Total	90.7	117.0	129.3	129.3	129.3	92.3	92.3	85.3
Operating income	27.3	83.6	106.7	106.7	106.7	143.7	143.7	150.7
Non-operating expenses								
General adm.	0.4	0.6	0.8	0.8	0.8	0.8	0.8	0.8
Financial expenses	29.5	30.2	19.8	17.4	14.9	2.5	-	-
Total	29.9	30.8	20.6	18.2	15.7	3.3	0.8	0.8
Net income before tax	-2.6	52.8	86.1	88.5	91.0	140.4	142.9	149.9
Tax	-	27.4	47.4	48.7	50.1	77.2	78.6	82.4
Net income after tax	-2.6	25.1	38.7	39.8	40.9	63.2	64.3	67.5
Accumulated net income	-2.6	22.5	61.2	101.0	141.9	398.1	719.6	1,047.5

Table 7.1.10 Projected Cash Flow for Project B

(Unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Source of funds								
Cash and deposit (beginning)	1.0	2.0	10.9	81.4	134.5	400.7	741.7	1,098.2
Financial resources								
Long-term loan	-	-	-	-	-	-	-	-
Short-term loan	54.6	-	-	-	-	-	-	-
Total	54.6	-	-	-	-	-	-	-
Sales revenue	118.0	200.6	236.0	236.0	236.0	236.0	236.0	236.0
T o t a l	173.6	202.6	246.9	317.4	370.5	636.7	977.7	1,334.2
Use of funds								
Production cost (excl. dep. & amo. incl. gen. adm.)	48.1	74.6	86.1	86.1	86.1	86.1	86.1	86.1
Repayment								
Long-term loan	31.0	32.0	32.0	32.0	32.0	32.0	-	-
Short-term loan	32.0	54.6	-	-	-	-	-	-
Total	63.0	86.6	32.0	32.0	32.0	32.0	-	-
Financial expenses								
Long-term loan	55.7	22.3	19.8	17.4	14.9	2.5	-	-
Short-term loan	4.8	8.2	-	-	-	-	-	-
Total	60.5	30.5	19.8	17.4	14.9	2.5	-	-
Tax payable	-	-	27.6	47.4	48.7	61.0	78.6	164.8
Cash and deposit (end)	2.0	10.9	81.4	134.5	188.8	455.1	813.0	1,083.3
T o t a l	173.6	202.6	246.9	317.4	370.5	636.7	977.7	1,334.2

Table 7.1.11 Projected Profit & Loss for Project C

(unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Sales revenue								
(Quantity, 1000 tonnes)	(300)	(400)	(400)	(400)	(400)	(400)	(400)	(400)
(Unit price US$/tonnes)	(621)	(621)	(621)	(621)	(621)	(621)	(621)	(621)
Amount	186.3	248.4	248.4	248.4	248.4	248.4	248.4	248.4
Production cost								
Variable cost	161.7	215.6	215.6	215.6	215.6	215.6	215.6	215.6
Fixed cost	15.9	15.9	15.9	16.9	16.9	4.9	4.9	2.9
Total	177.6	231.5	231.5	232.5	232.5	220.5	220.5	218.5
Operating income	8.7	16.9	16.9	15.9	15.9	27.9	27.9	29.9
Non-operating expenses								
General adm.	-	-	-	-	-	-	-	-
Financial expenses	10.0	10.6	8.6	6.9	5.4	0.9	-	-
Total	10.0	10.6	8.6	6.9	5.4	0.9	-	-
Net income before tax	-1.3	6.3	8.3	9.0	10.5	27.0	27.9	29.9
Tax	-	2.7	4.6	5.0	5.8	14.9	15.3	16.4
Net income after tax	-1.3	3.6	3.7	4.0	4.7	12.1	12.6	13.5
Accumulated net income	-1.3	2.3	6.0	10.0	14.7	54.8	117.8	182.6

Table 7.1.12 Projected Cash Flow for Project C

(Unit: US$ million)

Year after Start-up	1	2	3	4	5	10	15	20
Source of funds								
Cash and deposit (beginning)	2.0	2.0	2.0	2.0	7.4	43.2	109.6	182.6
Financial resources								
Long-term loan	-	-	-	-	-	-	-	-
Short-term loan	17.3	9.0	2.3	-	-	-	-	-
Total	17.3	9.0	2.3	-	-	-	-	-
Sales revenue	186.3	248.4	248.4	248.4	248.4	248.4	248.4	248.4
T o t a l	205.6	259.4	252.7	250.4	255.8	291.6	358.0	431.0
Use of funds								
Production cost (excl. dep. & amo. incl. gen. adm.)	164.6	218.5	218.5	218.5	218.5	218.5	218.5	218.5
Repayment								
Long-term loan	11.0	11.0	11.0	11.0	11.0	12.0	-	-
Short-term loan	8.0	17.3	9.9	2.3	-	-	-	-
Total	19.0	28.3	20.9	13.3	11.0	12.0	-	-
Financial expenses								
Long-term loan	18.8	8.0	7.1	6.3	5.4	0.9	-	-
Short-term loan	1.2	2.6	1.5	0.3	-	-	-	-
Total	20.0	10.6	8.6	6.6	5.4	0.9	-	-
Tax payable	-	-	2.7	4.6	5.0	9.4	15.3	32.8
Cash and deposit (end)	2.0	2.0	2.0	7.4	15.9	50.8	124.2	179.7
T o t a l	205.6	259.4	252.7	250.4	255.8	291.6	358.0	431.0

Table 7.1.13 Projected Profit & Loss for Project D-1

(unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Sales revenue								
(Quantity, 1000 tonnes)	(480)	(816)	(960)	(960)	(960)	(960)	(960)	(960)
(Unit price US$/tonnes)	(834)	(834)	(834)	(834)	(834)	(834)	(834)	(834)
Amount	400.5	680.8	801.0	801.0	801.0	801.0	801.0	801.0
Production cost	124.4	211.4	248.7	248.7	248.7	248.7	248.7	248.7
Variable cost	191.6	191.6	191.6	191.6	192.6	46.6	46.6	32.6
Fixed cost								
Total	316.0	403.0	440.3	440.3	441.3	295.3	295.3	281.3
Operating income	84.5	277.8	360.7	360.7	359.7	505.7	505.7	519.7
Non-operating expenses								
General adm.	1.2	2.1	2.4	2.4	2.4	2.4	2.4	2.4
Financial expenses	103.2	113.5	73.4	59.1	50.7	8.4	-	-
Total	104.4	115.6	75.8	61.5	53.1	10.8	2.4	2.4
Net income before tax	-19.9	162.2	284.9	299.2	306.6	494.9	503.3	517.3
Tax	-	78.3	156.7	164.6	168.6	272.2	276.8	284.5
Net income after tax	-19.9	83.9	128.2	134.6	138.0	222.7	226.5	232.8
Accumulated net income	-19.9	64.0	192.2	326.8	464.8	1,342.3	2,474.8	3,619.9

Table 7.1.14 Projected Cash Flow for Project D-1

(Unit: US$ million)

Year after Start-up	1	2	3	4	5	10	15	20
Source of funds								
Cash and deposit (beginning)	3.0	5.0	6.0	223.8	416.3	1,363.0	2,522.5	3,725.0
Financial resources								
Long-term loan	-	-	-	-	-	-	-	-
Short-term loan	250.0	38.8	-	-	-	-	-	-
Total	250.0	38.8	-	-	-	-	-	-
Sales revenue	400.5	680.8	801.0	801.0	801.0	801.0	801.0	801.0
T o t a l	653.5	724.6	807.0	1,024.8	1,217.3	2,164.0	3,323.5	4,526.0
Use of funds								
Production cost (excl. dep. & amo. incl. gen. adm.)	158.2	246.1	283.7	283.7	283.7	283.7	283.7	283.7
Repayment								
Long-term loan	108.0	109.0	109.0	109.0	109.0	109.0	-	-
Short-term loan	126.0	250.0	38.8	-	-	-	-	-
Total	234.0	359.0	147.8	109.0	109.0	109.0	-	-
Financial expenses								
Long-term loan	237.4	76.0	67.6	59.1	50.7	8.4	-	-
Short-term loan	18.9	37.5	5.8	-	-	-	-	-
Total	256.3	113.5	73.4	59.1	50.7	8.4	-	-
Tax payable	-	-	78.3	156.7	164.6	207.0	276.8	569.0
Cash and deposit (end)	5.0	6.0	223.8	416.3	609.3	1,555.9	2,763.0	3,673.3
T o t a l	653.5	724.6	807.0	1,024.8	1,217.3	2,164.0	3,323.5	4,526.0

Table 7.1.15 Projected Profit & Loss for Project D-2

(Unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Sales revenue								
(Quantity, 1000 tonnes)	(490)	(833)	(980)	(980)	(980)	(980)	(980)	(980)
(Unit price US$/tonnes)	(761)	(761)	(761)	(761)	(761)	(761)	(761)	(761)
Amount	372.7	633.6	745.4	745.4	745.4	745.4	745.4	745.4
Production cost								
Variable cost	123.1	209.3	246.2	246.2	246.2	246.2	246.2	246.2
Fixed cost	185.5	185.5	185.5	185.5	186.5	44.5	44.5	31.5
Total	308.6	394.8	431.7	431.7	432.7	290.7	290.7	277.7
Operating income	64.1	238.8	313.7	313.7	312.7	454.7	454.7	467.7
Non-operating expenses								
General adm.	1.2	2.1	2.4	2.4	2.4	2.4	2.4	2.4
Financial expenses	115.9	115.0	81.4	57.0	48.9	8.2	-	-
Total	117.1	117.1	83.8	59.4	51.3	10.6	2.4	2.4
Net income before tax	-53.0	121.7	229.9	254.3	261.4	444.1	452.3	465.3
Tax	-	37.8	126.4	139.9	143.8	244.3	248.8	255.9
Net income after tax	-53.0	83.9	103.5	114.4	117.6	199.8	203.5	209.4
Accumutated net income	-53.0	30.9	134.4	248.8	366.4	1,136.3	2,153.8	3,183.1

Table 7.[redacted]6 Projected Cash Flow for Project [redacted]2

(Unit: US$ million)

Year after start-up	1	2	3	4	5	10	15	20
Source of funds								
Cash and deposit (beginning)	3.0	5.0	6.0	138.8	315.7	1,154.4	2,195.1	3,277.6
Financial resources								
Long-term loan	-	-	-	-	-	-	-	-
Short-term loan	278.0	108.3	-	-	-	-	-	-
Total	278.0	108.3	-	-	-	-	-	-
Sales revenue	372.7	633.6	745.4	745.4	745.4	745.4	745.4	745.4
T o t a l	653.7	746.9	751.4	884.2	1,061.1	1,899.8	2,940.5	4,023.0
Use of funds								
Production cost (excl. dep. & amo. incl. gen. adm.)	155.8	242.9	280.1	280.1	280.1	280.1	280.1	280.1
Repayment								
Long-term loan	105.0	105.0	105.0	105.0	105.0	106.0	-	-
Short-term loan	124.0	278.0	108.3	-	-	-	-	-
Total	229.0	383.0	213.3	105.0	105.0	106.0	-	-
Financial expenses								
Long-term loan	229.5	73.3	65.2	57.0	48.9	8.2	-	-
Short-term loan	34.4	41.7	16.2	-	-	-	-	-
Total	263.9	115.0	81.4	57.0	48.9	8.2	-	-
Tax payable	-	-	37.8	126.4	139.9	180.9	248.8	511.8
Cash and deposit (end)	5.0	6.0	138.8	315.7	487.2	1,324.6	2,411.6	3,231.1
T o t a l	653.7	746.9	751.4	884.2	1,061.1	1,899.8	2,940.5	4,023.0

7.1.5 Financial Analysis

(1) Financial stability

In order to look at financial stability, a break-even point analysis has been adopted.

Results are shown in Table 7.1.17.

Table 7.1.17 Break-even Point

Project	Full production (1,000 t/year)	Break-even point Production (1,000 t/year)	Break-even point %
A	400	117.6	29.4
B	380	128.0	33.7
C	400	206.1	51.5
D-1	960	334.8	34.9
D-2	980	366.1	37.4

From the above it may be said that all projects excluding Project C are capable of realizing profits at an utilization rate of arround 30 to 40%. Especially, Project A may be considered as an excellent plan, breaking even at 29.4%.

Even for Project C, it is not a bad figure comparing with similar projects as it will break even at 50%.

(2) Financial profitability

(a) General indication

As general indication of profitability, "Accumulated Net Income after 20 Years from Start Up", "Marginal Profit Ratio" and "Ratio of Net Income" have been adopted as shown in Table 7.1.18.

Table 7.1.18 General Indication of Profitability

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Accumulated net income after tax in 20th year from start-up	277.4	1,047.6	184.3	3,619.9	3,183.1
Marginal profit ratio at 5th year (%)	49.5	68.2	13.2	69.0	67.0
Ratio of net income to net sales at 5th year (%)	30.5	38.6	4.4	38.3	35.1

From the table, it may be said that all projects, except for Project C, indicate extremely high profitability in comparison with similar steel projects.

(b) Internal rate of return

In evaluating investment profitability, the internal rate of return by the discounted cash flow method is generally used. With this method, the amount of recovery will be calculated against initial investment on current value basis, using the following equation.

$$Co = \frac{R1}{(1 + i)} + \frac{R2}{(1 + i)^2} + \cdots + \frac{Rn + Rv}{(1 + i)^n}$$

Co = initial investment

i = discount rate

Rn = profit during the n-th year

n = project period in year

Rv = residual value

In short, this method predicts profit rate by equalizing the combined amount of annual profits estimated on current value basis and residual value also estimated on current value basis to the initial investment (Co).

In other words, the internal rate of return (ROI) finds investment profit rate, i.e., how much can be returned to capital resources.

Table 7.1.19 shows the ROI of each Project. And Appendix to 7-3 shows cash flow and discounted cash flow in each year of each Project

Table 7.1.19 Internal Rate of Return

Project	ROI (%)
A	16.12
B	14.62
C	7.58
D-1	14.27
D-2	13.49

With ROI analysis, it is possible to judge the feasibility by seeing if ROI exceeds the country's marginal investment cost. Country's marginal investment cost is usually almost equal to long-term interest cost or somewhat exceeds it.

This master plan assumes long-term loan to be obtainable under the conditions similar to the OECD guideline for suppliers credit. On the basis of this assumption, all projects except for Project C are said to be feasible in terms of ROI.

On the other hand, if it is necessary to obtain a long-term loan at an interest rate exceeding ROI, the project is considered to be less feasible. In that sense, Project C may be said to be relatively easy to be taken up as it will involve a smaller initial investment, but most hard to realize profits.

(3) Comprehensive evaluation

So far each project has been evaluated from various aspects if it is feasible as a business enterprise. Looking at the results of such evaluations in a comprehensive manner, it may be said that all projects, except for Project C, will create an excellent results.

Especially, Project A may be said as an excellent business remarkably exceeding other similar steel projects. Generally speaking, a steel project tends to be a national project to create a foundation of industry. It requires an enormous amount of initial investment, and yet realizes relatively small returns.

However, such high profitability of the projects is due to the fact that the market prices of imported products, which include current high level tariff (mostly 70%) have been used in calculation. Thus, these projects may be said as receiving subsidies equal to import duties. In a future project, it may be necessary to return such profits to steel consuming industries by lowering their sales prices in order to further develop the iron and steel industry in Pakistan.

7.2 Economic Analysis

In Section 7.1 "Financial Evaluation", each project was considered as a business concern to evaluate its feasibility.

Results may be said quite satisfactory as to all projects, even in Project C. The primary object of this Master Plan is to consider the future of the steel industry in Pakistan, and an evaluation from the standpoint of the national economy is said more important than an evaluation at a business concern level.

From such viewpoint, an economic evaluation is to be attempted.

7.2.1 Tax Revenues to Pakistan Government

It is not an overexaggeration, as mentioned above, to say that the high level profit of each project actually includes government subsidies. Revenues for government in the form of import taxes will disappear if any of the projects is realized.

It is therefore necessary to calculate loss which will accrue to the government and corporate tax increase when a project is realized.

On the basis of the above-mentioned consideration, increase and decrease in government revenues have been calculated as shown in Table 7.2.1.

Table 7.2.1 Tax Revenue of Government

(Unit: US$ million)

Project	Increase	Decrease	Balance
A	340	748	-408
B	1,281	1,802	-521
C	223	1,936	-1,713
D-1	4,424	4,897	-473
D-2	3,891	4,677	-786

All of the projects indicate drop of tax revenues of the government.

This does not mean that the projects lose reasons to be set up but only means decrease in government revenues.

In order to reach a correct conclusion, added value which is composed of net income after tax, capital consumption, distribution of labour and so on, and also foreign currency saving would have to be taken into consideration.

It may be said, however, that Project D-1 suffers a quite small tax revenue decrease in comparison with the size of investment, on the contrary Project C suffers a large tax revenue decrease in spite of a relatively small investment.

7.2.2 Foreign Currency Saving

Pakistan's chronic trade deficit can be recovered to a considerable extent by out-of-trade foreign currency earnings, but deficit in the balance of current account has been a serious national issue.

To continue to depend on import for steel products means to further aggravate foreign currency balance. Thus, how much foreign currencies each project could save is a very important indicator to demonstrate its value.

Each project is assumed to save foreign currencies equivalent to C&F total. On the other hand, foreign currency are assumed to be used for the foreign currency portion of the construction costs, financial expenses and raw material import. Table 7.2.2 shows each project's balance during its project life.

Table 7.2.2 Foreign Currency Saving

(Unit: US$ million)

Project	Gross Saving	Use (A)	Net Saving (B)	Efficiency (B)/(A)x100%
A	1,084	818	266	33%
B	2,559	1,268	1,291	102%
C	2,749	1,925	824	43%
D-1	8,568	6,068	2,500	41%
D-2	8,282	6,002	2,280	38%

In terms of absolute positive balance, Projects D-1 and D-2 each shows the highest net saving, but they also use a considerable amount of foreign currencies. Thus, they are not considered so excellent in terms of efficiency of foreign currency use.

On the other hand, only Project B will realize a net saving larger than foreign currency use. Although B cannot compete against Project D-1 or D-2 in terms of absolute amount of saving, it is expected to show more than twice higher efficiency in foreign currency use than D-1 or D-2.

Also Project A and C are not indicating bad figure.

7.2.3 Added Value Analysis

As part of Economic Analysis, tax revenues of government and foreign currency use have been analyzed, but they are only some aspects of the national economy. As a factor of total impact upon the national economy, added values have been estimated as shown in Table 7.2.3.

Table 7.2.3 Added Value

(Unit: US$ million)

	Project				
	A	B	C	D-1	D-2
Labour fee	4	24	4	44	44
Depreciation and amortization	90	417	129	1,418	1,368
Financial expense	35	149	55	526	541
Tax	340	1,280	223	4,424	3,891
Net income	277	1,048	183	3,620	3,183
Total added value (A)	746	2,918	594	10,032	9,027
Total construction cost (B)	101	455	147	1,556	1,501
Efficiency $\frac{(A)}{(B)}$	7.4	6.4	4.0	6.4	6.0

Both Projects D-1 and D-2 show excellent added values. Also, added values from Project A, B or C cannot be said small.

In analyzing efficiency in terms of return on investment, time factor should be taken into consideration, but it will be done in the following section "ROI on National Economy Bais" and simple investment efficiency will be analyzed here.

In terms of efficiency, Project A stands out, followed by Project B, D-1 and D-2. Project C is little bit smaller than the others but it cannot be said poor in efficiency.

7.2.4 ROI on National Economy Basis

The financial evaluations from the standpoint of business concern demonstrated excellent profitability as the present market prices were used as bases. As discussed in 7.1.5, such prices include government subsidies for the Projects in reality.

Here, apparent figures will be modified and corrected from the standpoint of the national economy. For example, sales prices and raw material costs will be adopted as shadow prices on the basis of international market prices to review cash flow and also to calculate internal rate of return.

ROI on national economy basis for each project is shown in Table 7.2.4.

Table 7.2.4 ROI on National Economy Basis

Project	ROI on National Economy Basis (%)
A	6.64
B	5.65
C	0.41
D-1	6.03
D-2	5.40

Results indicate that Project A has the highest profitability in substantial meaning.

Other projects except for Proje C cannot be said better than other steel projects in terms of profit-ability. It may be said in summary that if inter-national market prices which do not include import taxes are use as sales prices instead of domestic market prices which include import taxes of current high level, all of the projects cannot be said as show a high profitability but rather low profitability.

Project C indicates quite low level figure, which means if the substantial subsidies aren't applied it cannot be feasible.

Generally speaking, however, steel projects are often treated as national projects in developing countries. Also, high profitability cannot be expected as steel is a basic material. And countries often take some protective measure, such as tax exemption and subsidies, for a certain initial period from the standpoint of the national economy.

Therefore, the figures indicated above are not to deny the feasibility of the projects from the standpoint of the national economy. In short, they may be said to be worthwhile of being carried out from the comprehensive standpoint of foreign currency saving and added values.

7.3 Conclusion and Recommendation for Action

7.3.1 Introduction

In 7.1 Financial Evaluation and 7.2 Economic Evaluation, we have evaluated the five prospective Projects discussed in Chapter 6 to see the feasibility of each Project from a standpoint of business concern and also of the national economy.

The findings are that each project is excellent from the standpoint of a private corporation, even though they have some rank. By looking at various conditions such as market and financial source, it should be decided to launch which project.

It may be concluded that all projects demonstrated to bring about positive benefits in added value and foreign currency saving and also indirect benefits such as employment creation, promotion of industrialization and accumulation of modern technology.

As a result, we have reached the conclusion that all of the five Projects are worthwhile to be realized in Pakistan.

7.3.2 Possible SCENARIO

The question is how these projects should be realized under what time schedule, taking into consideration demand and supply balance, construction period and period required for preparation.

As mentioned in the early part of Chapter 6, these five Projects have been selected without considering whether only one of the two should be selected or whether they could coexist. How we have come up to the stage to review whether they are coexist or not.

Project A: A plan to supply DRI as a substitute for imported scrap to the existing ingot/billet makers. Possible to coexist with any other projects.

Project B: In order to meet increased demand for bars and sections, which will be produced at a DR integrated steel works to balance supply and demand. Either this Project or Project C involving only a rolling mill should be selected.

Project C: The excess capacity of the existing ingot/billet makers will be utilized. A rolling mill will produce bars and sections using 150 mm sq. billets made by Project D-2. Either Project B or this Project should be selected.

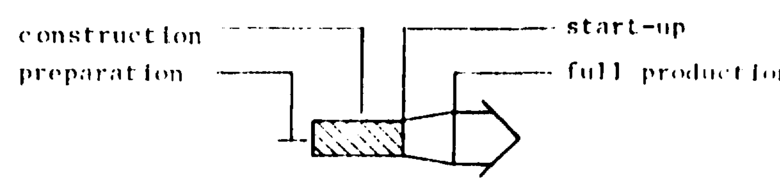
Project D-1: The first plan to double current production. In order to utilize the 1.8 million-tonne capacity of the hot strip mill. Either Project D-2 or this Project should be selected.

Project D-2: The second plan to double current production. To supply liquid steel not only for flat products but also for billets, provided that billets will be supplied to a limited extent of quality steel. It is natural to consider the rolling mill under Project C in combination with Project D-2. Either Project D-1 or this Project should be selected.

In view of the above consideration, Table 7.3.1 shows the time schedule for each Project, taking into consideration construction period, period required for preparation and time when demand and supply will be balanced.

Table 7.3.1 Time Schedule of Projects and SCENARIO

Products	Project	1981-82 · 1984-85 · 1989-90 · 1994-95 · 1999-2000	SCENARIO I	SCENARIO II
D R I	A		○	○
Bars and Sections	B	(i) (ii)	○ (i)&(ii)	○ (ii)only
	C		—	○
Flat Products	D-1		○	—
	D-2		—	○



Then, two SCENARIOS could be formed:

SCENARIO I:

Project A should be immediately set about to construct a DR plant to supply DRI to the existing ingot makers which are suffering from insufficient supply of raw materials.

Then, starting preparation around 1986-87, a DR integrated works (Project B (i)) should be constructed to supply bars and sections as construction materials.

Meanwhile, starting preparation around 1987-88 when Pakistan Steel has already reached a stable operation, and start in 1989-90 to construct additional facilities for doubling Pakistan Steel toward full operation by 1996-97. (Project D-1)

In order to meet increased demand for bars and sections, the DR integrated steel works should be expanded to 800,000 tonnes/year level by 1995-96. (Project B (ii))

As Projects B and D-1 will be carried out during the same time from 1989-90 to 1991-92, some difficulties are expected in securing necessary funds and in carrying them out, but it is not impossible to implement them concurrently as they reach their peak at different times.

SCENARIO II:

Project A should be immediately carried out to construct a DR plant to supply DRI to the existing ingot makers which are suffering from insufficient supply of raw materials.

Then, construction of doubling Pakistan Steel should be started around 1987-88. (Project D-2) To do so, it is necessary to start preparatory works and studies around 1985-86.

In order to complete D-2 at the same time (1992-93), construction works should be started for a rolling mill (Project C) in 1989-90.

In addition, it will be necessary to install a DR integrated steel works (Project C) as there will be a short supply of bars and sections coming to 400,000 tonnes in around 1991-92.

Comparing these two SCENARIOS, we recommend to adopt SCENARIO I.

There are three reasons for this recommendation:

First, as a basic philosophy for country's steel industry, monopolized production has usually evil influence for national economy and various products which should meet quite different basic requirement should be supplied by several manufacturers, even though it seems sometimes unavoidable.

In other words, it should be adopted as a fundamental thinking to specialize Pakistan Steel in flat products.

Second, it is clear that a DR integrated steel works (Project B) will demonstrate merits from the financial and economic stand-point. Also, the rolling mill (Project C) will not be so attractive, which mill will use billets produced by Pakistan Steel.

Third, a DR integrated steel works will eventually have to be constructed (Project B (ii)) in order to meet increased demand even under SCENARIO II. Thus, Project D-2 will be only a temporary measure. Therefore, it should be more natural and reasonable to adopt SCENARIO I to double the production capacity of the DR integrated steel works.

7.3.3 Additional Remarks

Up to now we have discussed, on the basis of some assumptions, how Pakistan should go about its steel industry.

Here, we have some suggestions as regards the directions in which the existing industries should proceed in the future.

Existing Ingot Makers and Rolling Mills

Melters, semi-integrated mills and re-rollers are included in this category. We assumed that their production will maintain their present levels as a whole although there may be slight increases due to technical improvements and made no special reference to the details of their production.

There is no doubt that these existing ingot makers and rolling mills will go through the process of scrap and build to grow to more up-to-date and greater in scale and productivity. Those which lag in this race of modernization will be left behind only to die out.

What is important is that the iron and steel industry should not rely only on the big projects such as those mentioned before. As for some types of products, the role to be played by ingot makers will remain unchanged to certain extent until the year 2000 and the government should proceed in the direction of taking full advantage of such vital energies of private industrial enterprises.

Special Steel of Pakistan

As was studied in detail by the feasibility study, carried out by JICA in 1980, the principal reason for its closedown is considered to be mainly for the market demand, therefore, more careful consideration should be given and arrangement of surroundings should be made for the effective utilization of the existing facilities including as temporary conversion to the production of mild steel in the future.

Shipbreaking Industry

This industry play a very significant role in respect of supply of low-cost raw materials for the iron and steel industry and the creation of vast employment. This industry should continue to play a definite role in such respects in the future even though it will be difficult for the industry to make very rapid expansion in the foreseeable future because of the increasing demand for quality controlled products, the space restrictions at the site of shipbreaking, and the limit to the supply of ships to be scrapped.

Next, some mention should be made about the probability of forecast. We have reviewed supply and demand balance on the assumption to utilize the existing facilities (ingot makers, rolling mills, Pakistan Steel, etc.) to their full capacities. In order to supplement the deficiency of those existing facilities, we have proposed the Projects.

For the maximum utilization of the existing faiclities, it is necessary to get some assistances from the government, to have careful planning and training and to introduce technologies from advanced steel producing countries.

Looking at steel industries in developing countries, it is unfortunate to see that none of them are realizing full utilizing their capacity except for South Korea and Taiwan which are called the middle advanced steel producing countries. As for Pakistan Steel, for instance, we calculated that it should be able to produce 1.05 million tonnes against the rated capacity of 1.1 million tonnes, considering the capacity utilization rate of 95.5% reached in Japan as an ideal rate. However, a rate of 80% is normal in developing countries, and the rate will be even smaller if middle advanced steel producing countries are excluded from the statistics.

What we fear is that Pakistan may not be able to satisfy the assumptions listed earlier and thus may be unable to fully utilize the existing facilities. Then, production costs will be further raised and the Projects we have proposed will have to be set about much earlier than the SCENARIO.

Therefore, government officials and persons concerned should not consider this Master Plan as a static time table. Instead, the plan should be used in a dynamic manner, watching the production trend at Pakistan Steel and the utilization of the existing facilities including ingot makers, rolling mills, etc.

Appendix to 2-1 Melters

Public Sector

Name of Company	Location	Kind of Furnace	Capacity of Furnace (tonnes/heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/annum)
Heavy Foundry and Forges Ltd. (HFF)	Punjab	Arc	3 15	1 2	66,000
Karachi Shipyard and Engineering Works	Sind	Arc Induction	3 1	1 2	8,000
Pakistan Railways	Punjab	Arc	4.5 5	1 1	19,000
Wah Industries	"	Arc	5	1	10,000

Private Sectors

Name of Company	Location	Kind of Furnace	Capacity of Furnace (tonnes/heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/annum)
Ahmed Investment Ltd.	Sind	Arc	10	2	48,000
Al-Noor Steel Industries Ltd.	Sind	Arc	5	1	12,000
Afzal Steel Industries	Punjab	Induction	1	1	2,400
Al-Madina Arc Steel Ltd.	"	Arc	1	1	2,400
Awan Steel Industries	"	Arc	1	1	2,400
Brother Steel Mills	"	Induction	1	1	2,400
Elektromolt Ltd.	"	"	3	1	7,200
Friends Co-operative Steel Casting Mills	"	Arc	0.5	1	1,200
General Steel Industry	"	"	5	1	12,000
Karim Aziz Industries	"	"	5	1	12,000
Life Metal Works.	"	Induction	1.5	1	3,600
Lahore Alloys Ltd.	"	"	2	1	4,800
La-Jawab Steel Casting	Punjab	Arc	1	1	2,400

Private Sector

Name of Company	Location	Kind of Furnace	Capacity of Furnace (tonnes/heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/annum)
Mirza Technical Industries Ltd.	Punjab	Induction	2	1	4,800
Mohamad Din & Sons	"	"	1	1	2,400
Mughal Brothers Industries Ltd.	"	"	0.5	1	1,200
Malik Steel Industries	"	"	2	1	4,800
Naseem Steel Mill	"	"	0.5	1	1,200
Nama Steel Centre	"	"	1	1	2,400
Noor Steel	Sind	Arc	5	1	12,000
O.K. International Industries (Pak.) Ltd.	Punjab	Induction	1	1	2,400
Pak Steel Mills					
(Shaliman Town)	"	"	1	1	2,400
(Bund Road)	"	"	1	1	2,400
Pak Sartaj Steel Mill	"	"	1	1	2,400
Sartaj Paint & Varnish Works	Punjab	Induction	1	1	2,400
Sartaj Steel & General Mills	"	"	1	1	2,400
Standard Steel Mills	"	"	1.5	1	3,600
Steelforce Iron & Steel	"	Arc	2	1	4,800
Steel Casting Ltd.	"	Induction	0.5	1	1,200
Supraa Steels	"	"	0.5	1	1,200
Yazdani & Co., Ltd.	"	"	1.5	1	3,600
Zahid Steel Mill	"	"	1	1	2,400

Appendix to 2-2 Semi-Integrated Mills

Public Sector

Name of Company	Location	Melting Facilities: Kind of Furnace	Capacity of Furnace (tonnes/ heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/ annum)	Re-Rolling Facilities: Size of Mill	Capacity of Mill (tonnes/ annum)	Actual Production Rolled Products (tonnes/ annum)	Remarks
The Pakistan Engineering Co., Ltd. (PECO) (Badami Bagh)	Punjab	Induction Arc	2.5 4	1 1	13,000	16" 15" 8"	9,000 9,000 3,000		
The Pakistan Engineering Co., Ltd. (PECO) (Kot Lakhpat)	"	Arc	10	3	72,000	20" 10"	21,000 6,000	18,000 5,000	

Private Sector

Name of Company	Location	Kind of Furnace	Capacity of Furnace (tonnes/ heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/ annum)	Size of Mill	Capacity of Mill (tonnes/ annum)	Actual Production Rolled Products (tonnes/ annum)	Remarks
Abbas Steel Industries Ltd.	Sind	Arc	3	1	7,200	10"	5,000		
Allah Ditta Abdul Rashid Steels	Punjab	"	5	1	12,000	10"	5,000		
Chinab Engineering Works & Iron Foundry	"	"	0.5	1	1,200	8"	2,500		
H.S. Nizam-ud-din & Sons	"	Induction	1	1	2,400		3,000		
Haydari Steel Industries Ltd.	Sind	"	5	1	12,000				

Appendix to 2-2 Semi-Integrated Mill (Cont'd)

Name of Company	Location	Melting Facilities: Kind of Furnace	Capacity of Furnace (tonnes/ heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/ annum)	Re-Rolling Facilities: Size of Mill	Capacity of Mill (tonnes/ annum)	Actual Production Rolled Products (tonnes/ annum)	Remarks
Haleem Steel Re-Rolling Mills	Punjab	Arc	1.5	1	3,600	8"	2,500		
Inland Steel Works Ltd.	"	Induction	2	1	4,800	8"	2,500		
Ittefaq Foundries Ltd.	"	Arc	5	4	48,000	8" 10" 14"	6,900 9,000 24,000	5,000 7,000 21,000	Continuous casting machine is under construction.
Ittehad Steel Ltd.	"	Induction	4	1	9,600	-	1,000		
Javed Pervez Corp., Ltd.	"	Arc	5	1	12,000	12"	15,000	12,000	
Kamran Steel Re-Rolling	"	Arc	5	1	12,000	18" 14"	20,000 8,000		18" Mill is under construction.
Lion Industries & Re-Rolling Mills	"	Induction	1	1	2,400	8"	2,500		
Nawaz Shehbaz Ltd.	"	Arc	5	1	12,000	8"	7,000		
New Sartaj Steel & General Mills	"	Induction	1	1	2,400				
Nowshera Engineering Co., Ltd.	NWFP	Arc	5 2	2 2	33,600	12" 8" 6"	15,000 6,000 2,500		
Orient Technical Works	Punjab	"	7.5	1	18,000	10"	5,000		

Appendix to 2-2 Semi-Integrated Mills (Cont'd)

Name of Company	Location	Melting Facilities: Kind of Furnace	Capacity of Furnace (tonnes/heat)	Number of Furnace	Annual Production Capacity of Crude Steel (tonnes/annum)	Re-Rolling Facilities: Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production Rolled Products (tonnes/annum)	Remarks
Panjab Steel Ltd.	Punjab	Arc	5	2	24,000	12" 8"	6,000 4,500		Continuous casting machine is under construction.
Sind Steel Corporation	Sind	"	5	1	12,000				
United Iron & Steel Ltd.	Punjab	Induction	2.2	1	5,300	8"	3,000		
Frontier Industries Corporation	NWFP	Induction	2	2	9,600	14"	12,000		Both melting and re-rolling facilities are under construction.

Appendix to 2-3 Re-Rollers

Public Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Metropolitan Steel Corporation Ltd.	Sind	HOOP BAR STRUCTURE 10"	95,000	70,132
Quality Steel Works Ltd.	Sind	12"	18,000	8,015
		10"	3,300	3,011
		8"	4,200	3,627

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
A. B. Chisty & Sons, Re-rolling Mills	Punjab		200	
Abdullah Khan Steel, Re-Rolling Mills	"		11,700	
Afzal Steel Re-rolling Mills	"		650	
Ahmed Enterprise	Sind	16"	18,000	
A. Ismailjee & Sons	Punjab		2,000	
Ali Son Steel Re-rolling Mills	"		-	
Allied Metal Industries	Sind			
Allied Steel Re-rolling Mills	Punjab		3,000	
Al-Mahmood	Sind			
Al-Noor Inds. Ltd.	Punjab		-	

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Ahmad Bakhsh & Bros.	Punjab		3,600	
Amin Re-rolling Mills	"		1,600	
Aryan Steel Industries Ltd.	"		9,000	
Ashraf Engineering Works Ltd.	"			
Awami Re-Rolling Mills	Sind			
Baluchistan Steel Mills Ltd.	"			
Barkat Ali & Sons	Punjab		300	
Bashir Ahmad Gondal	"		2,000	
B. R. Inds.	"		2,500	
Carstair & Cummings Ltd.	Sind			
The Cast Iron Foundry	"			
Chand Steel Re-rolling	Punjab		1,000	
Chaundhry Steel Re-rolling Mills	"		2,000	
Cooperative Steel Re-rolling Mills	"		650	
Dada Steel Mills	Sind			
Eastern Steels	"			

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Eastern Steel Re-rolling Mills	Punjab		24,000	
Fazal Mohammad & Bros., Re-rolling Mills	"		6,000	
Fazil Bros.	"		2,200	
Ferrous Metal Industries	"		1,000	
Friends Engg. Re-rolling Mills	"		1,500	
G. A. Steel Re-rolling Mills	"		-	
General Steel Mills Ltd.	"		4,200	
Ghanchi Re-rolling Mills	Sind			
Hafiz Bros. Re-rolling Mills	Punjab		2,000	
Hamid & Co.	"		1,300	
Hardware Manufacturing Corporation Ltd.	Sind	12" 8" 8"	30 000	14,425
H. S. Steel Mills	Punjab			
H. S. Steel Re-rolling Mills	"		6,700	
Idrees & Co., Ltd.	"		9,000	

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Iqbal Majid re-rolling Mills	Punjab		2,400	
Islam Inds., Re-rolling Mills	"		4,800	
Ismailjee & Sons Ltd.	"			
Ittefaq Re-rolling Mills	"		1,600	
Ittefaq Steel Re-rolling Mills	"		3,000	
Ittehad Steel, Re-rolling Mills	"		4,000	
Ittehad Steel Re-rolling Mills	"		1,200	
Jan Steel Mills	"			
Karachi Metals Ltd.	Sind			
Karachi Rolling Mills Ltd.	"			
Karachi Steel Industries Ltd.	"			
Karimi Steel Corporation	"			
Kh Abdul Hamid & Co. Re-rolling Mills	Punjab		1,000	
Khadim Steel Re-rolling Mills	"		1,800	

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Khawaja Mi'ls Steel Re-rolling Kala Gujaran	Punjab		4,200	
Khokhar Engineering Co.	Sind			
Lahore Steel Re-rolling Mills	Punjab		3,000	
Lasani Steel Mills	"		6,000	
Madina Rolling Mills	Sind			
Malik Engg. Works	Punjab		3,600	
Malik Mohammad Din & Sons	"		3,200	
Malik Steel Re-Rolling Mills	"			
Maqbool Steel Re-Rolling Mills	"			
Millsons Steel Industries Ltd.	Sind			
Modern Steel Mills	Punjab			
Modern Steel Re-rolling Mills	"		3,600	
Moghal Mechanical Co. Steel Re-rolling Mills	"		3,000	
Moghal Steel Re-rolling Mills	"		1,400	

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Mohammadan Steel Re-rolling Mills	Punjab		3,600	
Mohammadi Steel Re-rolling Mills	"		600	
M. S. Steel Mills	Sind			
M. Siddique & Bros.	Punjab		2,400	
Multan Re-Rolling Mills	"		1,200	
Mumtaz Steel Re-Rolling Mills	"			
Muslim Rolling Mills Ltd.	Sind			
Muslim Steel Mills Ltd.	"			
Muslim Steel Re-rolling Mills	Punjab		600	
National Foundry & Re-rolling Mills	"		600	
National Steel Re-rolling Mills	"		4,200	
National Steel Spring & Re-rolling Mills	"		6,000	
Nawab Brothers	Sind			
Nawab Shah Steel Re-rolling Mills	Punjab		-	

Appendix to 2-3 Re-Rollers (Cont'd)

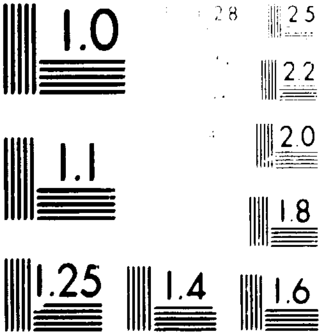
Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Nawaz Foundry Works & Re-rolling Mills	Punjab		1,000	
New City Steel Mills	"		4,800	
New Era Steels	Sind			
New Lahore Steel Re-rolling Mills	Punjab		-	
New Shalimar Steel Re-Rolling Mills	"			
New Steel & General Mills	"		1,200	
Northern Industries Ltd.	"		7,000	
Pakistan Steel Products	Sind			
Pak Madina Steel Mills	Punjab			
Pakistan Steel Re-rolling Mills	"		6,000	
Pakistan Oil Expellers & Steel Re-rolling Mills	"	12" 9" 8" 6"		2,432
Pakistan Steel Re-Rolling Mills	"		160	
The Pipe Casting Works	"		1,200	
P. R. Re-rolling Mills	"		18,000	

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
The Punjab Steel Re-rolling Mills	Punjab		3,600	
Qadri Brothers	Sind			
Qasim Bros., Ltd.	Punjab		-	
Rahim Steel Re-Rolling Mills	"			
Ravi Steel Re-rolling Mills	"			
Rawal Steel Industry 1/9 Sector	"			
Razeque Steels Ltd.	Sind	13" 6")	17,000	14,000
Rehman Chohan Steel Re-rolling Mills	Punjab			
Republic Industrial Corporation	Sind			
Royal Steel Re-rolling Mills	Punjab			
R. R. Steel Inds.	"		4,500	
Safdar & Co., Ltd.	"		6,000	
Samara Inds., Re-rolling Mills	"		1,200	
Said Steel Re-rolling Mills	"		4,200	


1.0
2.8
2.5
2.2
1.1
2.0
1.8
1.25
1.4
1.6

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Sarhad Re-Rolling Mills	Sind			
Sartaj Re-rolling Mills	Punjab		2,600	
Sh. Abdul Rahim Allah Ditta Re-rolling Mills	"		300	
Shaheen Steel Re-Rolling Mills	"			
Shalimar National Engg. Works	"		400	
Shalimar Steel Industries	Sind			
Shalimar Steel Re-rolling Mills	Punjab		1,750	
Sh. Chiragh Din Gulzar Mohammad Steel Re-rolling Mills	"		3,600	
Sheikh Fazal Faqir Mohd Re-rolling Mills	"		4,800	
Sh. Fazal Mohammad Fiaz Mohammad Steel Re-Rolling Mills	"			
Sitara Safe Factory & Steel Re-rolling Mills	"		3,600	
Standard Rolling Mills Ltd.	Sind			

Appendix to 2-3 Re-Rollers (Cont'd)

Private Sector

Name of Company	Location	Size of Mill	Capacity of Mill (tonnes/annum)	Actual Production (tonnes/annum)
Standard Steel Re-rolling Mills	Punjab		6,000	
Star Rolling Mills Ltd.	Sind			
Star Steel Re-Rolling Mills	Punjab			
Super Steel Re-rolling Mills	"		3,600	
Taj Steel Mills	"		5,000	
Union Foundry & Steel Re-rolling Mills	"		24,000	
Union Steel Ltd.	Sind			
United Steel Corp.	Punjab		-	
United Steel Re-Rolling Mills	"			
Victory Iron & Steel Mills	"		4,800	
Yaqoob Industries	Sind			
Yusuf Re-Rolling Mills	"			
Zhob Steel Mills	Punjab		7,500	

Appendix to 3-1

Competition of Iron and Steel with Non-Ferrous Materials

Any study of the competitions between iron and steel, and non-ferrous materials should properly be made on individual cases in detail. However, in this Master Plan, we are taking a general look at their conditions at present and in future in view of the nature of the study.

For studying the actual conditions of these competitions, it is the most useful way to observe them from the consuming industries' side. As steel consuming industries in Pakistan, the construction, machining and consumables manufacturing industries are enumerated.

First of all, the actual present conditions of competition and their prospects mainly in the construction industry in advanced countries, are made clear, which is the largest steel consuming industry. And also future conditions in Pakistan are seen through.

Secondly, the prospects for other consumables, i.e. automobiles and household appliances in Pakistan, are studied by clearifying competition conditions of these goods in advanced countries.

1. Competition in the construction industry

   The steel products consumed in the construction industry in Pakistan are mainly reinforcing bars, which are consumed together with the cement for concrete. Among the steel structural materials for buildings, sections have recently begun to be used for construction of factory buildings, but they are used only in limited quantities. Few plates and pipes are used in this field. Almost of all the bridges are constructed of concrete, very few are constructed by plates or sections, and seldom by prestressed concrete method.

Besides concrete and steel products, brick and wood are widely used as the building materials in the present Pakistan. Both are popular building materials from old times in Pakistan because they can easily and cheaply be supplied domestically, and also easily be processed.

Before forecasting the competitive conditions between iron and steel products and other materials in Pakistan construction industry in future, those in the present advanced countries will be described. In these countries, the position of wood as the structural material for buildings is getting lower both in the prices and consumed quantities because of shortage of the resources.

It is rather difficult to compare steel materials with concrete with respect to their characteristics and economics as the construction materials, because they are currently being improved in the characteristics and application methods. Their merits and demerits, and practicability must separately be judged on individual cases taking their use, purpose environmental conditions, total cost and work executionability into account.

Therefore we generally describe the competitive conditions between iron and steel products i.e. sections, plates and pipes, and concrete.

(i) Port and oceanic structures

It is pointed out that steel materials have such demerits as rusting and corrosion, fragility at low temperatures and fatigue corrosion.

In the case of concrete, there are problems of collapse by freezing or dissolution, swelling by seawater, seawater resistance (corrosion of reinforcing bars) and uneven subsidence of heavy structures.

(ii) Dam

It's mainly structured of concrete without reinforcing bars, but the countermeasures are sought against low watertightness, water leakage, damages by freezing, cracks and exfoliation, and exposure of reinforcing bars. Further it has the problem of damage and wear by gravels.

(iii) Bridges for railway and road

In large-span bridges, steel products have been more advantageous than concrete in weight and construction works. But the development of cantilever bridging method employing the prestressed concrete and the selecting tendency toward arch bridges and diagonal beamed bridges have recently caused some competition between steel products and concrete.

The construction of concrete bridges has increased especially because of their effect of reducing noise and vibration. However, the number of composite type bridges made of steel and concrete utilizing the merits of steel is likely to increase in future in view of repeated stress fatigue, resonance of beams, cracks and subsidence of the concrete bridges.

(iv) Buildings

Steel materials are widely selectable in their sectional shapes, materials and sizes. Especially the utilization of very thick H-shaped steel and box type steel has increased for multi-storied buildings. On the other hand, steel products has been advantageous in connection method due to the pervation of high-tension bolts and new welding method.

According to the applications, the steel frame structure is often used in small-scale low buildings such as factories, warehouses, residential houses, offices and stores, while the steel frame and reinforced concrete structure is popular in multi-storied buildings. The reinforced concrete structure is widely adopted in 3-9 storied buildings by reason of construction costs. and in hospitals and school buildings by reason of sound insulation.

Concrete is widely adopted in buildings because it has the basic characteristics of heavy weight, large thickness and fireproofness, and is generally low cost. However, it has also problem of the shearing failure of reinforced concrete pillars at earthquakes.

Thus, in the present advanced countries having a very large supply capacity of iron and steel products, the sections, plates and pipes are widely used in construction works, and it shows that steel has an equal or superior competitiveness than concrete. This trend will remain essentially unchanged in future.

It is difficult to forecast exactly the competitive conditions of iron and steel products in the construction field in the future Pakistan. Generally speaking, they will not largely change from the present status, because, first of all, Pakistan is not an earthquake country and big change cannot be foreseen in building standard in future. Secondly, the supply of concrete, brick and wood will stably and cheaply be secured from the domestic sources, and thirdly, their processing techniques of these materials have been established and will be maintained in future on the basis of long years' experience and labor intensive system suitable for Pakistan.

(2) Automobile industry

In Pakistan, some parts of motorcycles are completely knocked down and are planned to be domestically produced in the near future.

Further there is the CKD programme for automobiles, which will also be domestically produced in not remote future. The competitive conditions between iron and steel products and non-ferrous products in advanced industrial countries will be mentioned, which will be suggestive to consider the demands for iron and steel in the Pakistan automobile industry in future.

The following table shows the changes in weight ratios of materials of automobile components in Japan and U.S.A.

Comparison of component materials
in small- and medium-sized automobiles

(unit: %)

Country	Japan				U.S.A.
Year	1968	1970	1973	1977	1977
Iron & Steel products	81.2	79.3	81.3	81.0	78.4
Aluminium	2.3	3.2	2.8	2.6	2.7
Plastics	1.5	2.0	2.9	3.5	3.5
Others	15.0	15.5	13.0	12.9	15.4
Total	100.0	100.0	100.0	100.0	100.0

Source: JISF

Steel products account for an absolutely large percentage of the total weight of an automobile. But this percentage is expected to lower as the steel products are replaced by non-ferrous materials under the great theme of reducing the automobile weight. So the demand of steel products in automobile industry looks to further be reduced in future.

However, the development of high-tension steel sheets has caused users to shift from aluminium alloy steel sheets to high-tension steel sheets. On the other hand, the demand for surface treated steel sheets are rapidly increasing with a view to improving the resistance to corrosion by salt, whereby the total demand of general steel products is on the increase.

Aluminium and plastics are quite small in their consumed quantities, but remarkable in the increasing rates, as compared with steel materials.

First, among the parts around engine, cylinder head is in most cases made of cast or die cast aluminium, and cylinder block is presently the part of competition between aluminium and steel. Discussion is being made as to the use of extended aluminium for body panel, bumpers, wheels and ornaments, but aluminium is inferior to cold rolled steel sheets in costs, thickness, strength and workability.

Second, plastics have already been adopted in fairly many parts where such adoption matches with the requirements for reducing the weight, cost reduction and design. For example, radiator grill, lamp housing and meter cluster in which mechanical strength and ervironmental conditions are not very important have come to be made of plastics. Further many parts such as handle, gear, bush, tank and electric appliances have been made of plastics utilizing their special functions and lightness.

Many forecasts on materials of automobile component in future show that steel materials will reduce their shares in application while aluminium and plastics will considerably advance into this field.

As already mentioned, main trends of material changes in the 1st round are:
Cast products: rollback of cast or die cast aluminium alloys and cast iron.
Interior articles, small parts and independent parts: toward plastics.
Parts for exhaust gas and ornaments: toward stainless steel.
Steel plates and sheets: toward high-tension steel and surface treated steel.

The following are the 1990 automobile materials forecasts made by Japanese and U.S. automobile industries at different time points.

(unit: %)

	Japan	U.S.A.
Steel	50	54
Cast iron	10	8
Aluminium	10	12
Plastics	10	9
Others	20	17
Total	100	100

(Sources: Japan Machinery Academy, Automotive News, 1976 Market Data Book Issue)

(3) Other fields

In advanced industrial countries, aluminium and plastics are more used in household electric appliances than in automobiles. It seems that Pakistan has no special characteristics in these fields and will follow the world trend.

In the field of cans for drink in advanced countries, aluminium is competing with steel for tinplates and TFS (chrome-base surface treated steel plate), with both of which bottles are competing. These conditions vary with the countries according to the purchasing power for the final products and the material supply costs.

In the present Pakistan, bottles are mainly used as drink containers because of its purchasing power and material costs. It is doubtless that Pakistan will also have increased demand for steel cans in future, if the users' purchasing power increases, vending machines spread and the supply power of tinplates and TFS increases.

In the field of other liquid containers in Pakistan, steel cans are widely used for ghee oil. In advanced countries like Japan and U.S.A., the demand for steel cans expanded rapidly through the establishment of a system to supply the material stably and at low cost, and the increase in individuals' consumptions. It is also expected in Pakistan that the demand for steel cans will increase and replace bottles in future though there are problems in saving of resources, environmental pollution, etc.

In advanced countries, concerning furnitures, office desks and lockers for which many steel sheets are likely to be consumed, wooden products are being replaced by steel ones, while in Pakistan, they are mostly made of wood as it can domestically supplied at low prices.

(4) Conclusion

The conditions of competition of iron and steel products with concrete, wood, brick, aluminium and plastics in the fields of construction, automobiles, containers and others have been described. Generally speaking, these non-ferrous materials have rapidly or steadily increased their consumptions according to the demand of the times or as a result of technical developments.

However, it is clear that they are neither undermining the basic position of steel materials in the market, nor they are going to replace the latter in the near future.

To cope with this tendency, the iron and steel industry has also been making earnest efforts to introduce technical innovations in various fields with a view to achieving the reduction of production cost, light weight of product, improvement of quality and corrosion resistance and improvement of the processing method to enable more complicated shapes.

As the conclusion, in coming ten or twenty years, it is expected that the cost superiority of iron and steel over other materials will be basically unchanged. Therefore, it will never happen that the steel industry is, in a basic meaning, replaced by any other industries, though substituion of other materials for iron and steel may be made also in future to a certain limited extent, reflecting the relative rise of energy cost.

As already mentioned, the competitive conditions of iron and steel products with other materials in the present Pakistan have lots of different points from those in advanced countries. However, if the production costs of iron and steel products are reduced and their supply power increases in Pakistan, the present competitive conditions in advanced countries seem to have many suggestions about the future competitive conditions in Pakistan.

Appendix to 3-2

Definition of Terms for Iron and Steel Products

Iron and steel are primary materials of first rate significance not only for the industry but for the entire national economy. In that context, iron and cement are the resting pillars of an advanced society. Vital steel materials are processed into a vast range of products and qualities to satisfy an equally vast range of demands and applications.

Despite extensive work in recent years by numerous national commitees for terminology standardization, there still exist no globally accepted standardized definitions for iron and steel products.

"Systemized International Trade Classification" (S.I.T.C.) and the "Brussels Tariff Nomenclature" (B.T.N.) have made significant advances in creating an internationally standardized terminology, but from a technological standpoint these are still insufficiently detained. Another organization to make substantial progress in this sector is the European Community (E.C.) with their EURONORMEN. The following standards are of fundamental importance:

- EURONORM 20 - 74 "Definition and classification of steel grades"
- EURONORM 79 - 69 "Definition and classification of steel products by shapes and dimensions"

These two standards have so far appeared only in German and French.

For purposes of the present study, a slightly modified system of product definitions based on EURONORM 79 - 69 has been adopted. This system is apparent in the following tabulation.

Definitions of Terms for Iron and Steel Products

Type of Product	Product Category
I. STEEL PRODUCTS	
(a) Crude Steel Products	ingots in various forms and sizes
(b) Semi-finished Steel Products	slabs blooms billets (all dimensions in compliance with EURONORM 79-69)
(c) Finished Steel Products	flat products (plates, hot rolled strip, cold rolled strip, sheets) non-flat products such as: bar and wire rod, sections, rails and accessories, wire other products such as: tubular products, cast and forged steel products, tin plates
II. IRON PRODUCTS	cast iron products
III. PELLETS	agglomerated iron ore fines
IV. SPONGE IRON	direct reduced iron ore

Appendix to 3-3

Indirect Steel Imports of Pakistan

Pakistan is importing steel consuming goods such as capital, goods and durable consumer goods in considerably large quantities. Then, how much are such indirect steel imports? Totalization of indirect steel imports involves much difficulty. "World Indirect Trade in Steel 1976" prepared by IISI (International Iron and Steel Institute) from export statistics of 14 western advanced countries is now available. The indirect steel imports of Pakistan is shown in Table A 3.1 for reference. According to this table, the indirect steel imports of Pakistan in 1976 amounts to 97.5 thousand tonnes. Since Pakistan is importing a considerable amount of capital goods and durable consumer goods from socialist countries, the coverage of figures indicated in this table is considered low.

The indirect steel imports of developing countries is shown in Table A 3.2. The recent increase in imports of Middle East is noticeable. In 1976, 26% of the world total is held by developing coutnries.

Table A 3.1 Indirect Steel Imports of Pakistan in 1976

	(1,000 tonnes)	(%)
Intermediate Goods	2.7	2.8
Machinery other than Electrical	51.3	52.6
Electric Machinery & Equipment	3.8	3.9
Rolling Stocks	2.5	2.6
Passengers Cars	2.8	2.9
Commercial Vehicles	9.4	9.6
Motor Vehicle Parts	6.7	6.9
Domestic Appliances & Equipment	0.8	0.8
Other Manufactures	17.5	17.9
A. Pakistan Total	97.5	100.0
B. World Total	55,360.7	-
$\frac{A}{B}$ (%)	0.2	-

Source: IISI

Note:
- Exports' Statistics of 14 Western Advanced Countries
- Finished steel products
- B includes social countries
- Import volume before 1973 is unknown

Table A 3.2 Indirect Steel Imports of Developing Countries

(Unit: 1,000 tonnes)

	1965	1970	1973	1976
Latin America	1,427	2,138	2,528	3,395
Asia except Japan	1,590	2,286	2,646	3,112
Middle East	749	1,000	1,716	5,481
Africa except S. Africa	1,001	1,449	1,594	2,559
A. Developing Countris Total	4,767	6,873	8,484	14,547
B. World Total	21,226	34,888	45,764	55,361
$\frac{A}{B}$ (%)	22.5	19.7	18.5	26.3

Source & Note: Same as Table A3.1

Appendix to 3-4

Answers to the Questionnaire

Questionnaires relating to the steel consumption by product categories were addressed to more than 15 steel consuming industries, but the answers to them were obtained only from 5 industries. The answers with three data obtained from steel consuming industries, added, to which we visited are tabulated as follows:

(Unit : 1,000 tonnes)

	A	B	C	Total
Bars	0.86	0.02	2.06	2.94
Wire Rods	0.00	0.00	0.00	0.00
Wires	0.02	0.00	0.00	0.02
*Sections	8.59	0.00	0.04	8.63
Plates (uncoated)	6.03	0.00	0.00	6.03
Sheets and Strips etc.	0.04	0.00	0.01	0.05
Glavanized Sheets	0.14	0.00	0.03	0.17
Tinned Sheets	0.00	38.95	0.00	38.95
Welded Pipes	0.55	0.00	5.88	6.43
Seamless Tubes	0.22	0.00	0.00	0.22
Total	16.45	38.97	8.02	63.44

Note: A : 3 manufacturers of machinery and ship building etc.

B : 2 manufacturers of tinned cans

C : WADA (Water Wing only), Sui Northern Gas Pipelines, Pakistan Railways

* Sections includes rails

Though partly accurate, these data can hardly constitute the basic data for estimating the steel consumption of Pakistan on the whole.

Appendix to 3-5

Building Construction Activities and Building Materials

In the report made by the Physical Planning and Housing Division of the Planning Commission, investment in building construction and, material component and steel consumption in it in fiscal 1979-80 are estimated as follows:

	Public	Private	Total
Investment in Building Construction (Rs million)	6,944	4,450	11,394
Material Component (Rs million)	4,513	2,893	7,406
Steel Products Required (thousand tonnes)	95	61	156

Note: Steel products required don't include pipes.

Furthermore, it is also estimated that, of unit cost of building construction, 65% is material component and remaining 35% is labour component.

Appendix to 3-6

Parameters for Developing Country to Develop Its Iron and Steel Industry

In a developing country, the development of iron and steel industry is progressed by being in possession and stable operation of any of integrated iron and steel plants including the DR integrated, and requires the following conditions:-

- Magnitude of the economy almost fits the country for "taking-off"
- Its domestic steel market exists more than one million tonnes of crude steel per year.

In addition to above two conditions,

- Its population exceeds nine millions.

(1) Magnitude of economy for "taking-off"

(i) In such a country, the iron and steel industry is made progress and developed by following qualitative conditions,

- rapid growth of the domestic iron and steel market, and

- development of back-up conditions for iron and steel industry such as raising fund, ability of planning and management, a certain level of operational technology and existence of supporting industries.

(ii) In 3.6.3(3) taking-off parameters were examined by means of IISI. Here they are further supplemented by the following parameters and applied to the 28 developing countries,

- Ratio of machinery and transportation equipment to the total export amount exceeds 3%.

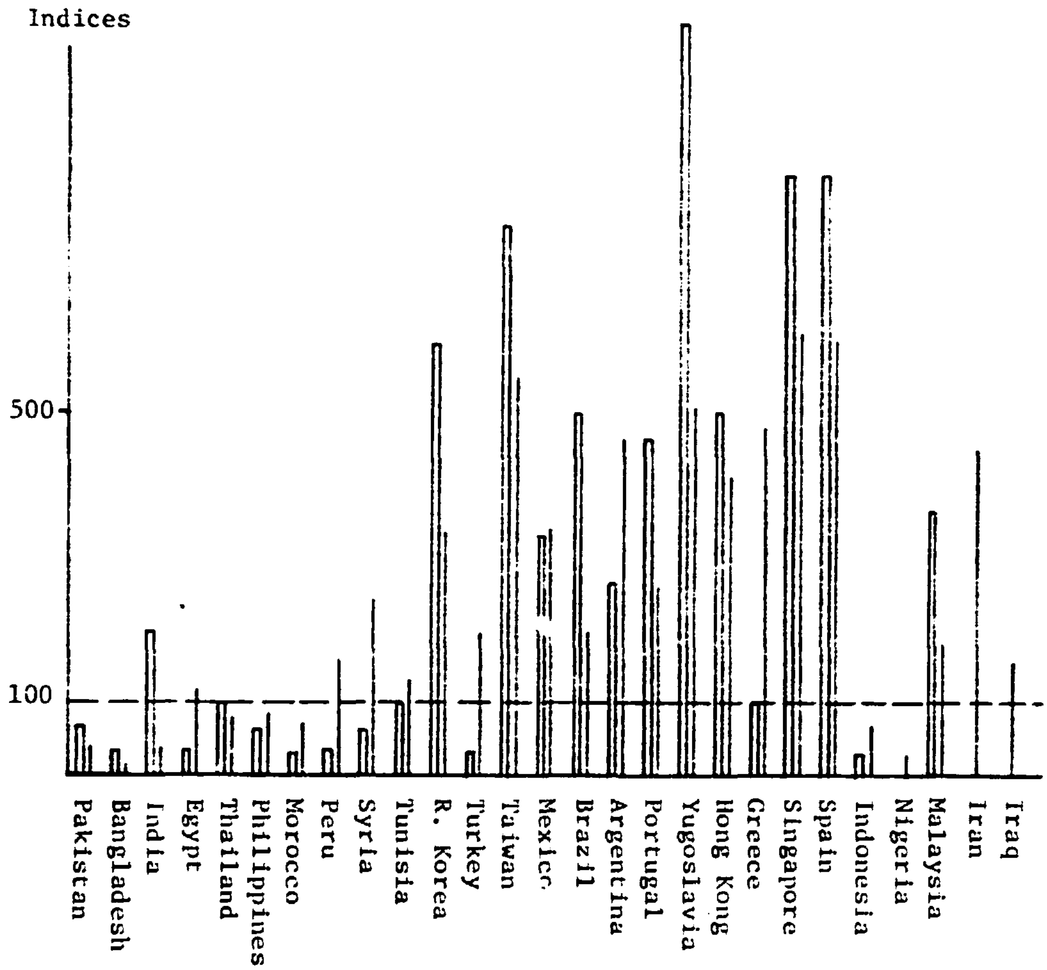
- Energy consumption per capita takes more than 400kg of coal equivalent.

Fig. A shows the ratio and consumption in developing countries with the above values taken as 100. Table A shows their summary.

Further the satisfying degrees by countries for the IISI's parameters are summarized in Table B, and their satisfying degrees for the composite parameters of IISI and Kobe Steel are shown in Table C.

In Table C the countries considered to have the magnitude economy for take-off are:-

Spain, Singapore, Hong Kong, Yugoslavia, Taiwan, R. Korea, Mexico, Argentina, Brazil, Portugal, Greece, Turkey, Syria, Egypt, Iran, Iraq, Tunisia and Malaysia.



Note: ▭ Percentage share of machinery and transport equipment to total exports (A).

— Energy consumption per capita (coal equivalent) (B).

Indices shown as 3% of the share to 100 in (A) and 400 kg of energy consumption per capita to 100 in (B).

Source: The World Bank "World Development Report 1980". Taiwan in (A) by "The Trade of China" by the Statistics Department, Inspectorate General of Customs, Taiwan .

Fig. A Indices of Conditions for "Take-off" in Developing Countries in 1978 by KOBE STEEL

Table A Numbers of Conditions to be Satisfied for "Take-off" of the TWO by KOBE STEEL

No. of Conditions Satisfied	2	1	0
Developing Countries Satisfying Conditions	Spain	Turkey	Morocco
	Singapore	Syria	Philippines
	Greece	Peru	Bangladesh
	Hong Kong	Thailand	Pakistan
	Yugoslavia	Egypt	Nigeria
	Argentina	India	Indonesia
	Portugal	Iran	
	Brazil	Iraq	
	Mexico		
	Taiwan		
	R. Korea		
	Tunisia		
	Malaysia		

Table B Numbers of Conditions to be Satisfied for "Take-off" of the FOUR by IISI

No. of Conditions Satisfied	4	3	2	1	0
Developing Countries Satisfying Conditions	Spain	Portugal	Greece	Peru	Pakistan
	Singapore	Argentina	Tunisia	India	Bangladesh
	Hong Kong	Brazil	Morocco	Nigeria	
	Yugoslavia	Turkey	Thailand		
	Taiwan	Syria	Indonesia		
	R. Korea	Philippines	Malaysia		
	Mexico	Egypt			
		Iran			
		Iraq			

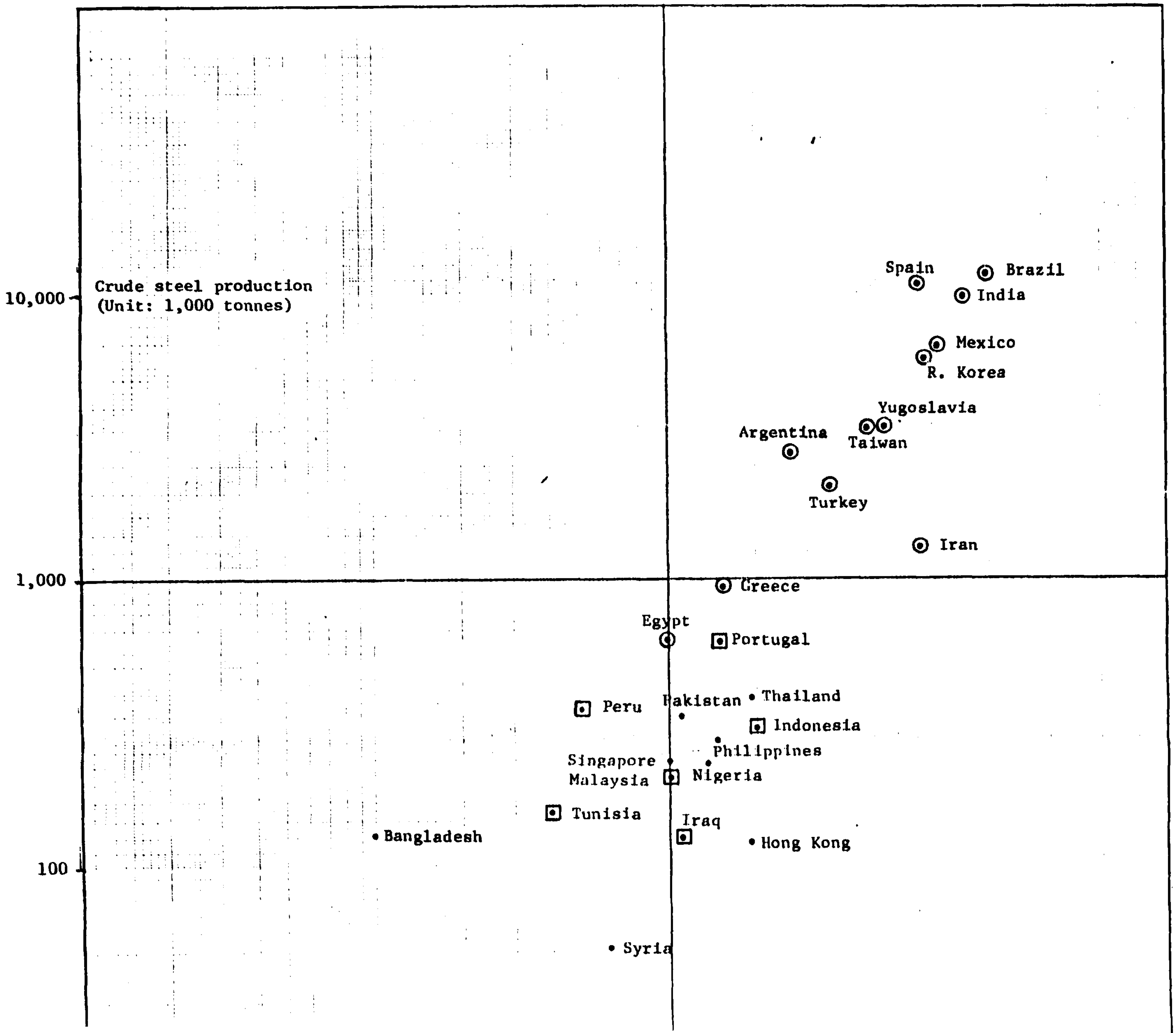
Table C Numbers of Conditions to be Satisfied for "Take-off" of the SIX by IISI and KOBE STEEL

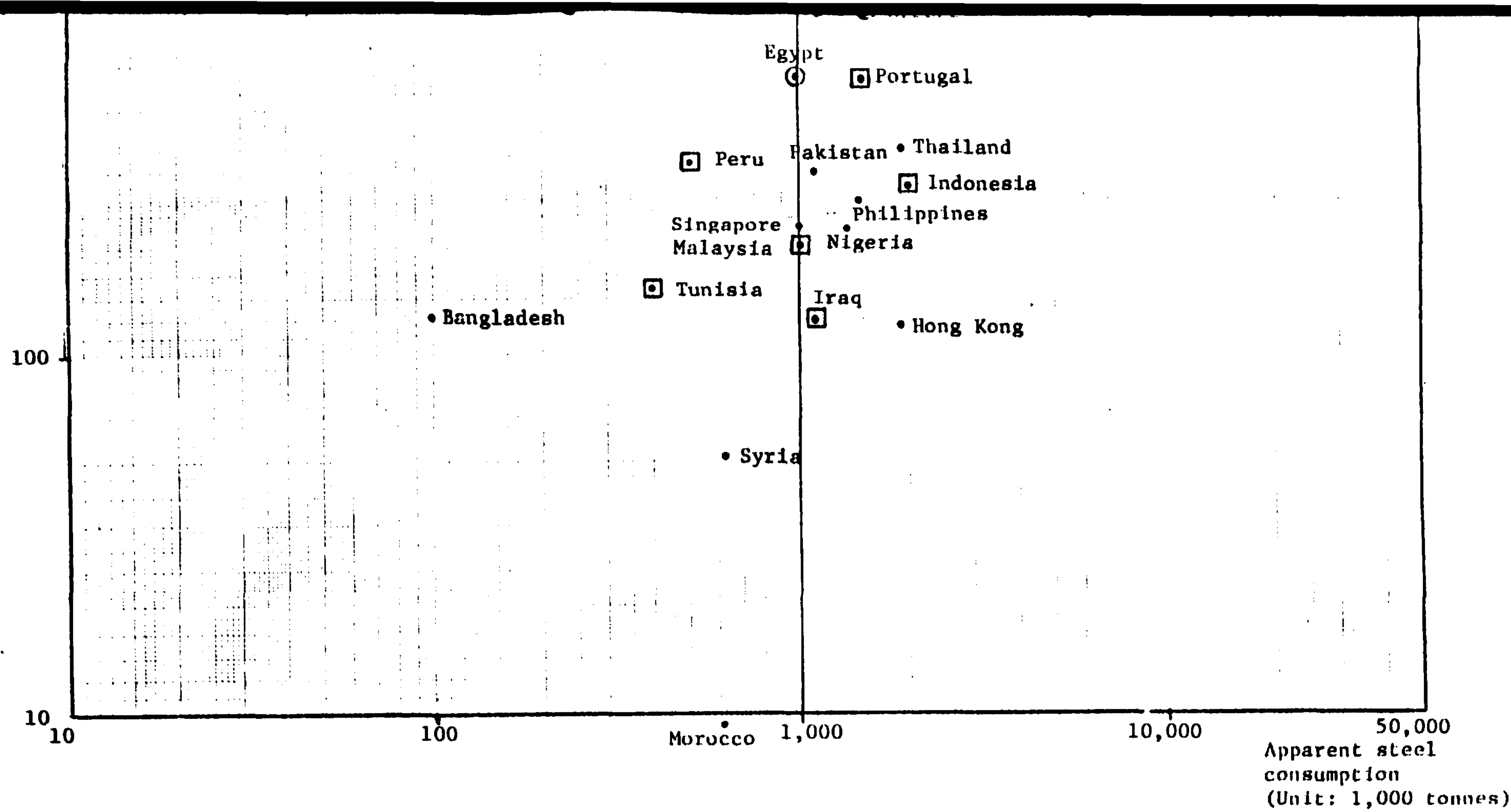
No. of Conditions Satisfied	6	5	4	3	2	1	0
Developing Countries Satisfying Conditions	Spain	Argentina	Greece	Philippines	Morocco	Nigeria	Pakistan
	Singapore	Brazil	Turkey	Thailand	Indonesia		Bangladesh
	Hong-Kong	Portugal	Syria		Peru		
			Egypt		India		
	Yugoslavia		Iran				
	Taiwan		Tunisia				
	R. Korea		Malaysia				
	Mexico		Iraq				

(2) Iron and steel market and population

(i) Scale of steel market

Fig. B shows the crude steel production on the ordinate, and the apparent steel consumption on the abscissa in developing countries in 1978. Further it shows the every country having the BF and/or DR integrated iron and steel palnt(s) with annual production capacity of more than 1 million tonnes of crude steel and also with that capacity of less than 1 million tonnes.


Crude steel production
(Unit: 1,000 tonnes)
10,000
1,000
100
Spain
Brazil
India
Mexico
R. Korea
Yugoslavia
Argentina
Taiwan
Turkey
Iran
Greece
Egypt
Portugal
Peru
Pakistan
Thailand
Indonesia
Philippines
Singapore
Malaysia
Nigeria
Tunisia
Iraq
Bangladesh
Hong Kong
Syria



Note: ⊙ This country owns integrated iron and steel works with an annual production capacity of 1 million tonnes or above.

⊡ This country owns integrated iron and steel works with an annual production capacity of less than 1 million tonnes.

Source: IISI and others.

Fig. B Apparent Steel Consumption and Crude Steel Production in Developing Countries in 1978

According to Fig. B, many countries that have domestic steel market of more than 1 million tonnes per year, tend to have at least one integrated iron and steel plant. Further, countries that have more than 2.5 million tonnes, tend to have multiple integrated iron and steel plants thus, the iron and steel industry in these countries reaches higher level. If the minimum scale of steel consumption for a developing country to develop its steel industry is regarded as one million tonnes a year, developing countries which are over this are:

Pakistan, India, Thailand, Philippines, R. Korea, Turkey, Mexico, Brazil, Argentina, Portugal, Yugoslavia, Hong Kong, Greece, Singapore, Spain, Indonesia, Nigeria, Malaysia, Iran and Iraq. Egypt also has a similar market scale and can belong to this group.

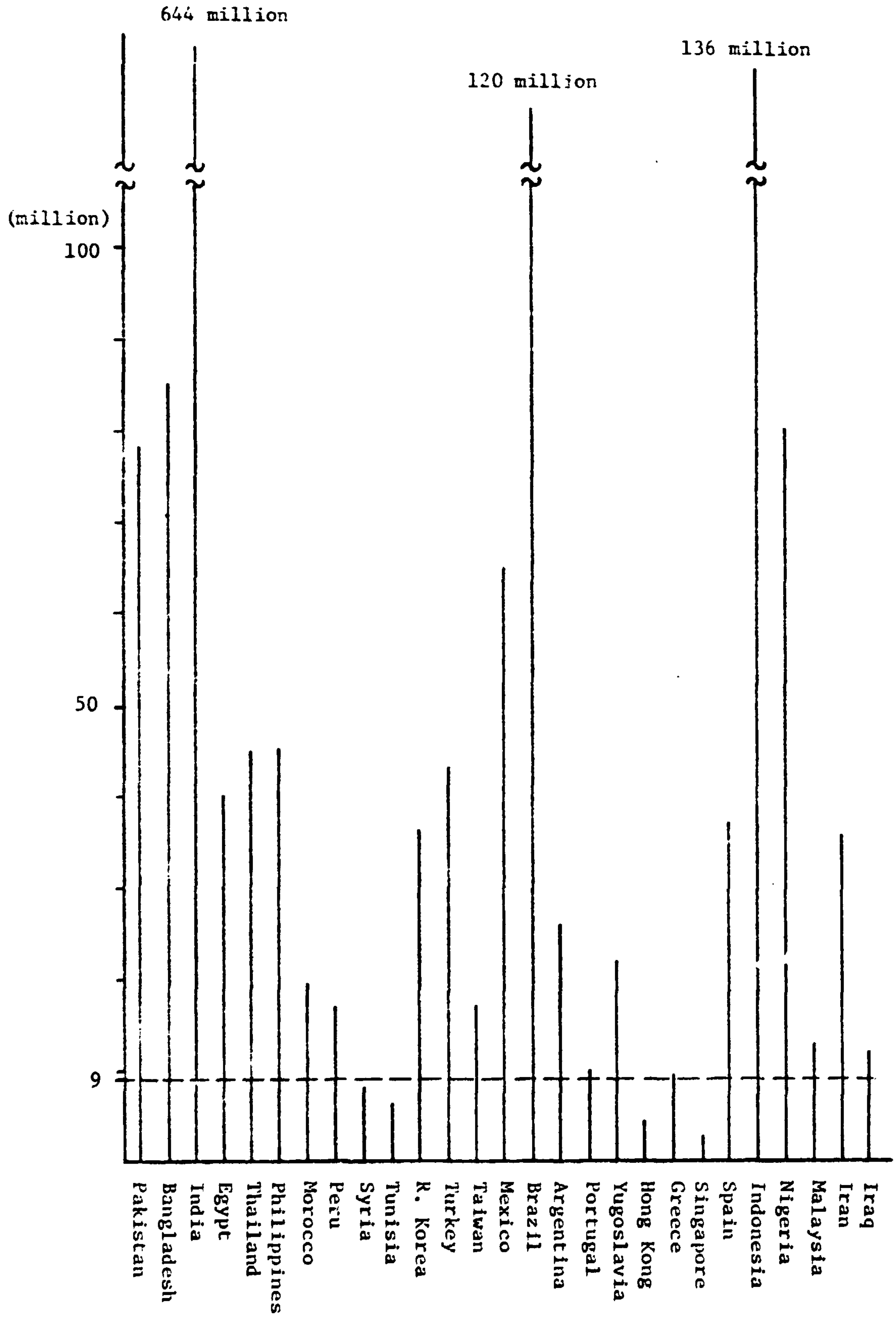
The current development degree of iron & steel industry in any developing country can be estimated by the production level of crude steel and production capacity of integrated iron and steel plant (including the DR integrated).

The development degree can further be cleared up if the operation conditions of iron and steel industry in that country is additionally checked. However this item is short of data and omitted here.

(ii) Scale of population

In order of smaller population five developing countries having the integrated plants are listed up below. Tunisia (with population: 6.0 millions and crude steel production of 150,000 tonnes/y).

Greece (with 9.4 millions and 936,000 tonnes/y), Portugal (with 9.8 millions and 625,000 tonnes/y), Iraq (with 12.2 millions and 126,000 tonnes/y) and Malaysia (with 13.3 millions and 203,000 tonres/y). The integrated iron and steel works owner country with the least population is Tunisia with a population of 6 millions. The others mostly have a population of more than 9 millions. The Tunisian integrated iron and steel plant have an estimated annual crude steel production capacity of 230,000 tonnes at present. The Tunisian integrated are too small in scale considering that in developing countries, the BF integrated will have a production capacity of at least 1 million tonnes per year.

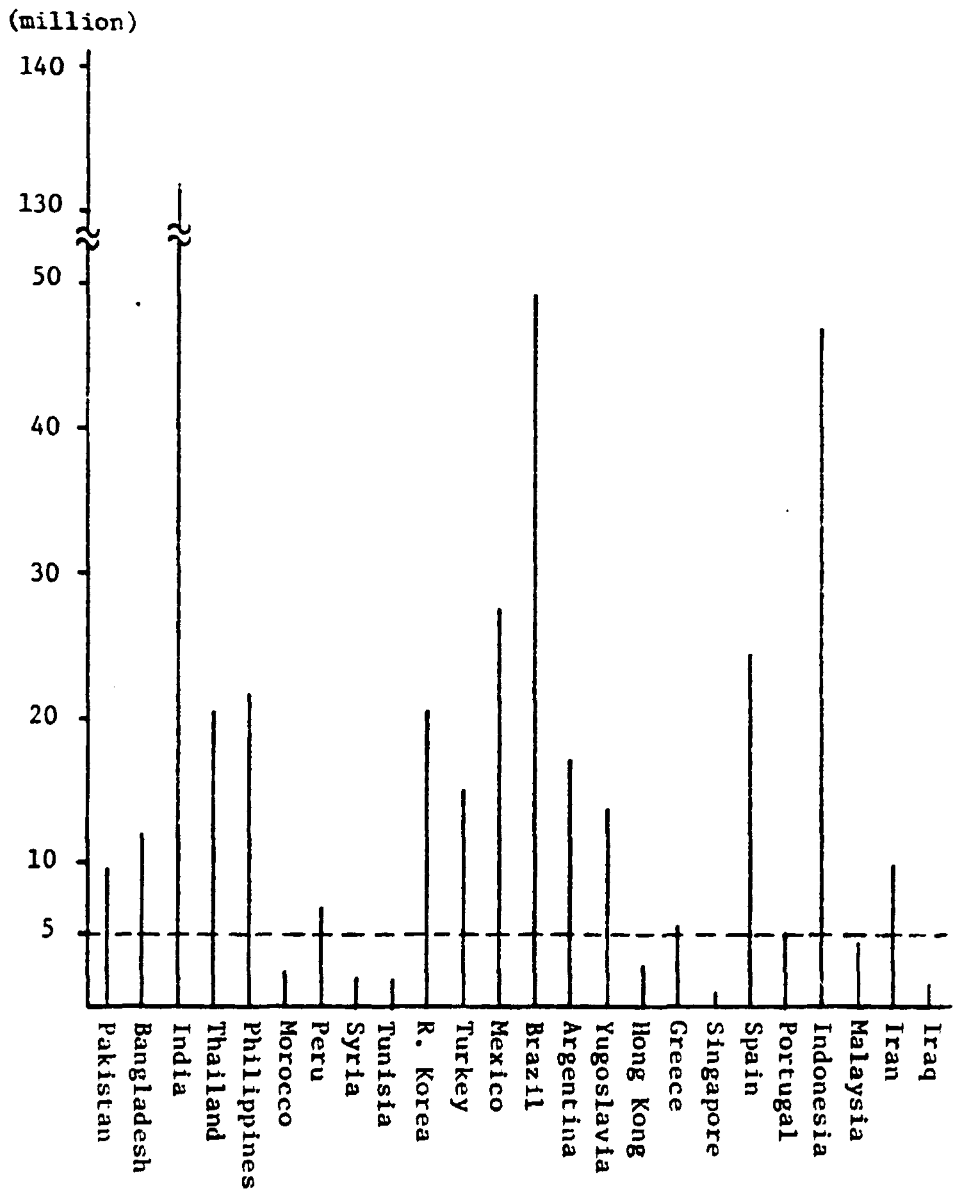


Source: World Bank
[World Development Report 1980]

Fig. C Population of Developing Countries in 1978

Generally the necessary population for the proper development of iron and steel industry is estimated to be in the order of 9 millions.

Further concerning the population, the adult literate population which provides the base for skilled labour is taken up to check the relation with the iron and steel industry in developing countries. Fig. D shows that any of developing countries is can own the integrated iron and steel plant if it has the adult literate population of about 5 millions.



Note: Adult means persons aged 15 and over.

Source: World Bank [World Development Report 1978, 1979, 1980, 1981] & United Nations' Population Statistics.

Fig. D Adult Literate Population of Developing Countries in 1976

(3) Development conditions of iron and steel industry in developing countries.

The take-off conditions, the scale of steel market and population have so far been examined concerning 23 developing countries.

Now the development conditions of iron and steel industry in developing countries are summarized below.

(i) The iron and steel industry in a developing country can have integrated iron and steel plants, when the domestic steel market becomes 1 million tonnes a year in scale and the population exceeds 9 millions (of which adult literate population is more than 5 millions).

(ii) However the integrated iron and steel plants require a large amount of fund and comprehensive planning ability for their construction, and certain levels of technology, skilled labour, management ability and maturity of supporting industries after their construction. Therefore the economic take-off conditions must also be satisfied.

(iii) The developing countries which satisfy all these conditions are:

Spain, Yugoslavia, Taiwan, R. Korea, Mexico, Argentina, Brazil, Portugal, Greece, Turkey, Egypt, Iran, Iraq and Malaysia.

These conditions are not applicable to developing countries which are also rich in the iron and steel resources. For sound development of integrated iron and steel plants, it is necessary that the development of steel consuming industries in the market aspect, and the existence of technology, supporting industries and skilled labor in the supply aspect are well balanced.

The future of iron and steel industry in Pakistan will be mentioned below with these conditions taken into account. It is very difficult to forecast the f.ture take-off conditions in Pakistan, but it will be done while studying the present status of some other developing countries which have already well satisfied these take-off conditions than Pakistan.

According to their forecast, GNP per capita (at 1963 prices) in Pakistan will increase from US$149 in 1979-80 to US$179 in 1989-90 and US$227 in 1999-2000. The 1999-2000 GNP per capita in Pakistan is approximate to the 1978 level of those in Thailand, Philippines and Egypt. Other take-off conditions of Pakistan are difficult to be forecast numerically. In any developing country where the steel consumption per capita has reached the level of 100kg, the take-off conditions are fully satisfied and the domesitc steel consumption is on large scale, and in many cases its iron and steel industry has moderately advanced. The 1999-2000 steel consumption per capita in Pakistan will still be low, i.e. 34kg, which is almost equal to the present level of those of Thailand and Philippines. These countries cannot yet be regarded as being ready for the take-off.

Thus so far as the GNP and steel consumption per capita are concerned, it will be after 2000 for Pakistan to fully meet the take-off conditions.

Pakistan is already well grounded for developing the manufacturing industry and further the machinery industry, but their products are still so high in price that no stable expansion of their market can be foreseen in future. It seems therefore difficult to predict that in that country, various take-off conditions will also be rapidly expanded and met in future.

The Pakistani iron and steel industry has already had the necessary level of domestic steel consumption and the absolute level of population necessary for its development. So its steady development will be finally assured when the take-off conditions are met.

Appendix to 4-1

Manufacturing of Tin-Free Steel in Pakistan

(1) For discussing the manufacture of tin-free steel (TFS) to be used as a substitute for tin plate in Pakistan, it is first of all necessary to grasp the general characteristics of TFS in comparison with those of tin plate known mainly in advanced industrial countries.

(i) Material

As for black plates, i.e. the material of TFS, like those for tin plate, cold rolled strip from capped steel, rimmed steel and continuous cast steel are used. Therefore there is no difference between TFS and tin plate in the manufacturing techniques and cost of black plate and its quality.

(ii) Manufacturing equipment

The TFS manufacturing equipment are considered to be almost same with the electrolytic tin plate manufacturing equipment, except for that the former lacks and reflow section. The manufacturing technique is also considered the same between the two.

The TFS manufacturing equipment can also make tin plates, and some such combination lines are actually in operation. In this case, however, such a layout is necessary where the TFS electrolytic chrome acid treatment tank and the tin plating tank are arranged in series and one of them can be by-passed according to the kind of product to be produced.

(iii) Corrosion resistance

As mentioned in Chapter 4, section 4.4.8, though TFS film is very thin, it shows an excellent corrosion resistance when the surface is coated with paint. But TFS chrome has no what-is-called self-victimizing corrosion resistance as is shown by tin in tin plates which is itself liquidated and protects the iron surface. Consequently TFS has no problem when used for cans of low corrosive drinks such as beer and carbonic acid drinks, but when used for cans of strongly corrosive natural foods or acid drinks, there is the danger of hydrogen expansion, pitting or stress corrosion cracks unless TFS cans are completely coated with paint without any defect or combination cans with tin plate are manufactured.

Therefore for manufacturing cans for natural foods and drinks by means of TFS alone, such advanced paint coating techniques and equipment as can eliminate every defect in the coat paint are necessary.

(iv) Workability

Made of hard chrome, TFS film has the demerit that its worked parts tend to have minute cracks or it easily has scratches on the surface. But they can be prevented by the paint coating technique. However it is a large demerit of TFS that it cannot be soldered like tin plate.

In the case of TFS, have been developed and put into practical use such epochmaking jointing methods as Miraseam method by nylon-base adhesives, Conoweld method by temporary welding and butt welding and Toyoseam method based on a laminate adhesion method, which can substitute for the soldering method and have made possible the mass production of TFS.

However as compared with this soldering method for tin plate which can easily be performed manually, these TFS jointing methods require large-scale canning and jointing equipment and the correspondingly advanced canning technique.

(v) Use

Because of its corrosion resistance characteristics as mentioned in (iii), TFS has largely advanced in the fields of cans for artificial drinks like beer and carbonic acid drinks. In the field of natural food and beverage cans; TFS has begun to be used for some fish meat cans and can lids, but tin plates are still overwhelmingly used in this field. In the field of 18-litre (5 gallons) can, too, the use of tin plate cans is still the mainstream because they are more suitable for large-sized cans with heavy contents.

(vi) Price

The TFS which does not use high priced tin is essentially more advantageous than tin plate in respect of price.

However the development of TFS and aluminium as the substitute for tin plate and their use in large quantities have stimulated the development and use of very thin tin plates like drawing and ironing (DI) tin plate, and low-priced tin plate containing a smaller volume of tin. As a result, DI tin plate cans, DI aluminium cans and TFS cans are under competitive conditions with one another in some fields. So it cannot absolutely be said that tin plate is always less advantaged that TFS in price.

(2) On the basis of the above discussion, the possibility of TFS manufacture in Pakistan will be examined below.

In the market aspect in the present Pakistan, the use of cans for natural foods and drinks is considered to be the mainstream. This means that tin plate cans are more required than TFS cans in the market.

There is of course the demand for carbonic acid drinks, but they are presently sold exclusively in glass bottles in Pakistan. The reason is that in the carbonic acid drinks field, glass bottles are far cheaper than TFS cans, even if their recovery cost is considered, and TFS cans are not able to compete with glass bottles in this market field.

For the use of metal cans like TFS and aluminium cans in large quantities for carbonic acid drinks, it is necessary that the consumption level per capita, including the consumption of carbonic acid drinks, in Pakistan increases considerably, that the demand for these quite handy can containers increases following the enhancement of outdoor leisure activities of the public and that the automatic dispensers prevail fully utilizing the characteristics of cans that they have no danger of breakage, they have a high advertisement effect when printed in multi-colours, etc. On the other hand, there is little demand for beer cans in Pakistan. It can therefore be said that the present Pakistan market in this field is a tin plate market, and no TFS market has grown yet there though its growth can be expected in future.

In the manufacturing aspect, it can be said that there is no problem in the steel works' manufacturing equipment and techniques for black plates and surface treated steel plates, but there are problems for TFS in the down-stream industrial fields. As mentioned in (iii) and (iv), in contrast with the case of tinplates where white plates can be used and the canning by soldering is easy, TFS requires the down-stream industries to have large-scale equipments as well as advanced techniques for coating with paint and can manufacturing.

To our regret, no such down-stream industries have yet grown in the present Pakistan, and even if TFS steel plates could be made in steel works, their processing would be impossible.

In this aspect, too, the manufacture of TFS is still too early.

Thus TFS in Pakistan is still under-developed both in its market and processing industry.

Therefore in spite of the large merit that the chrome ore reserves in Pakistan can effectively be used, the present Pakitan is recommended not to proceed to the manufacture of TFS, but of tin plates.

However for Pakistan's undertaking the manufacture of tin plates, her tin plate manufacturing equipment are recommended to have the layout of electrolytic tin plate plating equipment in which is allowed in advance the space of the electrolytic chrome acid treatment tank so that TFS can also be manufactured in future, as already mentioned in (ii), in view of the increased TFS demand by the development of TFS down-stream industries and market in future.

Appendix to 6-1:

Review for Product Mix at the Start-up Perid of Pakistan Steel

Pakistan Steel will start the operation of a part of its production facilities in August, 1981. According to the schedule, the whole facilities of Pakistan Steel will be completed in 1984-85 through the completion of the cold rolling mill, galvanizing line and section forming mill. Fig. A-6-1 shows the learning curve at the start-up period of Pakistan Steel referring to some examples in other countries.

According to our projection, however, the demand for flat products will have not yet grown enough by 1984-85, therefore, the situation of supply and demand will be very delicate in each flat product.

The product mix is reconsidered for the two years of 1984-85, and 1985-86, start-up period of Pakistan Steel, from the viewpoint that 100% of slab is domestically consumed and that 100% of products is sold to the domestic market allowing new installment c. facilities. The results are shown in Table A-6-1.

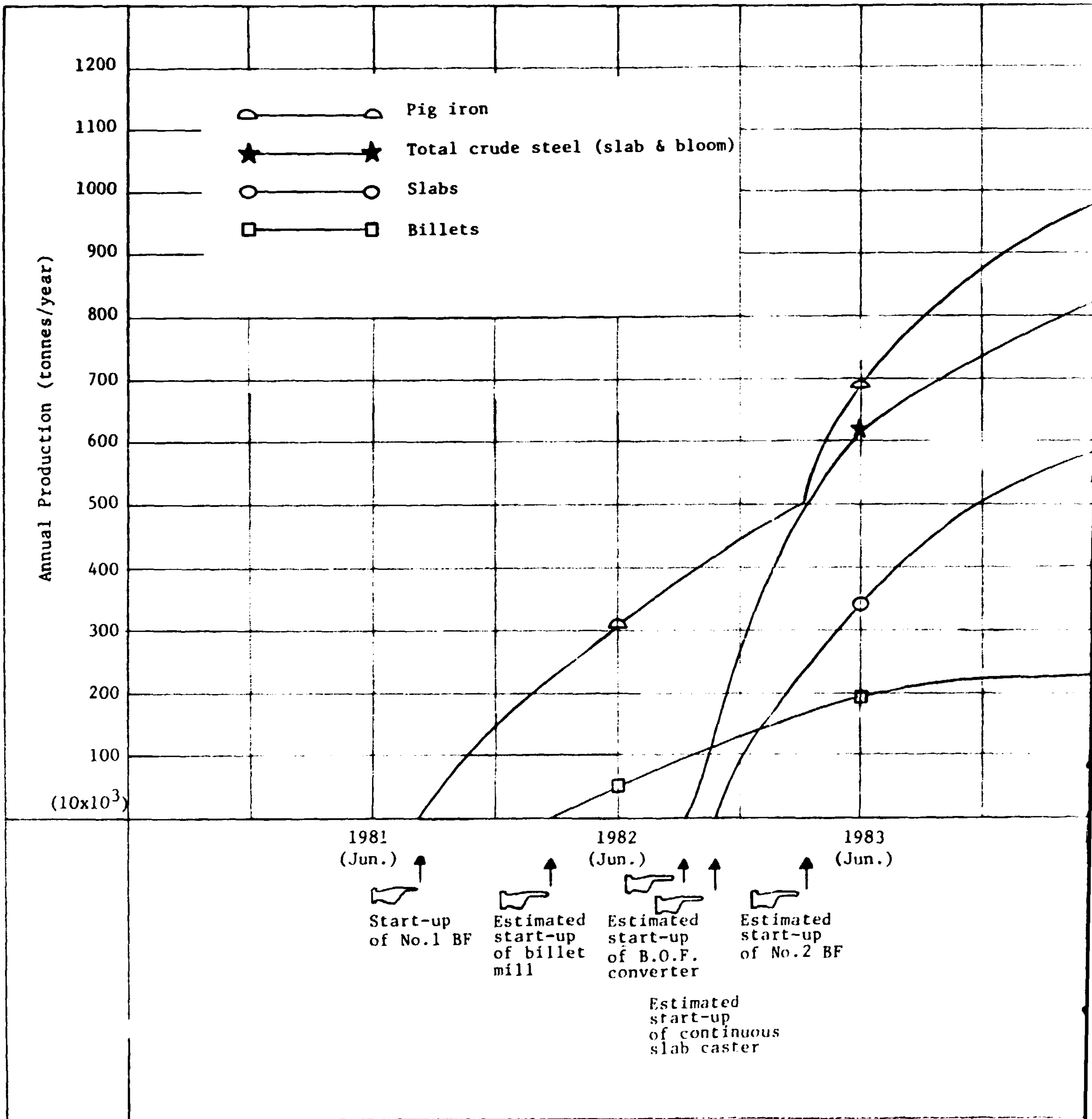
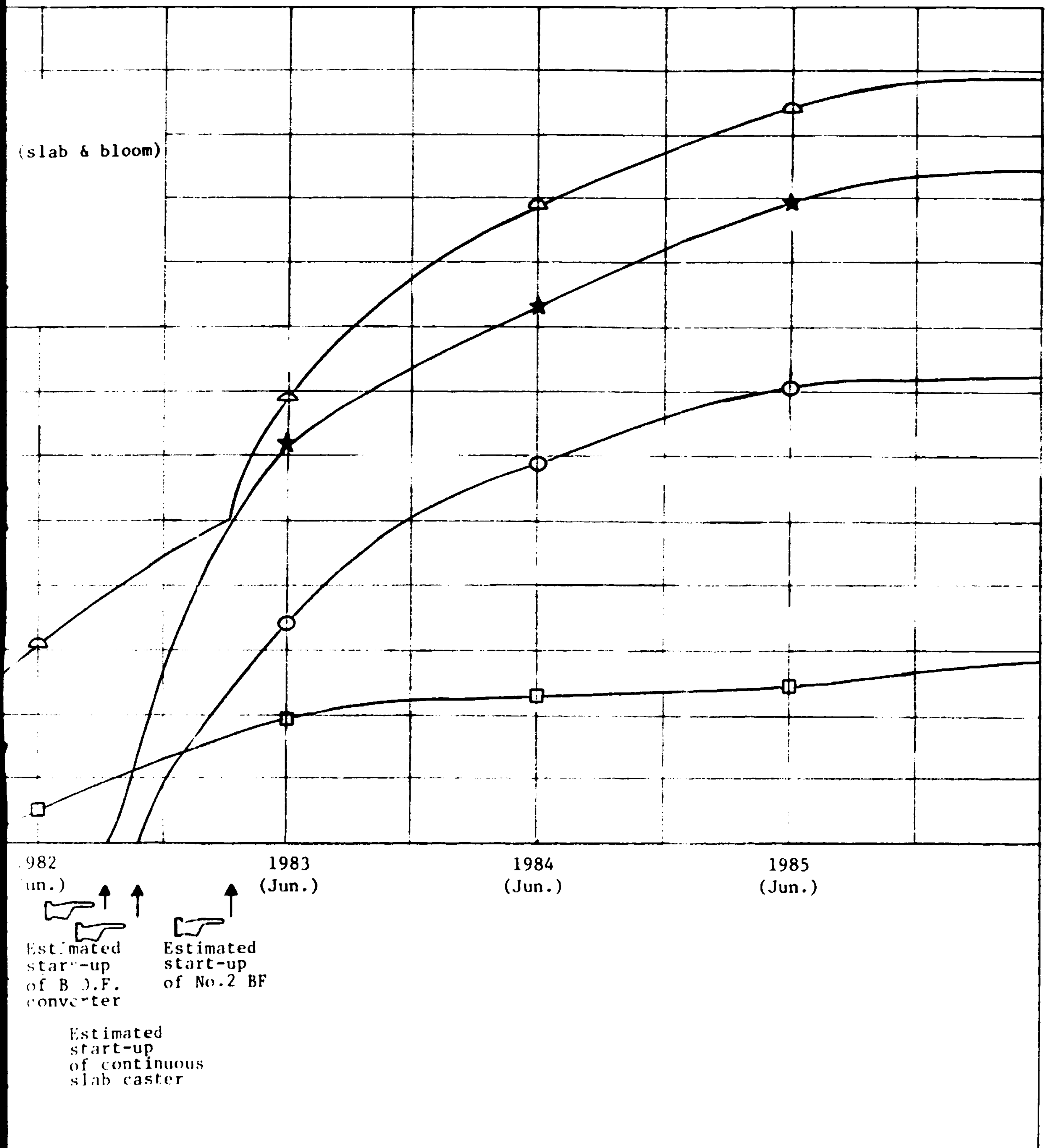


Fig. A6.1 Projected Production of Pakistan Steel in St

SECTION 1



cted Production of Pakistan Steel in Start-up Period

SECTION 2

Table A-6.1 Recommendable Product Mix of Pakistan Steel

		Demand		S u p p l		
					1984-85	
		84-85	85-86	Original Plan	Recommendable Plan	Increment
Product mix						
Plates		32	37	-	-	-
Hot rolled sheets		214	232	332	190	-142
Cold rolled sheets		188	206	90	160	+ 70
Galvanized sheets		76	84	100	70	- 30
Tinned plates and sheets		116	129	-	-	-
Other coated		2	2	-	-	-
Welded pipes		73	80	-	*(50)	(+ 50)
Flat total		701	770	552	470	- 52
Formed sections		-	-	120	120	-
Billets		-	--	380	240	-140
Steel products total		-	-	1,022	830	-192
Cast iron		-	-	135	135	-
Cokes		-	-	215	215	-
Facilities						
Slab CC	Production			(700)	(725)	(+ 25)
	Capacity			825	825	-
Bloom CC	Production			(400)	(255)	(-145)
	Capacity			480	480	-
Billet mill	Production			(380)	(240)	(-140)
	Capacity			380	380	-
Hot rolling mill	Production			(672)	(695)	(+ 23)
	Capacity			1,800	1,800	-
Cold rolling mill	Production			(200)	(275)	(+ 75)
	Capacity			200	275	+ 75

* mark indicates hot rolled coil or sheet supply to the e..

SECTION 1

dable Product Mix of Pakistan Steel

(Unit: 1000 tonnes)

	Supply				
		1984-85		1985-86	
6	Original Plan	Recommendable Plan	Increment	Recommendable Plan	Increment
7	-	-	-	-	-
2	332	190	-142	210	-122
6	90	160	+ 70	185	+ 95
4	100	70	- 30	80	- 20
9	-	-	-	-	-
2	-	-	-		
0	-	*(50)	(+ 50)	*70	+ 70
0	552	470	- 52	470	- 52
	120	120	-	120	-
	380	240	-140	280	-100
	1,022	830	-192	830	- 77
	135	135	-	135	-
	215	215	-	215	-
	(700)	(725)	(+ 25)	(725)	(+ 25)
	825	825	-	825	-
	(400)	(255)	(-145)	(295)	(-105)
	480	480	-	480	-
	(380)	(240)	(-140)	(280)	(-100)
	380	380	-	380	-
	(672)	(695)	(+ 23)	(695)	(+ 23)
	1,800	1,800	-	1,800	-
	(200)	(275)	(+ 75)	(275)	(+ 75)
	200	275	+ 75	275	+ 75

t rolled coil or sheet supply to the existing pipe makers

SECTION 2

In the original plan of Pakistan Steel, as shown in Table A 6.1 the supply of hot rolled sheets and galvanized sheets is much exceeding the demand, and if this situation goes on, they will have to either find the way out in the export or cutting down the operation. Either of these alternative ways is not promising.

Another possible alternative is to produce billets to the maximum extent of the production capacity. However, taking into consideration the role played by the shipbreaking and ingot making industries, it is considered to sell out the output of 1.02 million tonnes of slab bloom anticipated in 1985-86 by keeping the billet production at 270,000-280,000 tonnes while increasing the production of cold rolled sheets which are estimated relative small quantity in the original plan. In this case, a new cold rolling mill with a 100,000 tonnes/year production capacity must be constructed.

In this plan, however, it is also likely that no new facilities may need to be constructed according to the conditions in the start-up period of Pakistan Steel and the supply and demand conditions in the market. Careful discussions are necessary as too early decision may lead to wasteful investments.

Tinned plates are growing into a reliable demand item as their demand in more than 120,000 tonnes is forecast in 1985-86. On the other hand, installation of any tinning line is considered not recommendable for the time being because cold rolled coil which is the material for tinned plates is said to be comparatively harder to be processed than the other techniques for cold rolling, as it is so thin, i.e. less than 0.3mm, that high surface quality and also uniform quality of the material are required.

Appendix to 6-2

Selection of DR Module

As shown in the following table, a scale of recent DR modules are generally diversified from 400,000 t/y to 600,000-700,000 t/y. There might be a tendency that very recent DR modules including under construction are mostly large in scale.

RECENT INSTALLATION OF DIRECT REDUCTION PLANT IN DEVELOPING COUNTRIES

Country	Owner	Process/ Reductant	Capacity (t/y)	Location	Set-up	Remark
[Asia, Oceania]						
INDONESIA	Krakatau Steel No. 1	HYL/N-gas	500,000	Kata Baja (Merak)	1978	Steel making facilities for No. 1 plant o E.F./Billet mill 540,000 t/y o Wire rod mill 220,000 t/y o Section mill 85,000 t/y o Wire mill 30,000 t/y
"	" No. 2	"	500,000	"	1979	Operation suspended due to lack of down-stream facilities.
"	" No. 3	"	500,000	"	1979	"
"	" No. 4	"	500,000	"	1979	"
INDIA	Sponge Iron Company of India	SL-RN/Coal	30,000	Andra Pradesh	1979	
"	OSIL	ACCAR/Coal, Oil	150,000	Keonjhar	1982	
MALAYSIA	Gov. of Sabah State	Midrex/N-gas	600,000	Labuan Island	1984	Total products are for export.
BURMA	Government	Kinglor Metor/ Coal	20,000	N.A., Burma	1983	

RECENT INSTALLATION OF DIRECT REDUCTION PLANT IN DEVELOPING COUNTRIES

Country	Owner	Process/ Reductant	Capacity (t/y)	Location	Set-up	Remark
[North, Middle & South America]						
BRAZIL	Usiba	HYL/N-gas	250,000	Aratu	1974	
"	Acos Finos Piratini	SL-RN/Coal	65,000	Port Alegre	1973	
ARGENTINE	Dalmine-Siderca	Midrex/N-gas	330,000	Campana	1976	
"	Acindar	Midrex/N-gas	420,000	Villa Constitucion	1978	
"	Sidersur S.A.	HYL-III/N-gas	500,000	San Antonio Este	Under construction	Steel making facilities: E.F./C-C to make billets.
VENEZUELA	Minorca (Former Orinoco Mining)	HIB/N-gas	1,000,000	Puerto Ordaz	1972	
"	Fior de Venezuela	Fior/N-gas	400,000	Matanzas	1977	
"	Sidor No. 1 Phase	Midrex/N-gas	355,000	Matanzas	1977	
"	Sidor No. 1 Phase	HYL/N-gas	420,000	Matanzas	1976	
"	Sidor No. 2 Phase	Midrex/N-gas	1,200,000 (3 units)	Matanzas	1979	
"	Sidor No. 2 Phase	HYL/N-gas	2,112,000 (3 units)	Matanzas	1979	
MEXICO	HYLSA (M3)	HYL/N-gas	500,000	Monterrey	1974	Conversion completed June, 1981. Former capacity: 450,000.
"	HYLSA (P2)	HYL/N-gas	700,000	Puebla	1977	
"	HYLSA (M4)	HYL-III/N-gas	750,000	Monterrey	1983	

RECENT INSTALLATION OF DIRECT REDUCTION PLANT IN DEVELOPING COUNTRIES

Country	Owner	Process/ Reductant	Capacity (t/y)	Location	Set-up	Remark
MEXICO	Sicartsa	HYL-III/N-gas	2,000,000 (4 units)	Lazaro Cardenas	Under construction	Steel making facilities: E.F./C-C/Rolling mill to produce plate 1,500,000 t/y plus pelletizing plant.
"	Premexsa	HYL-III/N-gas	750,000	Altamira	"	Products are supplied to member companies of 10 semi-integrated mills.
PERU	Siderperu	SL-RN/Coal	300,000 (3 units)	Chimbote	-	Construction delayed.
TRINIDAD & TOBAGO	ISCOTT No. 1	Midrex/N-gas	420,000	Point Lisas	1980	Steel making facilities: E.F./C-C/Rolling mill to produce wire rod 550,000 t/y
"	ISCOTT No. 2	Midrex/N-gas	420,000	Point Lisas	End/1981	Part of products to be fed to steel making facilities and balance to be for open market.
[Middle East, Africa]						
QATAR	Qatar Steel Company	Midrex/N-gas	400,000	Umm Said	1978	Steel making facilities: E.F./C-C/Rolling mill to produce 330,000 t/y bar.
IRAN	National Iranian Steel	Purofer/N-gas	330,000	Ahwaz	1978	Steel making facilities at Ahwaz: E.F. 150 t x 6, Slab & Bloom C-C, Pelletizing plant 3,000,000 t/y. Operation suspended due to turmoil in Iran.
"	NISIC	Midrex/N-gas	1,200,000 (3 units)	Ahwaz	-	Nearly completed but construction suspended due to turmoil in Iran.

RECENT INSTALLATION OF DIRECT REDUCTION PLANT IN DEVELOPING COUNTRIES

Country	Owner	Process/ Reductant	Capacity (t/y)	Location	Set-up	Remark
IRAN	NISIC	HYL/N-gas	1,000,000 (3 units)	Ahwaz	-	Construction suspended due to turmoil in Iran.
IRAQ	Ministry of Industry	HYL/N-gas	1,485,000 (4 units)	Kohr Alzubair	1981	
NIGERIA	Federal Ministry of Industry	Midrex/N-gas	1,200,000 (2 units)	Port of Warri	1982	
SAUDI ARABIA	HADEED	Midrex/N-gas	800,000 (2 units)	Al Jubail	1983	Steel making facilities: E.F./C-C to make billets HADEED is JV of SABIC and Korf Stahl-AG.
LIBYA	General Corporation for Iron & Steel Projects (GCISP)	HYL/N-gas	1,200,000 (2 units)	Misrata	1985	Steel making facilities: E.F./C-C Rollings mills to produce 1,200,000 t/y of bar, shapes, H.R., C.R. sheets.
EGYPT	Ministry of Industry	N-gas	600,000	El-Dikheila	1985	Steel making facilities: E.F./C-C/Bar Mill to produce 730,000 t/y bar.
SOUTH AFRICA	Highveld Steel & Vanadium Corp.	Highveld-Lurgi/ Coal	1,000,000 (8 units)	Witbank	1977	
"	Dunswart Iron & Steel Works	Krupp/Coal	150,000	Benoni	1973	
"	Screw Metals	DRC	75,000	Germiston	1983	

This tendency of DR module toward larger scale shows that it is reasonable to employ a larger scale of module mainly for pursueing a big scale merit, if there is enough demand within the country of if stable and reliable market can be expected abroad.

However as examined in detail in Chapter 3, the DRI export market for Pakistan is not fully reliable. Therefore it is not recommended to enlarge the module scale depending on this export market.

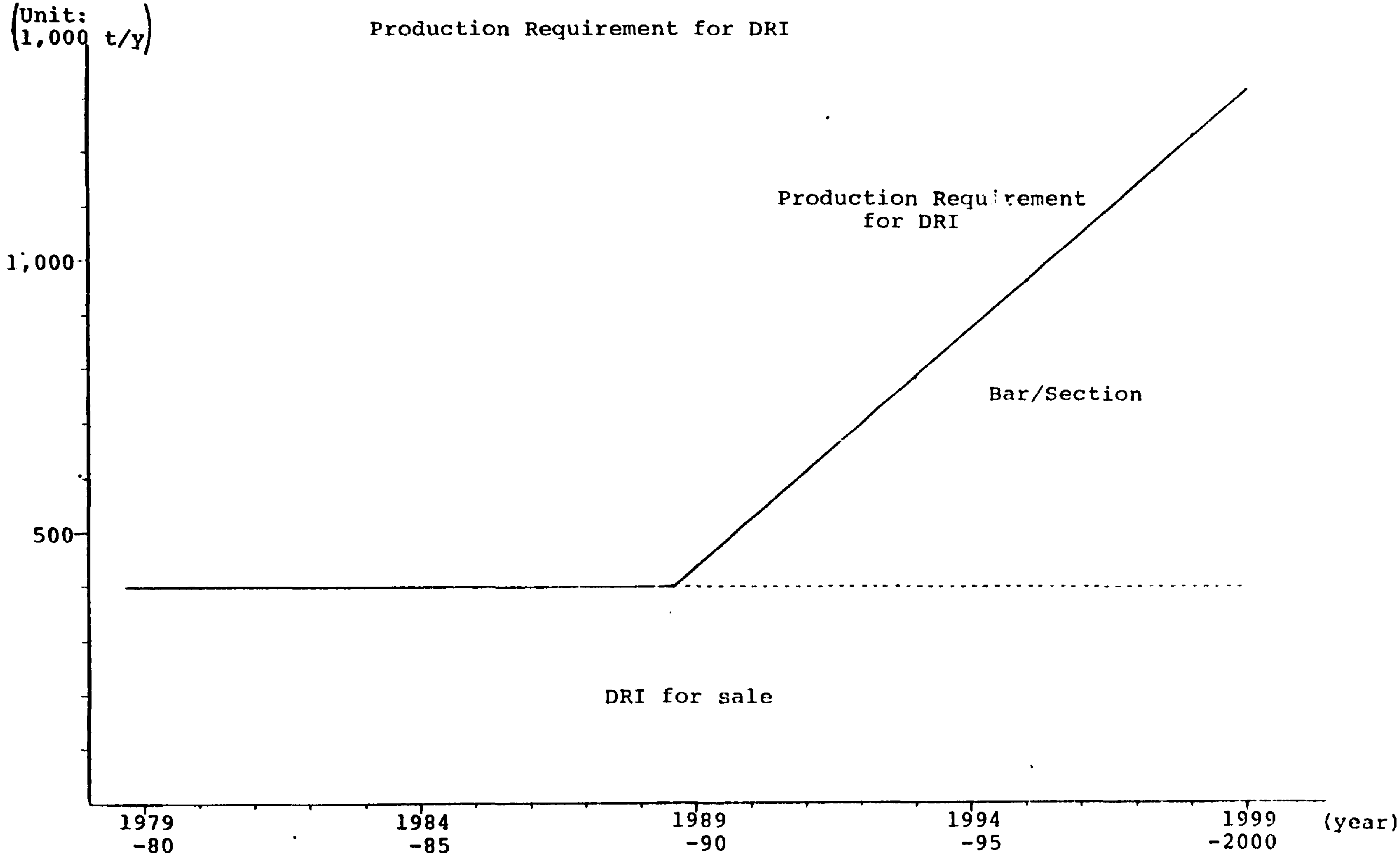
On the other hand the 400,000 t/y modules cannot be said being basically old-fashioned, though their recent installation records are not many. So that they will not be replaced with 600,000 - 700,000 t/y modules for the time being.

According to our opinion, the selection of scale of DR module depends mainly on demand, and in the case of integrated steel works, it is restricted by the capacities of downstream including rolling mill. For the production of DRI for sale, therefore, the larger the module scale is, the bigger merit can be obtained. Actually 600,000 - 700,000 t/y modules have been selected in such project that produces DRI for sales.

In the case of Pakistan, can be considered both the possibility of production of DRI sold to the ingot makers in place of scraps and that of the production of bar/ section by DR integrated steel works. These must be combined and considered in the discussion about the scale of DR module.

The following table shows the future trend of demand for these two kinds of products namely DRI and bar/section DRI.

Production Requirement for DRI



The possibility of the selection of module to meet this demand is examined below.

A. When a more favorable large-scale DR module with a capacity of 600,000 t/y is adopted,

Case 1: Judging from the capacity of rolling mill, the ptoduct mix of the integrated steel works shall be as follows:-

DRI: 200,000 t/y

Bar/section: 400,000 t/y

In this case, out of the 400,000 t/y demand of DRI, only 200,000 t/y can be supplied. Moreover the start-up of the plant will be put off till 1993-94 when the production requirement for bar/section will increase to about 400,000 t/y.

Therefore, the begining production of DRI, the favorable substitute for scraps, which can be started right now will be much delayed.

Case 2: It is theoretically possible to start the construction of the whole integrated steel works for the same product mix as in the case 1, without waiting for the growth of production requirement for bar/section. But this is unrealistic because the down stream will remain almost completely idle for more than several years.

Case 3: As intermediate alternative to cases 1 and 2, first of all to install a DR plant of 600,000 t/y module to meet the DRI demand of 400,000 t/y and, about 5 years later, construct the downstream in time with the period when the production requirements for bar/section will have grown.

In this case it is possible to avoid the low utilization of facilities to certain extent by gradually increasing the production of bar/section according to the growth of requirement while decreasing the sale of DRI. In this case, however, there can be foreseen such demerits that the DR plant will have to be operated at a quite low operation rate for as long as eight years, and that the scrap/DRI market will be confused by the unstable sales policy of new plant to the ingot makers.

B. When a 400,000 t/y module is adopted,

It will be possible to start construction of the DR plant right now for the exclusive purpose of selling DRI, the substitute for scraps, to the ingot makers without waiting for the growth of demand for bar/section, of which demand and supply is presently balanced.

For the DR plant in the DR integrated steel works for the production of bar/section, in case that a 400,000 t/y module is adopted any loss and bottle-neck in the material balance will be eliminated, because the capacity of the rolling mill for producing bar/section is usually 400,000 t/y per line and equal to the scale of DR plant. This agrees to what the recent DR integrated steel works suggests.

Further as only for a reference it was evaluated from the financial standpoint which should be selected for the DR plant, a module with 600,000 t/y capacity or one with 400,000 t/y capacity. Namely case 2 for a 600,000 t/y module regarded as having the highest operation rate and the most practicable, named Project B'was compared with the case of DR integrated steel works with a 400,000 t/y capacity (called Project B in Chapter 5) as follows.

Comparison of Project B and Project B'

(Unit : US$ million)

		Project B	Project B'
Construction cost	Direct construction cost	407	448
	Pre-operational expenses	48	51
	Total	455	499
Accumulated net income		1,047.6	857.6
Profitability indication	Marginal profit ratio at the first year of full production	68.2%	65.4%
	Ratio of net income to net sales at the first year of full production	16.4%	17.8%
	ROI (Internal rate of return)	14.62%	13.75%

As a result, Project B' was found to have an obviously lower feasibility than Project B. In conclusion, it is recommended to adopt a 400,000 t/y module for the DR plant in Pakistan and introduce the same scale of module for both of the DR plant for selling DRI, the substitute for scraps, and the DR integrated steel works for productwon of bar/section.

Appendix to 6-3

Reasons why DR-EAF Route Not Employed at Expansion of Pakistan Steel

DR-EAF route was considered for the expansion of Pakistan Steel, but it was not employed because of the following problems.

(1) A 1.1 million tonnes per year BF integrated steel plant with built-in potential for expansion to 2 million tonnes per year.

For Pakistan Steel, was prepared the basic plan of intergrated steel plant with a crude steel production capacity of 2 million tonnes per year based on BF-BOF route. Presently the 1st-stage construction with a crude steel production capacity of 1.1 million tonnes per year is under way. For this purpose, a prior investment for BF-BOF route is being made in the layout of each shop and plant, the capacity of some equipment, building spaces, utilities, etc.

(2) Complicated layout

The layout will become more complicated when DR-EAF route is incorporated into the existing BF-BOF route. Fig. A shows a tentative plan. DR plants (600,000 tonnes/year x 2) will be placed on the proposed expansion site for the raw material yard (located in the southeast of the present raw material yard).

Produced DRI needs to be conveyed to the steelmaking shop through a 2km long conveyor. The EAF's (120t/ch x 4) cannot be installed within the building of steel-making shop in view of its space and layout. EAF's and slab CC are planned to be installed within a northwestward extension of the steelmaking shop building. In the 1st-stage work, a hot strip mill with a 1.8 million tonnes per year capacity will be installed. So produced slabs will be fed to this mill. Since billet mill will be installed between the EAF-CC line and the hot strip mill, the slab produced will be carried to the hot strip mill through a deviation route by means of transportation like lorry trucks.

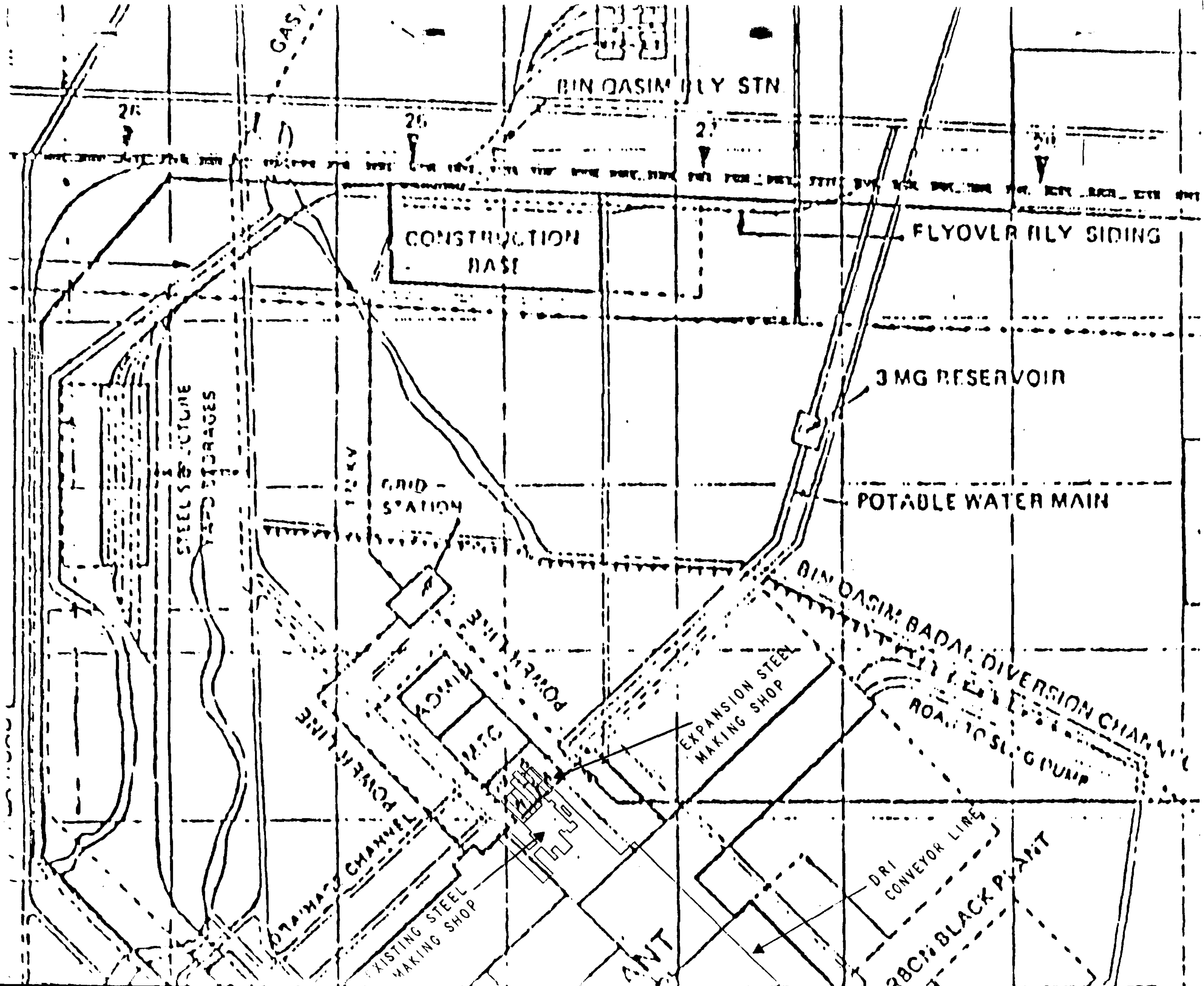
(3) Different tap to tap time between BOF and EAF

Tapping cycle differs between BOF and EAF (usually 55 minutes for BOF and 165 minutes for EAF). This complicates the operation of CC. Fig. B shows an example of the operation. Very careful operation and control of the product lots will be necessary. Further the steel-making will be made by 2 routes and a larger number of staffs and laborers will be needed.

(4) Natural gas

As mentioned in 2.2.3(2), the reserves of natural gas is unlikely to increase, and it is said that they will be exhausted in early 21st century if the production will be increased at random according to the rapid growth of requirement. The necessary quantity of natural gas for Projefts A (manufacture of DRI) and B (DR integrated for non-flat products) recommended in this report is estimated at about 560 million m^3 per year (about 55 million ft^3/d). But the total requirement of natural gas for Projects A, B & D (in Project D, the expansion of Pakistan Steel is made based on DR route) will be about 1,100 million m^3 (more than 14% of the gas produced in 1979-80). Although the production of natural gas will somewhat increase in future, it is undersirable in view of the above-mentioned conditions of resources that all the future expansion of iron and steel industry in Pakistan will be depend up on the basis of DR route. It was for this reason that Projects A and B were recommended to construct a 400,000-tonne per year module of DR plant step by step.

SECTION 1


GAS
BIN QASIM RLY STN
CONSTRUCTION BASE
FLYOVER RLY SIDING
3 MG RESERVOIR
POTABLE WATER MAIN
GRID STATION
POWER LINE
POWER LINE
DRAINAGE CHANNEL
EXPANSION STEEL MAKING SHOP
EXISTING STEEL MAKING SHOP
DRI CONVEYOR LINE
BIN QASIM BADAL DIVERSION CHANN

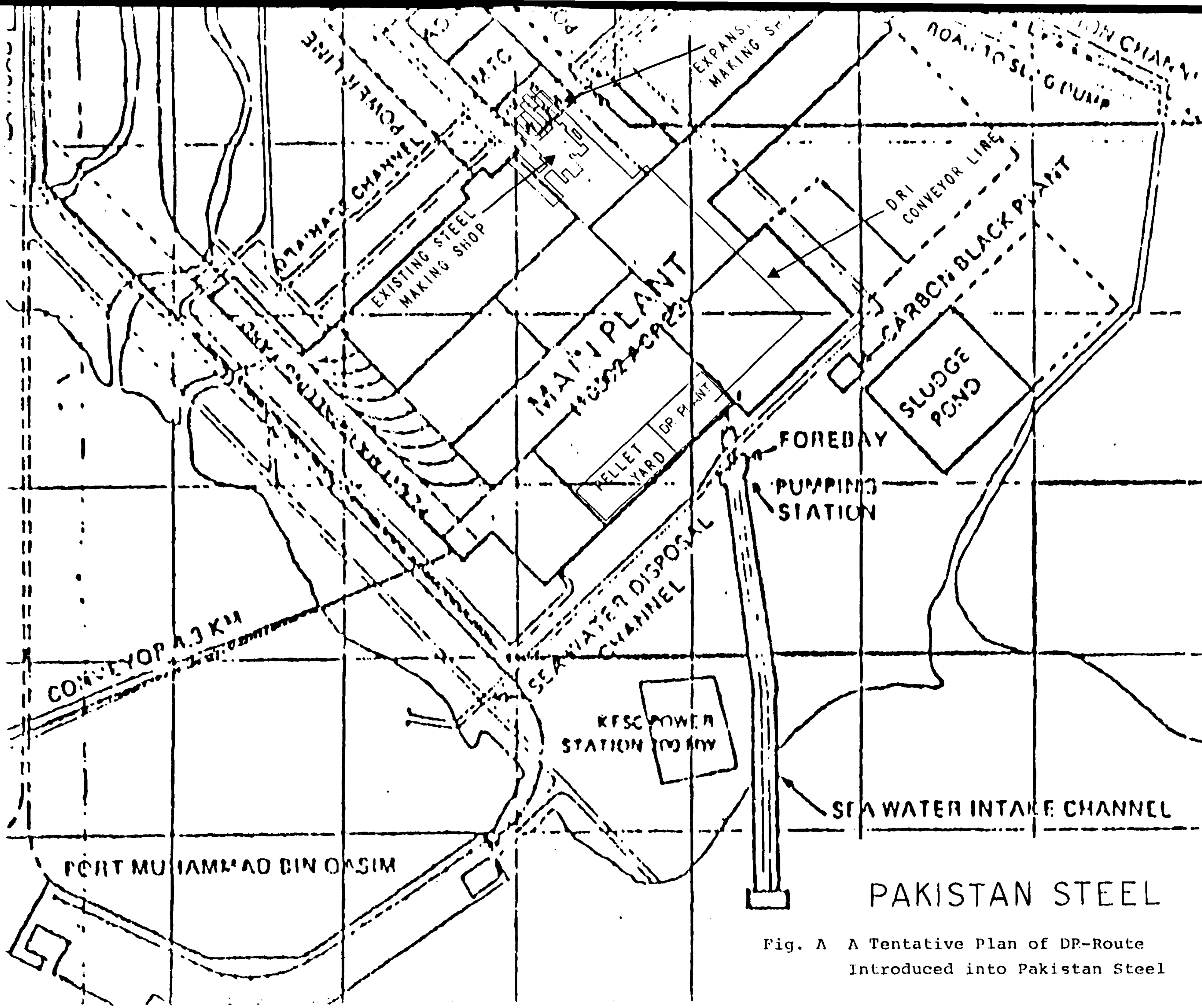
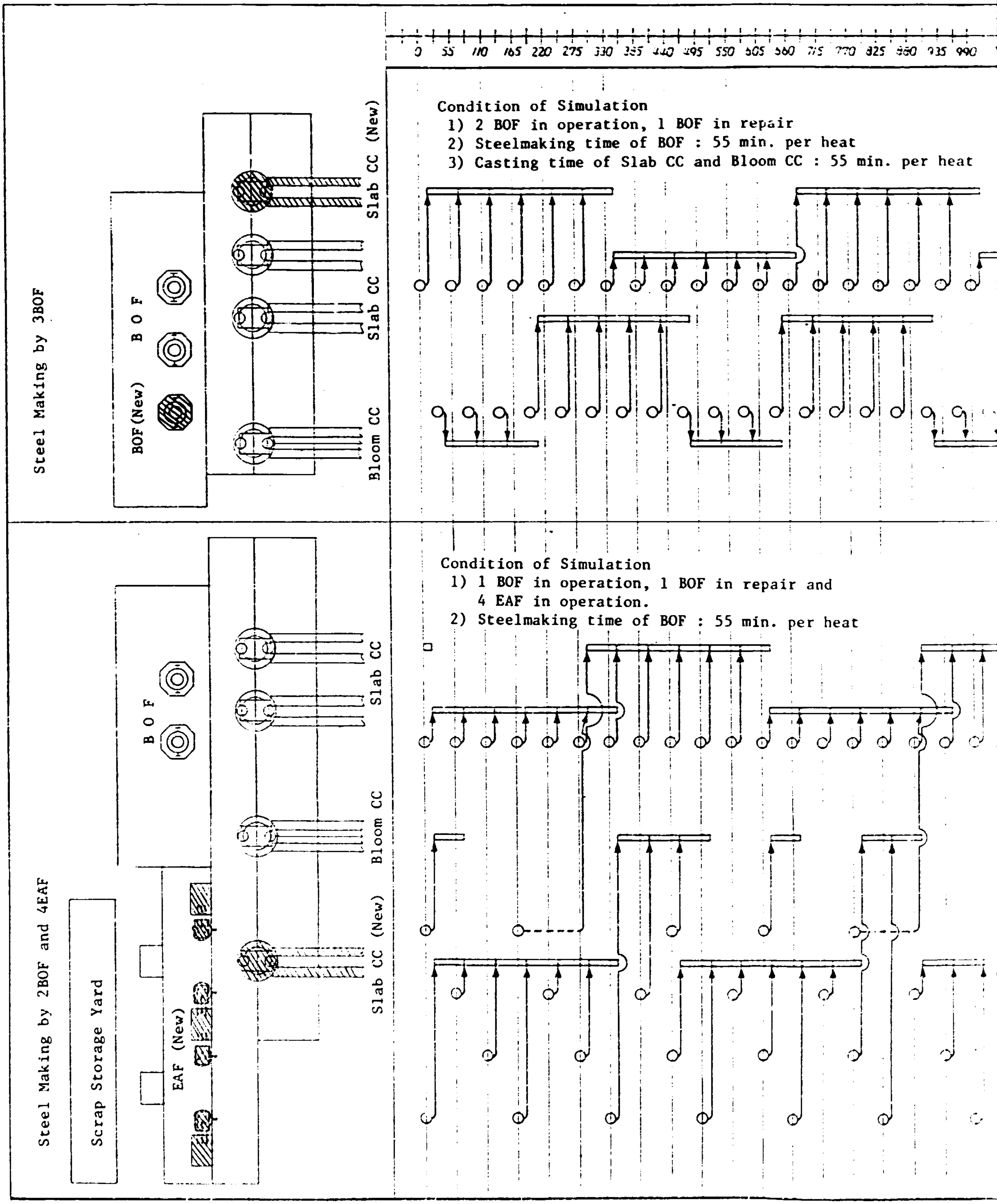


Fig. A A Tentative Plan of DR-Route Introduced into Pakistan Steel

Fig. B An Example of Simultaneous Operations of Cont



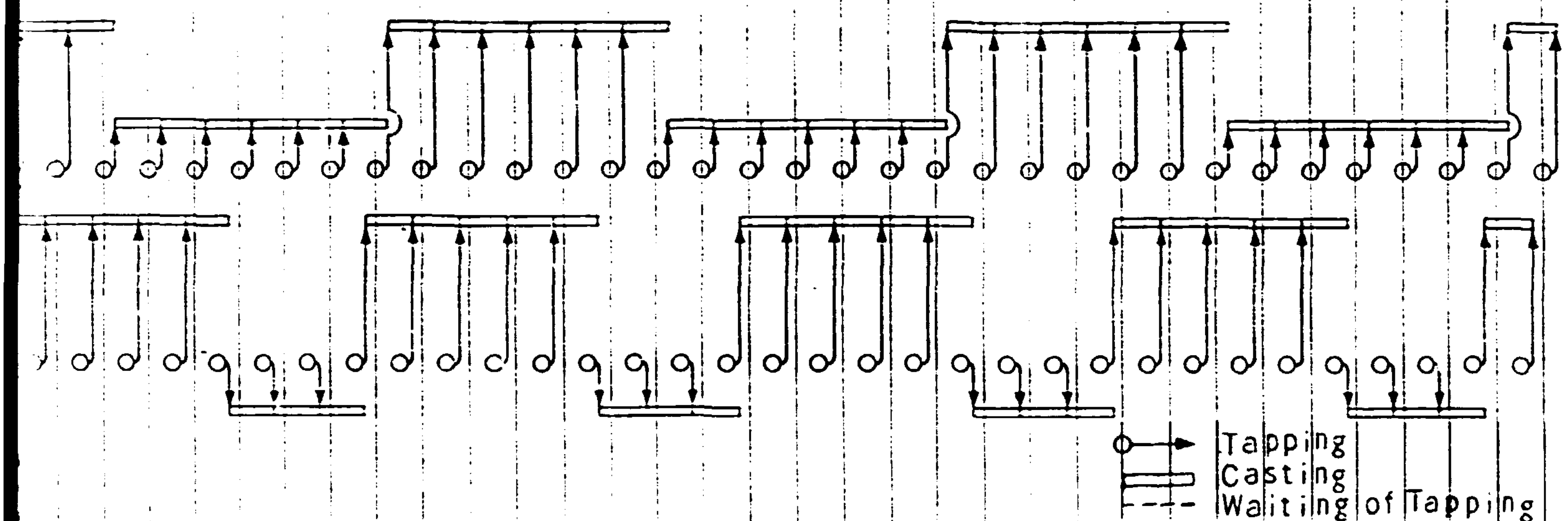
An Example of Simultaneous Operations of Continuous Casting Machines

(minute)

275 330 385 440 495 550 605 660 715 770 825 880 935 990 1045 1100 1155 1210 1265 1320 1375 1430 1485 1540 1595 1650 1705 1760 1815 1870 1925 1980 2035

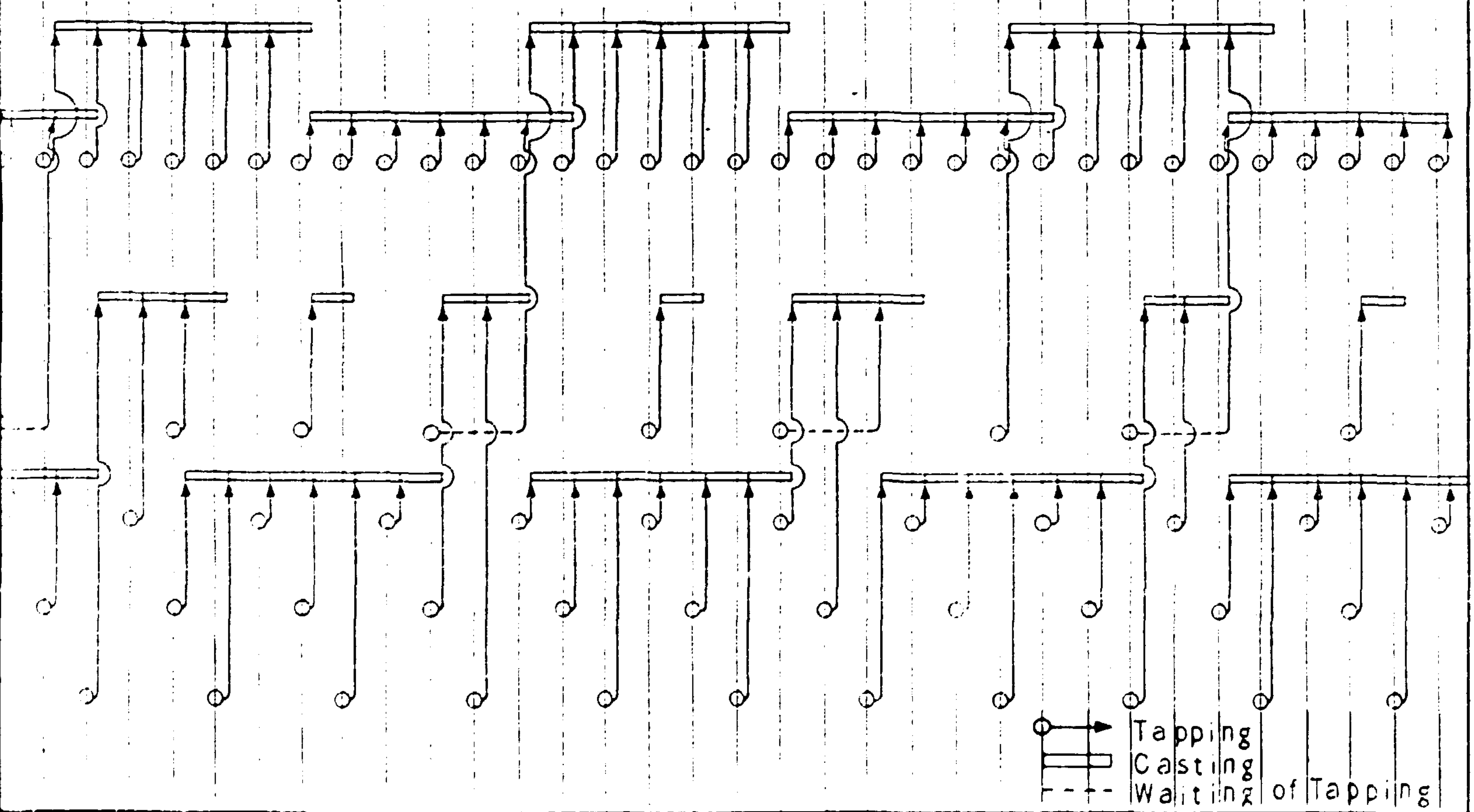
imulation
peration, 1 BOF in repair
ng time of BOF : 55 min. per heat
me of Slab CC and Bloom CC : 55 min. per heat

4) Target number of series of casting heats:
6 heats for Slab CC & 3 heats for Bloom CC



Simulation
peration, 1 BOF in repair and
peration.
ng time of BOF : 55 min. per heat

3) Steelmaking time of EAF : 165 min. per heat
4) Target number of series of casting heats :
6 heats for Slab CC & 3 heats for Bloom



(5) Power

DR-EAF route will of course consume a large amount of electric power. When this route is introduced into Pakistan Steel, about 350 MW of electric power will be needyd. The KESC electric power development scheme plans to produce 200 MW in 1983, 200 MW in 1984, 200 MW in 1986, 200 MW in 1988 and 200 MW in 1990, i.e. total 1,000 MW up to 1990. But the demand for electric power at Karachi area is actually so great that the supply is not equal to it. If Projects A, B & D are all carried out on the basis of DR-EAF route during 1991-96, more than 700 MW electric power will have to be supplied in addition to the amount above-mentioned. The network to WAPDA will be expanded in future (presently 80 MW), to from WAPDA to KESC but the problems of distribution loss and distribution cost remain to be solved. As mentioned in the section of natural gas, one of the reasons why the DR base Project will be carried out by steps also includes the problem of electric power.

(6) Coal back in premier role

As mentioned (2) in 2.1.2, having fallen from grace for some time in the era of cheep and abundant oil and gas supplies, coal has again sprung into prominence.

From the situation of a shrinking industry in 1950's and 1960's, the coal industry is now revitalised with the promise of unprecedented expansion. An attention is being given to the exploration and development of coal world-wide, recognising its new role. It will give rise to new trading patterns, with the USA, Canada, Australia, China and South Africa emerging as world leaders for coal production and export. The world's resources of coal for exceed those of any other energy mineral. Coal has, therefore, a long-term future both in steelmaking and direct thermal power generation when the reserves of oil and gas being to wane.

Under these circumstances, it is unlikely that only coal, among energy sources, will abnormally rise in price in future.

Appendix to 7-1 Comparison of Construction Cost

(1) Existing & Under-Construction Steel Works

Company or Country (location)	Start-up	Production capacity (1000 t/y)		Construction Cost (US$ million)	Construction cost per annual tonne		Remarks
		Crude Steel	Products		(US$/t) Of Crude Steel	(US$/t) Of Products	
Qatar Steel Co. (Umm Said)	1978	400	Billet 50 Bar 330 380	300	750	789	DR Integrated
Nigeria (Warri)	1982	1,050	Bar Rod 400 Billet 600 1,000	750	714	750	DR Integrated
HADEED (Saudi Arabia Al-Jubail)	1983	850	Bar Rod 800	670	788	838	DR Integrated
Egypt (El-Dikheila)	1985	800	Bar Rod 730	835	1,044	1,144	DR Integrated

(2) Existing & Under-Construction Steel Works

Company or Country (location)	Start-up	Production capacity (1000 t/y)		Construction Cost (US$ million)	Construction cost per annual tonne		Remarks
		Crude Steel	Products		(US$/t) of Crude Steel	(US$/t) of Products	
UNIDO Master plan in Thailand		1,600	Flat products 1,340 DRI 600 1,940	1,793	[1] 815	924	DR integrated [1] including DRI in Crude Steel
	1979	1,600	Flat products 1,340 DRI 600 1,940	2,104	[2] 956	1,085	BF integrated DR [2] including DRI in Crude Steel
JICA Feasibility study in Philippine		510	Non-flat products 450	504	988	1,120	DR integrated
JICA Feasibility study in Thailand	1979	1,570	Flat products 1,050 Slab/bloom billet 400 1,450	1,440	917	993	BF integrated
	1979	1,300	Flat products 1,100	1,407	1,082	1,279	EP integrated
UNIDO Master plan in Bangladesh	1981	440	Billet 400 DRI 250 650	590	[3] 861	914	DR semi-integrated [3] including DRI in Crude Steel

Appendix to 7-2

Breakdown of Estimated Variable Cost

Among the manufacturing costs in each Project, the breakdown of variable cost is shown in below for a reference. These details have not been confirmed by obtaining quotations from vendors for each case, and they are only assumed in a preliminary way based on our exprience, actual survey results and available reports. It is therefore necessary to confirm every value and figure, and to make a detailed feasibility study prior to carrying out these Projects.

Appendix to 7-2 Break-down of Estimated Variable Cost

Project A
(DRI 400,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Oxide Pellet	1.34 t	60.0	80.4
Lump Ore	0.15 t	50.0	7.5
Natural Gas	350 Nm^3	0.02	7.0
Electric Powr	140 KWh	0.03	4.2
Consumables and Others	-	-	4.8
Total			103.9

Appendix to 7-2 Break-down of Estimated Variable Cost

Project B
(Bar/Section 380,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Oxide Pellet	1.411 t	60.0	84.7
Lump Ore	0.158 t	50.0	7.9
Scrap	0.132 t	150.0	19.8
Auxiliary Materials	-	-	16.2
Natural Gas	460 Nm^3	0.02	9.2
Electric Power	990 KWh	0.03	29.7
Consumables and Others	-	-	30.0
Total			197.5

Appendix to 7-2 Break-down of Estimated Variable Cost

Project C
(Bar/Section 400,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Billet	1.053 t	505	531.8
Electric Power	140 KWh	0.03	4.2
Consumables and Others	-	-	2.9
Total			538.9

Appendix to 7-2 Break-down of Estima‘_d Variable Cost

Project D-1 and D-2
(Liquid Steel : 1,115,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Coking Coal	0.717 t	88.0	63.1
Iron Ore Fine	1.022 t	47.0	48.0
Iron Ore Lump	0.417 t	50.0	20.9
Dolomite Fine	0.193 t	12.0	2.3
Limestone Lump and Fine	0.206 t	10.0	2.1
Auxiliary Materials	-	-	21.2
Electric Power	140 KWh	0.03	4.2
Consumables and Others	-	-	17.7
Total			179.5

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-1 and D-2

(Cast Slab : 1,050,000 t/y Project D-1)
(Cast Slab : 850,000 t/y Project D-2)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Liquid Steel	1.062 t	179.5	190.6
Utilities	-	-	1.6
Consumables and Others	-	-	4.8
Total			197.0

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-2

(Cast Billet : 200,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Liquid Steel	1.055 t	179.5	189.4
Utilities	-	-	1.4
Consumables and Others	-	-	3.1
Total			193.9

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-1 and D-2

(Hot Rolled Sheet : 1,005,000 t/y Project D-1)
(Hot Rolled Sheet : 815,000 t/y Project D-2)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Cast Slab	1.045 t	197.0	205.9
Utilities	-	-	3.8
Consumables and Others	-	-	0.6
Total			210.3

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-1 and D-2

(Cold Rolled Sheet : 630,000 t/y Project D-1)
(Cold Rolled Sheet : 520,000 t/y Project D-2)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Hot Rolled Coil	1.048 t	210.3	220.4
Utilities	-	-	5.0
Consumables and Others	-	-	5.7
Total			231.1

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-2

(Galvanized Sheet : 80,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Cold Rolled Coil	1 t	231.1	231.1
Utilities	-	-	1.9
Zinc	7.0 kg	1.2	8.4
Others	-	-	4.1
Total			245.5

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-1 and D-2
(Tinned Plate : 250,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Cold Rolled Coil	1 t	231.1	231.1
Utilities	-	-	2.4
Tin	7.3 kg	17.0	124.1
Others	-	-	4.8
Total			361.4

Appendix to 7-2 Break-down of Estimated Variable Cost

Project D-1 and D-2
(Tinned Plate : 250,000 t/y)

Item	Unit Consumption (A)	Unit Price (US$/unit) (B)	(A) x (B) (US$/product tonne)
Cold Rolled Coil	1 t	231.1	231.1
Utilities	-	-	2.4
Tin	7.3 kg	17.0	124.1
Others	-	-	4.8
Total			361.4

Appendix to 7-3

Cash Flow and Discounted Cash Flow

As the detailed analysis for cash flow analysis and ROI analysis in Chapter 7, cash flow and discounted cash flow in each year of each Project is described as under:-

PAKISTAN M/F
(CASE A)

UNIT US$ MIL.

YEAR	CASH FLOW OUT-FLOW	CASH FLOW IN-FLOW	DISCOUNT RATE 16.12 %	DISCOUNTED CASH FLOW OUT-FLOW	DISCOUNTED CASH FLOW INFLOW
1	20.0	0.0	0.8612	17.2	0.0
2	62.0	0.0	0.7416	46.0	0.0
3	30.0	0.0	0.6387	19.2	0.0
4	0.0	17.1	0.5500	0.0	9.4
5	0.0	24.4	0.4737	0.0	11.6
6	0.0	25.5	0.4079	0.0	10.4
7	0.0	24.9	0.3513	0.0	8.7
8	0.0	24.6	0.3025	0.0	7.4
9	0.0	23.2	0.2605	0.0	6.0
10	0.0	22.9	0.2244	0.0	5.1
11	0.0	22.6	0.1932	0.0	4.4
12	0.0	22.3	0.1664	0.0	3.7
13	0.0	18.1	0.1433	0.0	2.6
14	0.0	17.8	0.1234	0.0	2.2
15	0.0	17.8	0.1063	0.0	1.9
16	0.0	17.8	0.0915	0.0	1.6
17	0.0	17.8	0.0788	0.0	1.4
18	0.0	17.8	0.0679	0.0	1.2
19	0.0	17.8	0.0584	0.0	1.0
20	0.0	17.8	0.0503	0.0	0.9
21	0.0	17.8	0.0433	0.0	0.8
22	0.0	17.3	0.0373	0.0	0.6
23	0.0	39.3	0.0321	0.0	1.3
TOTAL	112.0	424.6		82.3	82.3

PAKISTAN M/F
(CASE B)

UNIT: US$ MIL.

YEAR	CASH FLOW OUT-FLOW	CASH FLOW IN-FLOW	DISCOUNT RATE 14.62 %	DISCOUNTED CASH FLOW OUT-FLOW	DISCOUNTED CASH FLOW INFLOW
1	14.0	0.0	0.8724	12.2	0.0
2	87.0	0.0	0.7612	66.2	0.0
3	271.0	0.0	0.6641	180.0	0.0
4	115.0	0.0	0.5794	66.6	0.0
5	0.0	69.9	0.5055	0.0	35.3
6	0.0	98.4	0.4410	0.0	43.4
7	0.0	102.5	0.3847	0.0	39.4
8	0.0	101.2	0.3357	0.0	34.0
9	0.0	99.8	0.2929	0.0	29.2
10	0.0	93.0	0.2555	0.0	23.8
11	0.0	91.6	0.2229	0.0	20.4
12	0.0	90.2	0.1945	0.0	17.5
13	0.0	88.9	0.1697	0.0	15.1
14	0.0	72.7	0.1480	0.0	10.8
15	0.0	71.3	0.1291	0.0	9.2
16	0.0	71.3	0.1127	0.0	8.0
17	0.0	71.3	0.0983	0.0	7.0
18	0.0	71.3	0.0858	0.0	6.1
19	0.0	71.3	0.0748	0.0	5.3
20	0.0	71.3	0.0653	0.0	4.7
21	0.0	71.3	0.0570	0.0	4.1
22	0.0	71.3	0.0497	0.0	3.5
23	0.0	67.5	0.0434	0.0	2.9
24	0.0	137.5	0.0378	0.0	5.2
TOTAL	487.0	1683.6		325.0	325.0

PAKISTAN M/P
(CASE C)

UNIT: US$ MIL.

YEAR	CASH FLOW		DISCOUNT RATE	DISCOUNTED CASH FLOW	
	OUT-FLOW	IN-FLOW	7.58 %	OUT-FLOW	INFLOW
1	34.0	0.0	0.9295	31.6	0.0
2	110.0	0.0	0.8640	95.0	0.0
3	54.0	0.0	0.8032	43.4	0.0
4	0.0	21.7	0.7466	0.0	16.2
5	0.0	27.2	0.6940	0.0	18.9
6	0.0	25.3	0.6451	0.0	16.3
7	0.0	24.9	0.5996	0.0	14.5
8	0.0	24.1	0.5574	0.0	13.4
9	0.0	22.0	0.5181	0.0	11.4
10	0.0	21.5	0.4816	0.0	10.4
11	0.0	21.0	0.4477	0.0	9.4
12	0.0	20.5	0.4161	0.0	8.5
13	0.0	15.0	0.3868	0.0	5.8
14	0.0	14.6	0.3595	0.0	5.2
15	0.0	14.6	0.3342	0.2	4.9
16	0.0	14.6	0.3107	0.0	4.5
17	0.0	14.6	0.2888	0.0	4.2
18	0.0	14.6	0.2684	0.0	3.9
19	0.0	14.6	0.2495	0.0	3.6
20	0.0	14.5	0.2319	0.0	3.4
21	0.0	14.6	0.2156	0.0	3.1
22	0.0	13.5	0.2004	0.0	2.7
23	0.0	48.5	0.1863	0.0	9.1
TOTAL	198.0	402.0		170.0	170.0

PAKISTAN M/F
(CASE D-1)

UNIT US$ MIL.

YEAR	CASH FLOW OUT-FLOW	CASH FLOW IN-FLOW	DISCOUNT RATE 14.27 %	DISCOUNTED CASH FLOW OUT-FLOW	DISCOUNTED CASH FLOW INFLOW
1	15.0	0.0	0.8751	13.1	0.0
2	271.0	0.0	0.7658	207.5	0.0
3	299.0	0.0	0.6702	200.4	0.0
4	596.0	0.0	0.5865	349.6	0.0
5	501.0	0.0	0.5133	257.1	0.0
6	0.0	242.3	0.4492	0.0	108.8
7	0.0	355.4	0.3931	0.0	140.1
8	0.0	360.6	0.3440	0.0	124.0
9	0.0	352.7	0.3010	0.0	106.2
10	0.0	348.7	0.2634	0.0	91.9
11	0.0	324.2	0.2305	0.0	74.7
12	0.0	319.6	0.2017	0.0	64.5
13	0.0	314.9	0.1766	0.0	55.6
14	0.0	310.3	0.1545	0.0	47.9
15	0.0	245.1	0.1352	0.0	33.1
16	0.0	240.5	0.1183	0.0	28.5
17	0.0	240.5	0.1036	0.0	24.9
18	0.0	240.5	0.0906	0.0	21.8
19	0.0	240.5	0.0793	0.0	19.1
20	0.0	240.5	0.0694	0.0	16.7
21	0.0	240.5	0.0607	0.0	14.6
22	0.0	240.5	0.0531	0.0	12.8
23	0.0	240.5	0.0465	0.0	11.2
24	0.0	284.5	0.0407	0.0	11.6
25	0.0	548.5	0.0356	0.0	19.8
TOTAL	1682.0	5931.8		1027.5	1027.5

PAKISTAN M/P
(CASE D-2)

UNIT US$ MIL.

YEAR	CASH FLOW		DISCOUNT RATE	DISCOUNTED CASH FLOW	
	OUT-FLOW	IN-FLOW	13.49 %	OUT-FLOW	INFLOW
1	14.0	0.0	0.8811	12.3	0.0
2	262.0	0.0	0.7764	203.4	0.0
3	289.0	0.0	0.6841	197.7	0.0
4	576.0	0.0	0.6028	347.2	0.0
5	484.0	0.0	0.5311	257.1	0.0
6	0.0	216.9	0.4680	0.0	101.5
7	0.0	352.9	0.4124	0.0	145.5
8	0.0	338.9	0.3634	0.0	123.1
9	0.0	325.4	0.3202	0.0	104.2
10	0.0	321.5	0.2821	0.0	90.7
11	0.0	297.8	0.2486	0.0	74.0
12	0.0	293.3	0.2190	0.0	64.2
13	0.0	288.9	0.1930	0.0	55.8
14	9.0	284.4	0.1701	0.0	48.4
15	0.0	221.0	0.1498	0.0	33.1
16	0.0	216.5	0.1320	0.0	28.6
17	0.0	216.5	0.1163	0.0	25.2
18	0.0	216.5	0.1025	0.0	22.2
19	0.0	216.5	0.0903	0.0	19.6
20	0.0	216.5	0.0796	0.0	17.2
21	0.0	216.5	0.0701	0.0	15.2
22	0.0	216.5	0.0618	0.0	13.4
23	0.0	216.5	0.0544	0.0	11.8
24	0.0	209.4	0.0480	0.0	10.0
25	0.0	333.4	0.0423	0.0	14.0
TOTAL	1625.0	5215.8		1017.8	1017.8

09 22