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TECHNOLOGICAL PROFILES ON THE IRON AND STEEL INDUSTRY*

BY

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TECHNOLOGICAL PROFILE

ON

WORLD IRON ORE SURVEY INCLUDING

BENEFICIATION, SINTERING AND PELLETIZING

Foreword

These four technological profiles, on a world iron ores survey including beneficiation, sintering and pelletizing, iron making, steel making and steel casting including continuous casting, have been prepared for the UNIDO Industrial and Technological Information Bank (INTIB), which is a component of the UNIDO programme on the development and transfer of technology.

INTIB is a pilot operation which began in July 1977 for a period of 18 months. During this pilot phase it is being concentrated on four industrial sectors: iron and steel, fertilizers, agro-industries, and agricultural machinery and implements. Each of these sectors has priority in other UNIDO endeavours: sectoral studies, consultations, eventual negotiations and technical assistance projects.

The concept of INTIB has its roots in the Lima Declaration and Plan of Action, adopted at the Second General Conference of UNIDO in 1975, and in various United Nations General Assembly resolutions, all envisaging such a service as a prerequisite to, and an instrument for, the transfer, development and adaptation of appropriate technologies.

With the targetted expansion of industry in developing countries from a 7 per cent share of global industrial output at the time of the Lima Conference to 25 per cent in the year 2000 - an objective set by the Conference - adequate information on new investments at the decision-maker level is crucial. The same is true for those advising the decision-makers: national industrial information centres, technology development institutes, investment banks and so on.

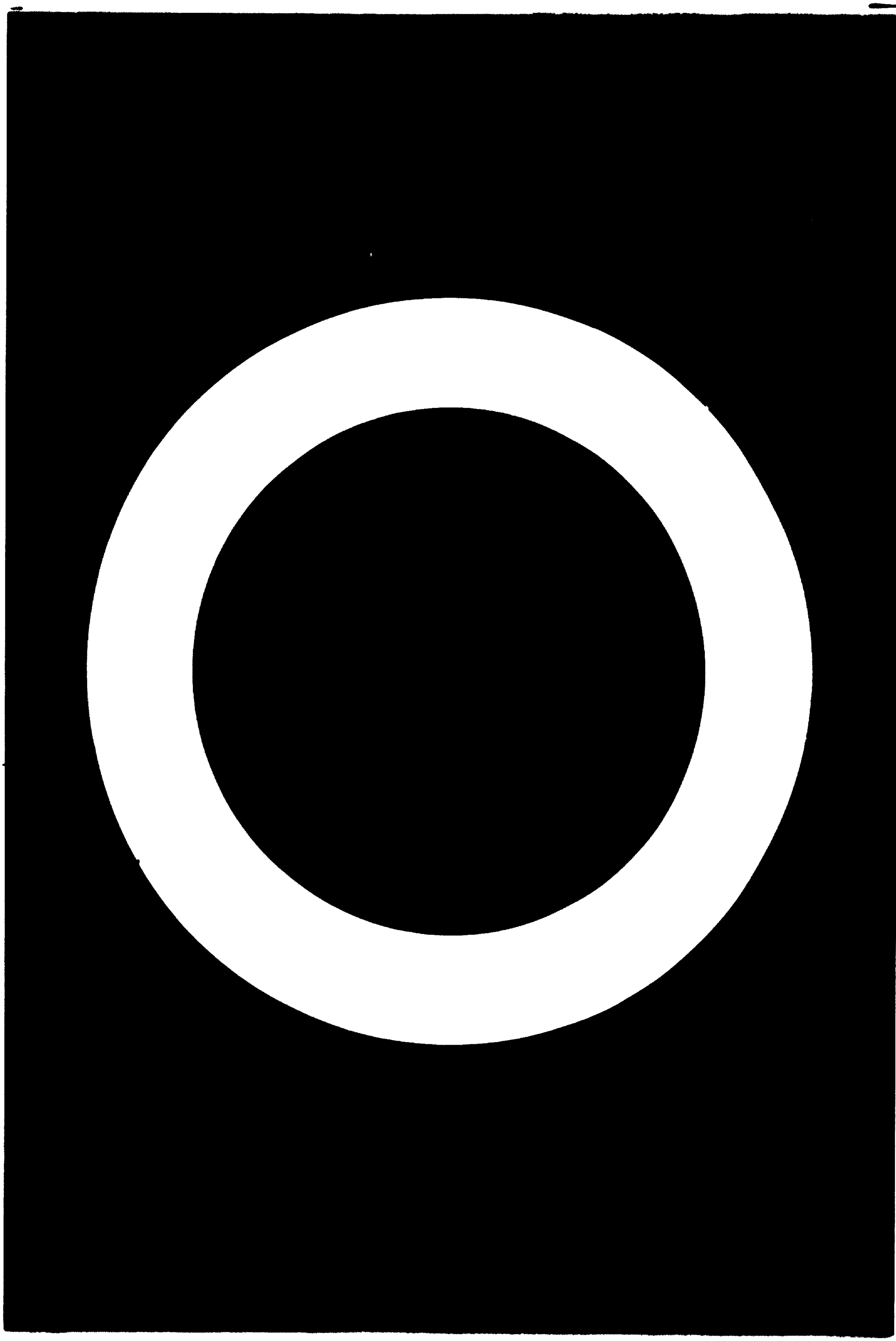
The novel character of INTIB, as compared with information services previously rendered by UNIDO, consists of addressing itself to the technology selection process at the stage preceding its acquisition and operation, and of offering advisory services beyond the provision of information.

INTIB draws upon services available in the Industrial Information Section, where it is housed, but also relies on the expertise of specialist staff in the Industrial Operations Division and from commissioned experts for the processing of information material obtained from sources within and outside UNIDO relevant to the technology selection process. The outcome of this effort takes the form of information supplied in anticipation of demand as well as directly solicited by individual request. In advance of demand is this series of technology profiles and monographs concerning matters to consider when selecting a technology from a variety of alternatives. Solicited information consists of replies to specific inquiries and advice.

The target users of INTIB include ministries of industry, planning and industrial development, multi-purpose technological institutions, transfer of technology centres and registries, and so on. The listing, however, is not exhaustive. The intention is to serve all those who can be identified as having genuine technology-selection responsibilities and problems, whether in an advisory role or decision-making capacity, in each of the four priority industrial sectors selected for this pilot phase.

Further information about INTIB and its related activities can be had on request by writing to the Chief, Industrial Information Section, UNIDO, Co-ordinator of INTIB, P.O. box 707, A-1011 Vienna, Austria.

These technological profiles were prepared by Mr. G.P. Mathur, acting as a consultant to UNIDO.



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1. Iron Ore Minerals

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

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

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

2. Major Deposits

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

USSR

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

Canada and West Indies

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

USA and Mexico

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

South America

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

Middle East, Asia and Far East

Saudi Arabia, Israel, Turkey, Iran, Afghanistan and Pakistan comprising West Asia, have iron ore occurrences. The deposits of Saudi

Arabia are mainly of Lake Superior type and contain mostly hematite with magnetite mineralisation sometimes. The deposits in Israel are of hematite and goethite. The Turkish deposits are mostly magnetite and are of Magnitnaya type. Similar type of deposits occur in Iran. The deposits of Afghanistan contain hematite and siderite. Magnitnaya type and bedded type of deposits are found in Pakistan with magnetite and hematite as principal iron-bearing minerals.

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

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

Africa

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

Europe

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

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

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

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

Australia and New Zealand

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

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

3. Production and Reserves

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

Table 1: World Iron Ore Production

Country	In million tons			
	1973	1974	1975	1976*
Algeria	3.130	3.792	3.300	3.200
Angola	6.048	4.980	3.360	3.300
Australia	83.568	96.688	97.365	92.400
Austria	4.211	4.246	3.833	3.784
Belgium	0.116	0.123	0.093	0.063
Brazil	55.019	79.973	88.493	70.000
Bulgaria	2.774	2.684	2.337	2.300
Canada	48.200	47.271	44.745	56.000
Chile	9.650	10.297	11.070	10.500
China	50.000	51.000	51.000	50.000
Colombia	0.442	0.500	0.623	0.600
Czechoslovakia	1.672	1.688	1.773	1.850
Denmark	0.012	0.006	-	-
Egypt	3.130	3.792	3.300	3.200
Finland	0.865	0.934	0.766	0.700
France	54.754	54.730	50.142	45.543
East Germany	0.520	0.250	0.590	0.500
West Germany	6.429	5.670	4.273	3.034
Greece	1.842	2.001	1.965	2.154
Guinea	-	-	-	-
Hungary	0.681	0.595	0.386	0.631
Hong Kong	0.151	0.160	0.161	0.037
India	34.426	34.230	40.271	41.400
Iran	0.600	0.620	0.650	0.650
Italy	0.675	0.795	0.739	0.643
Japan	1.007	0.780	0.942	0.800
North Korea	8.100	8.100	8.200	6.100
South Korea	0.467	0.493	0.525	0.500
Liberia	34.620	36.000	36.500	35.000
Luxembourg	3.782	2.686	2.315	2.079
Malaysia	0.516	0.468	0.349	0.300
Mauritania	10.416	11.110	8.500	8.000
Mexico	5.736	4.902	4.621	3.500
Morocco	0.376	0.534	0.554	0.350
Netherlands	-	-	-	-
Norway	3.970	3.918	4.064	4.291
Peru	8.964	9.563	7.753	7.000
Philippines	2.256	1.616	1.352	1.150
Poland	1.413	1.296	1.192	1.100
Portugal	0.057	0.024	0.045	0.043

Table 1: continued - World Iron Ore Production

Country	In million tons			
	1973	1974	1975	1976*
Rhodesia	0.550	0.550	0.600	0.600
Romania	3.234	3.205	3.065	2.300
Sierra Leone	2.400	2.508	2.500	2.400
South Africa	10.955	11.734	11.191	15.684
Spain	6.901	8.613	8.617	7.700
Sudan	-	-	-	-
Swaziland	2.148	2.055	2.232	1.932
Sweden	34.727	36.153	30.867	30.526
Switzerland	-	-	-	-
Thailand	0.036	0.036	0.032	0.020
Tunisia	0.811	0.820	0.652	0.500
Turkey	1.861	1.531	1.990	1.000
U.K.	7.105	3.602	4.490	4.583
U.S.A.	88.800	85.917	81.351	81.200
U.S.S.R.	216.104	224.883	232.803	239.000
Venezuela	22.860	26.408	24.104	23.000
Yugoslavia	4.670	5.034	5.239	4.265
WORLD	851.200	899.100	895.700	875.300

* Estimated or provisional.

Table 2: Global Distribution of Total Resources and Potential Reserves of Fe Ore Minerals

	F	M	G	S	FM		GS	FS	MP	MS	FMP	MSP	MG	SP	FMC	FMS	Not classified	
USSR	29,025 (20,875)	38,325 (21648)	106,363 (13,894)	1258 (1195)	36,255 (29,421)		522 (447)	9316 (9316)								300	82,937 (13,687)	
Australia New Zealand	(1630)	(660)	(5951)		(35)	(7953)		(322)	(144)		(2)				(120)			
USA	3561 (396)	12,969 (789)	907 (745)		65,555 (3227)	6139 (2267)	343 (343)	50					313 (113)		1742 (272)	10,254 (4)	3 (3)	FGS 30 (30) FMGS 4428 (28) others 2 (2)
Canada and West Indies Dominican Republic	12,235 (2025)	32,411 (8164)	- (1)		55,875 (20,898)	8370 (4320)		600	20 (10)	1000		1675 (40)		735 (420)		6020 (20)	1500	P (38), FI 1330 (350) FMI 320, FSC 2000 FMC 25, GSC 1500.
Middle East, Far East (Inc. India)	19,427 (8310)	7751 (2673)	3206 (655)	41	12,824 (4206)	566 (317)	2545 (508)	129 (29)					4 (2)		275 (108)		24,328 (88)	GSC (450)
India	15,516 (6982)	2332 (620)			8547 (419)	52 (52)	2540 (508)								53 (53)		12 (12)	
Africa	17,056 (2405)	2718 (373)	1297 (262)	6 (6)	4254 (603)	1358 (127)	92 (20)	168 (168)		55 (15)	41 (41)		46 (46) 8		1419 (1250)	1427 (432)	42 (42)	P 17, FPI (1) FMI 279, (28) FMC 1000 (1000)
S. America	84,869 (32,262)	788 (251)	1948 (301)		2610 (411)	2304 (929)												
Europe	777 (457)	3122 (3103)	1264 (794)	1900 (1680)	2498 (1278)	839 (139)	9460 (4840)	775 (675)	50 (10)	50 (50)					440 (100)	2240 (2120)	1110 (10)	MI 50 (50), GC 5148 (3048) SC 10, (2) FSC 50, (30) MSC 680 (230), GSC 1653 (1048), FGSC 1740, (1640) MGS 38 (38)
Sweden		2895			475													

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

ii) Figures without bracket indicate total resources (million tons) (ie. reserve potential ore) and those with bracket show reserve (million tons).

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

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

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

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

4. Beneficiation methods

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

The various beneficiation methods are briefly outlined below:

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

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

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

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

iv) Gravity methods:

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

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

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

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

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

v) Magnetic Separation:

a) Strongly magnetic minerals like magnetite are separated from non-magnetic minerals employing low intensity wet magnetic separator. The seperation is often preceded by desliming the feed for better efficiency.

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

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

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

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

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

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

4.1. Beneficiation Practices in some of the countries

Ores that contain 60-65 per cent iron, are generally considered of good quality and acceptable for direct use in blast furnace for smelting. The presence of the total gangue minerals consisting of oxides of silicon, aluminium and titanium up to a level of about 8 per cent, are acceptable. Phosphorus and sulphur contents of the ore, should be as low as possible.

A brief description of beneficiation techniques for the various types of iron ores found in different countries, has been outlined in the following pages. It may be mentioned that the exact process parameters will depend upon the amenability of ore to upgrading, nature and characteristics of the constituent minerals, sizes at which different minerals are liberated from each other, end-use of the beneficiated product, etc. The description given is, therefore, merely indicative of the broad process techniques in each case.

1. USA

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

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

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

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

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

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

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

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

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

2. Sweden

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

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

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

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

3. Canada

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

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

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

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

4. USSR

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

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

5. India

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

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

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

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

A typical flowsheet for hematitic ores is given in Fig. 1 and that for a magnetite-hematite ore in Fig. 2.

Fig. 1: Typical flowsheet for a hematite ore from India

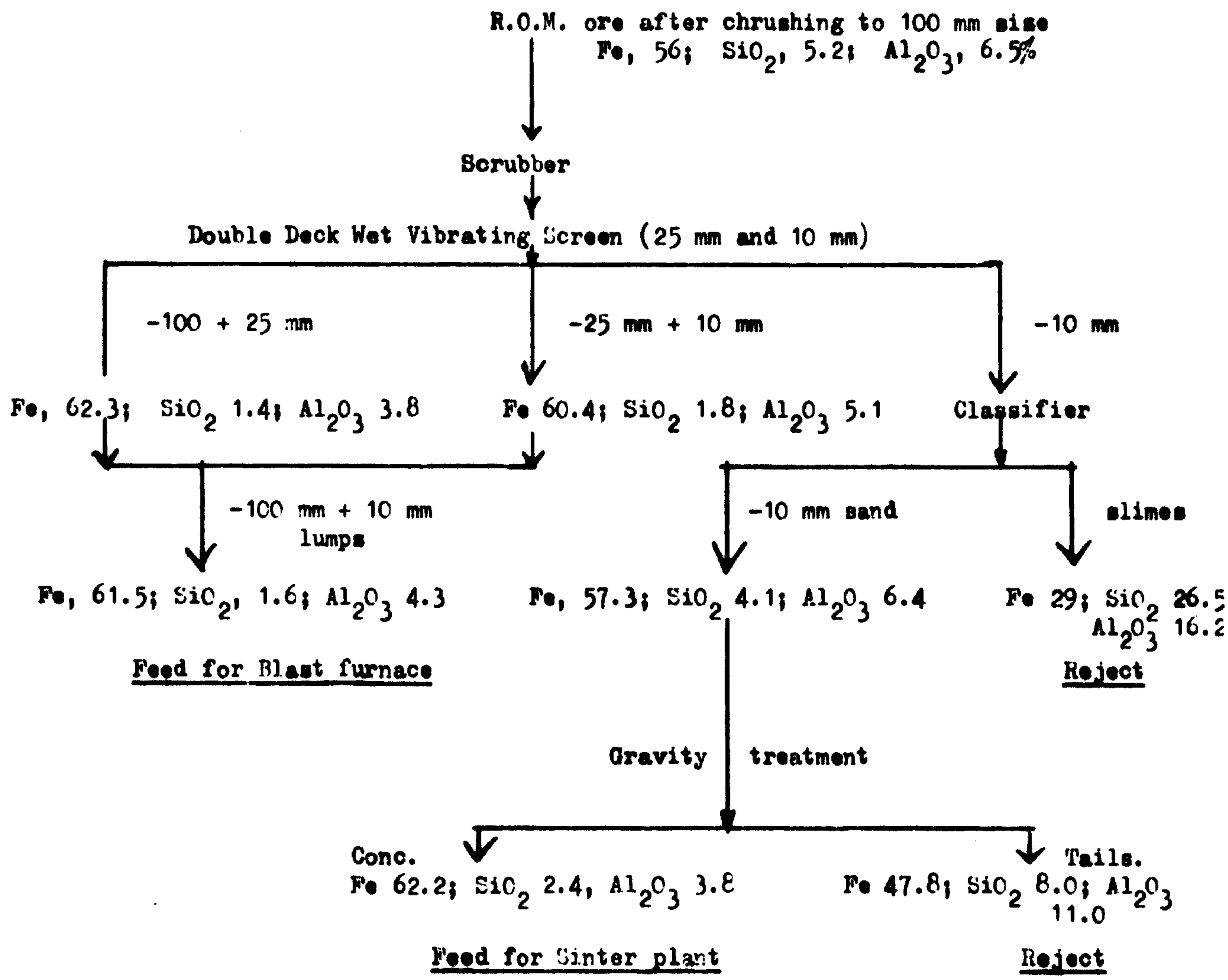
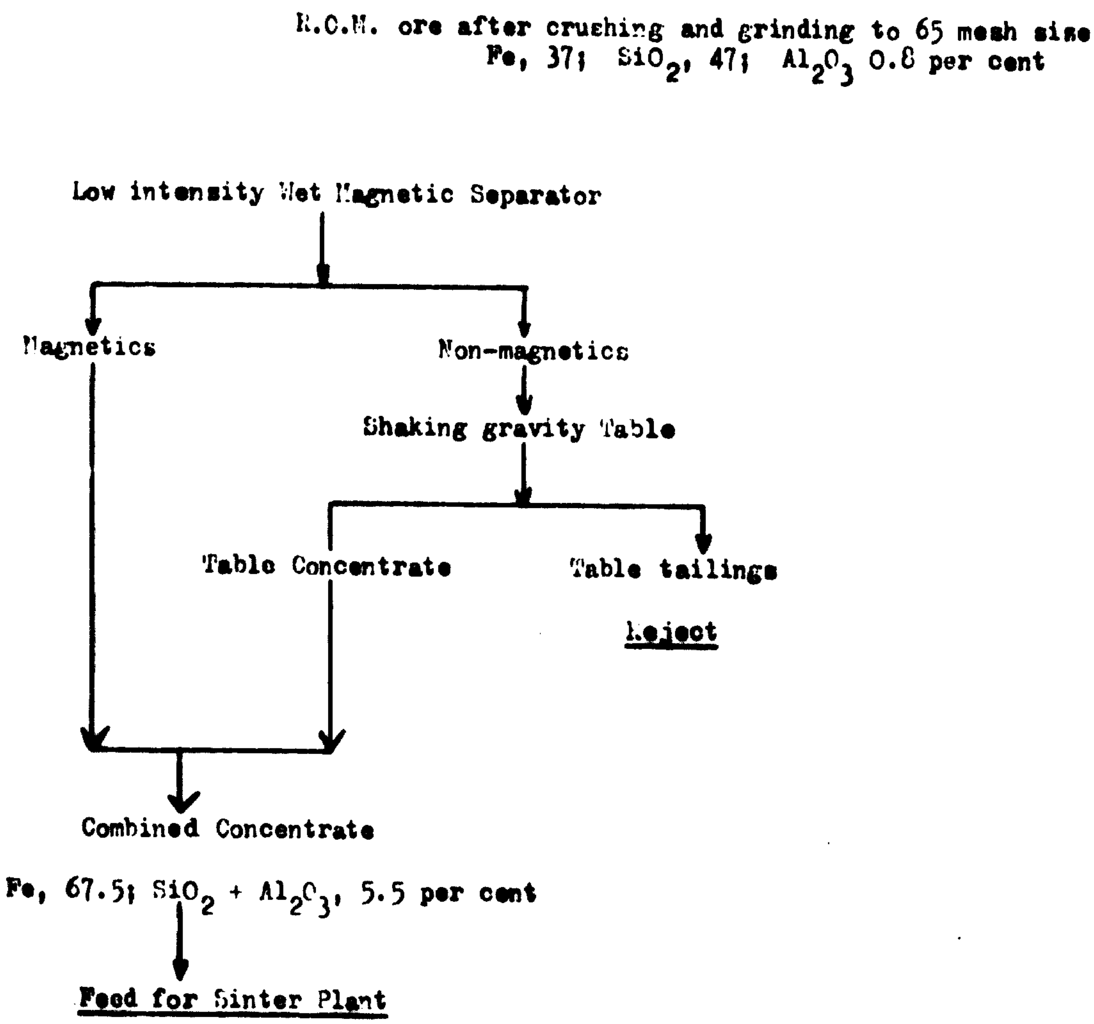


Fig. 2: Typical flowsheet for a magnetite-hematite ore from India



5. Agglomeration

Mechanized large scale mining, crushing and sizing, and subsequent beneficiation in many cases adopted to meet the ever-increasing exacting demands of iron smelters, necessarily produce large proportions of fines, sometimes up to 50 per cent by weight of the ore mined, besides the fines obtained in situ. In the case of magnetite ores, the entire concentrate quantity is in the form of fines.

These fines are utilised for ironmaking after sintering or pelletising.

5.1. Sintering

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

Earlier batch sintering machines, such as those of Greenawalt and Smidth types, were used. These have been replaced by the continuous machines of Dwight-Lloyd type, of different makes like Lurgi, MacDowell, Huntington-Heberlein.

The modern continuous sinter plants have large strand areas - 400 to 500 m^2, capable of producing 4 to 5 million tons of sinter per year. Introduction of grate-cooling systems for cooling hot sinter, have helped in raising productivity and reducing solid fuel consumption as well as maintenance costs to produce good quality, highly reoxidised, fine grained sinter.

5.2. Pelletizing

Pelletizing is resorted to where the ore particles are in very fine form either as beneficiated product or naturally occurring mineral like blue dust. The process consists of two principal steps: balling and induration. After grinding the ore, which could be either wet or dry, in open or closed circuit with the mill, dewatering and partial drying, green pellets of desired size, are made with the addition of suitable binder. Pellets can be made in drum, disc or cone types of pelletizers. The balling drum requires separate screening facilities to recirculate undersized pellets back into the balling circuit, whereas for pelletizing discs and cones, separate screening is not normally required, as sizing is done in during the balling operation and only the desired size of pellets are discharged.

Binders commonly used are bentonite, limestone and hydrated lime.

For making pellets of good quality having adequate green strength and subsequently strength of heat-hardened pellets of good reducibility, choice of type of grind, the size to which the ore should be ground and the specific surface area of the ground material, the schedule of drying and pre-heating, firing and cooling cycles, are the important parameters which should be carefully controlled.

Induration of pellets by heat/is achieved in vertical shaft furnaces, travelling horizontal grates, grate-kiln combinations and circular-grate pelletizing system. In all of these, the induration process involves drying of the green pellets, pre-heating to induration temperature, firing at the required temperation, and soaking for a definite period to create iron oxide and/or a slag bond formation between the grains, followed by regulated cooling of the product. Strict control of drying and heating cycles, is important to maintain product quality and avoid such problems as spalling, premature pellet breakage, and cluster formation.

Cold-bonded pellets: A development in recent years has been the introduction of cold induration processes. Grancold, Cobo and several other processes have been developed. Special types of cements (which do not contain sulphur) are used with the pelletizing feed before balling. The green balls, sometimes coated with iron concentrate fines to prevent cluster formation, are allowed to cure and harden for periods upto 5 weeks. 8 to 10 per cent of cement is normally required.

In case bonding is achieved by addition of lime, the green pellets after partial drying are allowed to harden at about 120°C to 150°C in a carbon dioxide atmosphere under pressure.

5.3. Cost Data

i) Iron Age Metalworking International (January and February, 1975) estimate capital costs for installation of a 5 million tons per annum pelletizing plant in Iran, to be $100 millions; and $111 millions for a 6 million tons per annum plant in Japan.

ii) Arthur D. Little Inc. estimate average pellet costs in U.S.A. to be between $16.6 and $19.3 per short ton of pellets of grade 63.8-64.8 per cent Fe. Average ore costs have been computed to be $0.2034 to 0.2688 per short ton unit contained Fe for average ore grade to be 55.4-65.8 per cent Fe.

Sinter has been costed by discounting lump ore costs by 2.0 cents per short ton unit of contained Fe. Capital investment cost for a 100 tpd sinter plant has been estimated at $100,000, and for a 1000 tpd plant, the cost will be approximately $550,000.

5.4. Pellet Production and Heat-hardening

World pellet production in various regions using different indurating systems is given in Table 3.

Table 3: Pellet Production in 1975
in million tons

	North America	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Australasia	Total
Shaft furnace	17.30	1.50	-	1.25	-	0.85	3.00	23.90
Travelling grate	37.65	10.60	21.10	7.43	-	2.00	6.70	85.48
Grate Kiln	42.25	-	-	7.50	-	2.00	9.85	61.60
Lepol furnace	-	-	-	0.45	-	-	0.30	0.75
Circular grate	-	0.75	-	-	-	-	-	0.75
Grancold	-	-	-	1.60	-	-	-	1.60
Total	97.20	12.85	21.10	18.23	-	4.85	19.85	174.08

Source: E. and S.C., Steel/GE. 3/R.3/Add. 1.

The share of the developing countries in 1975 was about 22-23 million tons produced from 14 plants located in 10 countries. The projected production for 1985 in the world would be 435 million tons, out of which the share of the developing countries would be about 165 million tons.

Data pertaining to shaft furnaces, travelling grate and grate-kiln installations of some pelletising plants, are presented in Tables 4, 5, and 6 respectively.

Table 4: GLOBAL LOCATION AND DESCRIPTION OF SOME PELLETIZING PLANTS

(a) SHAFT KILN

Plant	Company	Material type	Start up year	Capacity Mt/y.	No. of Kiln	Capacity/kiln tpd.	Kiln Geometry (M) L	W	L/W	C.S (m^2)	Sp. Capacity T/M^2 area. day.	Balling instal-lation.	Constructor
1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWEDEN:													
1. Bodas	Sandvikens Jernwerks	M	1952	0.04	1	121	1.10	1.07	1.11	1.27	95.4	D,1200 x 5000	Sala
2. Soderfors	Stora Kopper-bergs, Bergs-log AB	M	1952	0.015	1	45.5	1.62	dia		2.065	22.0	-	-
3. Falun	" "	M	1954	0.05	1	151.5	1.7	dia		2.3	71.4	D,2133 x 5000	Sala
4. Hellefors	Hellefors, Brucks	M	1953	0.015	1	45.5	2.22	dia		3.8	11.7	-	-
5. Hofors	SKS	M	1954	0.06	1	182.0	2.5	12.5	(2 shafts)	2.5	72.8	D, 975 x 5000	Sala
6. Persberg	Uddeholms AB	M(64)	1960-3	0.07	2	106	2.2	dia		3.81	27.8	D,1200 x 5000	Sala
7. Oskarshamn	Reymersholms Garula In-dustri AB	Roasted Pyrite (F,M)	1963	0.03	-	-	-	-		-	-	-	-
8. Strassa	Grangesberg	M(66)	1963-5	0.05	2	757	6	1.8	3.33	10.8	70.0	D(2)1830 x 5000	Surface Combuston
9. LKAB	Malmberget	M(66/71.5)	1955-65	0.8	4	608	6	1.8	3.33	10.8	56.11	(85) D (2)	Sala
CANADA: ONTARIO													
10. Marmora	Bethlehem Steel	M(66.5)	1955-7	0.45	4	340	4.26	1.75	2.44	7.45	45.6	(60/65) D(4),2133 x 4724	Surface Combuston
11. Hilton	Pickland Mather	M(68)	1958-60	0.90	3	910	1.83	4.27	2.4	8.64	104	(75) D-	" "
12. Moose MT	Hanna Mining	M(63/64)	1963	0.70	2	1060	4.42	2.29	1.93	10.1	105	(85/90) D	-
13. Griffith	Pickland Mather	M	1968	1.5	3	1515	6.4	2.44	2.62	15.6	97	-	-

Table 4: (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
USA:													
14. Grace, Penn.	Bethlehem Steel	M(65)	1960	1.35	5	820	4.57	1.98	3.31	9.05	90.6	(65) Cones	Surface Combustor
15. Cornwal, Penn.	"	M	1962	1.75	3	757	4.57	1.98	2.31	0.05	83.6	"	"
16. Hoytlakes, Minn.	Erie Mining Co.	M(64.1)	1956-7	10.50	27	1180	5.64	1.83	3.08	10.3	114.5	(91/92) D,2744 x 620	"
17. Pea Ridge Mo	Merramec Mining Co.	M(66/70)	1964	2.0	5	1210	4.57	1.96	2.31	9.05	133.8	D(5) 3048 x 6705	-
AUSTRALIA:													
18. Port Latta Tasmania	Savage River Mines (Pickland Mather)	M	1967	2.25	5	1200	-	-	-	-	-	-	Surface Combustor
FINLAND:													
19. Otanmaki	Otanmaki oy	M(67)	1956	0.15	2	227	2.72	dia		5.8	39.1	(85) D(2)1830 x 5000	Sala
FRANCE:													
20. Segre	Forges et Ac du Ford etole l'Est	M	1961	0.08	1	121	2.2	dia		3.82	31.6	D,1830 x 5000	"
ITALY:													
21. Ferromin	Elba	F	1955	-	1	-	2.01	dia		3.18	-	-	-
JAPAN:													
22. Chiba	Kawasaki Steel Co.	M (some F)	1959-62	1.30	17	232	-					-	Kawasaki
23. Hachinde	Nisso Steel Mfg.		1960-62	0.25	-	-				-			-
24. Tobata	Kowa Seiko	Chlorinated Roasting of Pyrite	1963	0.15	-	-					-		-

Table 4: (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
PHILIPPINES:													
25. Pellet Corp. of Phill. (Kawasaki)	Sarap	M/P	1966	0.75	3	757	-				-		A.G. McKee
YUGOSLAVIA:													
26. Skopje Macedonine Ludnici Leb-Zarnica	Zelezari Skopje	M (some H)	1968	0.15	1	455	6.1	1.2	5.06	7.3	62.2	D(2) 1830 x 3000	Sala
MOROCCO:													
27. Shaferif Nador	-	M	1972	0.85	-	-					-	-	-
USSR:													
28. Krivoi Rog		M					1.8	2.4					

Legend: M (64) = Magnetite (64% Fe)
H = Hematite
(85) D(2) = 85% -325 mesh conc. Drum, 2 nos.

Table 5: (b) TRAVELLING GRATE (CONTINUOUS GRATE OR STRAIGHT GRATE)

Plant	Company	Material type	Start up year	Capacity Mt/y.	No. of Units.	Capacity Unit tpd.	Grate Width	Size (m²) Area	Sp. capacity t/m² day	Wind boxes per grade	Balling instal-lation.	Construc-tor.
1	2	3	4	5	6	7	8	9	10	11	12	13
CANADA:												
1. Coppercliff	International Ni	M (Pyrite) (artificial) (67/68)	1956-61	0.85	1	1290	2.44	117.6	11.02	24	(75) Di(4) 5.49Ø	Lurgi/Dravo
Sundbury (Ont.)					1		2.44	160	8.063	32		
2. Colard (Ont.)	Island steel	F	1965	1.0	1	3030	3.05	229.8	13.18	38	Di(5), 5.49Ø	Dravo
3. Steep Rock (Ont.)	Steep Rock	F/G (53.4)	1967	1.0	1	3030	3.05	302	10.03	50	Di(5), 5.49Ø	Dravo
4. Wabush Mines (Que.)	Pickland Mather	Specular F(66)	1965	4.9	3	4950	3.05	229.8	21.54	38	90.0 D	Dravo
5. "	"	F	1968	1.1	-	3340					D, 3.05 x 9.45 m	Dravo
6. Carol New Foundland, Canada	Iron Ore Co.	Specular F(66) M	1963-6	9.5	4 2	- -	3.05 3.05	205.5 278.8	- -	34 46	(90) D 3.005 x 9.15 m "	Dravo "
BRAZIL:												
7. Tubarao	CVRD I	F	1969	2.0	1	12,120	3.43	278.5	43.52	27	-	-
	CVRD II	F	1973	3.0								
NETHERLANDS:												
8. Ijmuiden	Hoogovens	F,L	1970	2.5	1	7560	3.43	425.5	17.81	41	-	Lurgi/Dravo
AUSTRALIA:												
9. Dampier (W.A.)	Hammersley RST	F/L.	1968	2.0	1	6060	3.36	402.0	15.08	60	Di(6) 6.04Ø	Dravo
10. Robe River	-	L	1972	4.0								Lurgi
INDIA:												
11. Chowgule	-	F/L	1967	0.5	1	1670	2.5	109.7	15.23	-	D, 3.05 x 9.15 m	Lurgi

Table 5: (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13
USA:												
12. Silver Bay (Minn.)	Reserve Mining.	M(65.5) M	1955 1960	37.5 5.5 (10.0)	6 2	- -	1.83 2.44	94 172.2	-	28 27	(88.0; D (3) D(3)	A.G. McKee "
13. Eagle Mills (Mich.)	Cleveland Cliffs	F(64/66)	1965 1962	0.80 1.5	1	2424	1.83	125.0	19.37	28	(80.0 Di(4)	McDowel
14. Groveland (Mich.)	Hanna Mining.	F/M(60)	1963	2.0	1	5278.0	3.05	209.0	25.25	34	(75/60) D (4) 3.05 x 9.45 m	Dravo
15. Atlantic city (Wyo)	U.S. Steel	M(65)	1962	1.50	2	2272.5	1.83	94.0	21.25	32	D(6) 2.74 x 9.45 m	A.G. McKee
16. Eagle Mount (Calif.)	Kaiser Steel	F.M.	1965	2.2	1	6667	3.05	272	24.54	45	-	Dravo
17. Pilo Knob (Mo)	Hanna Mining	M	1968	1.2	1	3637	3.05	114.9	31.66	19		
18. Black River Falls (Wis) HYL	Inland Steel		1969	0.75	1							
USSR:												
19. Sokolovsk	-	M	1965-7	6.3	7	2850	-	108.8	26.2			
20. Krivoi Rog	-	M(64)	1965-9	7.4	4 2	- -	- -	108.8 306.8				
21. Krivoi Rog	-	M	1972	4.0	-	-	-	-				
22. Kachkanar	-	M(63)	1965-7	2.7	4	2046	-	6.5				
SWEDEN:												
23. Kiruna	LKAB	M	1965	1.5	1	4545	2.44	178.3	25.49	28	D(6) 2.74 x 9.15 m	Head Wrightson McKee
NORWAY:												
24. Mo-I-Rana	Norsk Jernverk	M(67)	1964	0.6	1	1830	-	146.9	12.38		D(3) 3.05 x 7.95	Simon Engg.
25. Liberia Buchanan	Lamco	P/L	1967	2.0	1	6060	3.36	3555	17.07	53	-	Dravo

Table 5: (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13
PERU:												
26. Marcona	Marcona Mining	M M	1963-6	3	2 1	-	2.44 3.05	130 238		25 44		Lurgi/ Bravo
27. hierro Peru-u	-	M,P	1963	1.2								
28. San Nicholas		M,P	1966	2.8								
CHINA:												
29. P.R.China Tech. Import		P,M	1966	1.1								
MEXICO:												
30. Hoyolata y	Lamma	M	1970	1.1	1	3340	3.05	160	18.56	20	-	McKee
31. Pena Colarada		M	1974	1.5								
32. Man Zanillo												
33. HylSA colima		M,P	1970	1.5								
ITALY:												
34. Follonica	Montecatini	M (Artificial)	1964	0.33	1	1000	1.8	30.4	19.85		-	Head Wrightson McKee

Legend: Di = Disc, D = Drum pelletiser

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

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

P = nem, M = Magnetite, L = Limonite

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

Table 6.

Plant	Company	Material type	Start up year	Capacity Mt/y.	No. of kilns	Capacity unit tpd.	Grate W	Area	Kiln dia	C. S. area	Vol.	L	L/D	Sp. Capacity, t m-3/day	Cooler oon dia	Area	Balling installation	Constructor
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
U.S.A:																		
1. Butler (Minn.)	Hanna Mining	M	1967	2.6	1	7070	4.57	144	6.1	29.4	1068	36.3	5.95	7.37	17.08	108.8	-	-
2. National (Minn.)	"	M	1969	2.8	1	8480	4.57	144	6.1	29.4	1069	36.3	5.95	7.94	17.08	108.8	-	-
3. Minntac (Minn.)	USSTEEL	M	1967	5.6	3	5720	3.66	107.2	5.64	25.0	772.5	30.9	5.48	7.05	15.25	90.7	D(2) 2.75 x 9.45 m	-
4. "	"	M	1972	6	1	-	-	-	-	-	-		-	-	-	-	-	-
5. Eveleth (Minn.)	Eveleth (Taconite)	M	1965	1.8	1	5450	3.66	107.2	5.64	25.0	772.5	30.9	5.48	7.05	15.25	90.7	D(2) 2.75 x 9.45 m	-
6. Empire (Mich.)	Cleveland Cliffs.	M(65.5)	1964-66	3.4	1 1	5130	3.66 3.66	89.3 98.3	5.18	21.15	616	29.2	5.64	8.35	12.5	68.7	(98) D	
7. Pioneer (Mich.)	"	F(natural fines.	1965	1.4	1	4240	3.66	179	4.88	18.77	530	28.7	5.88	7.88	12.5	68.7	Di(6) 5.48	
8. Republic (Mich.)	"	F(Conc) (63)	1962	2.25	2	3410	3.66	123.5	4.57	16.5	462	28	6.12	7.38	12.5	68.7	(80) D	-
9. Humboldt (Mich.)	"	F(62-5)	1960	0.8	2	1210	2.84	45.4	3.05	7.3	290	39.8	13.05	4.17	7.7	25.6	(75) D(4) 2.74 x 9.15 m	Allis Chalmers, Mc Kee
10. Keewatin	National Steel Corp.	M	1967	2.4	-	3640	belt drying furnaces (2), rotary hearth furnaces (2), Shaft Stoves (8)		-	-	-	-	-	-	-	-	D(6) 3.05 x 9.15 m	Mid-Land Ross
CANADA:																		
11. Adams (Ont.)	Jones Laughlin	M(66)	1964	1.25	1	3790	3.66	71.5	5.18	21.16	616	29.2	5.64	6.15	12.5	68.7	-	-
12. Sherman	Cleveland Cliffs.	M	1968	1.2	1	3440	3.66	62.8	4.57	16.5	462.5	28.0	6.12	7.87	12.5	68.7	-	-
13. Groh Lake	"	F	1972	6.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 6. (continued)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
JAPAN:																		
14. Kobe Steel	Fukuyama	F(natural fines)	1966	1.2	1	3640	3.66	125.4	5.18	21.15	61.6	29.2	5.64	5.9	12.5	87.4	-	-
15. "	Kakogawa	"	1970	3.0	1	9100	4.87	278.5	6.61	34.4	1560	45.9	6.98	5.75	17.08	108.8	-	-
16. Hirohata	-	Mixed ore	1972	2.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SWEDEN:																		
17. LKAB	Svappavaara	M	1969	1.8	1	5450	4.57	144	6.1	29.4	1068	36.3	5.95	5.1	17.08	108.8	-	-
NORWAY:																		
18. Sydvaranger	-	M	1969	1.2	1	3640	3.66	71.5	4.83	18.77	538	28.7	5.88	6.76	12.5	68.7	-	-
AUSTRALIA:																		
19. Broken Hill	-	F(natural fines)	1968	1.8	1	5450	3.66	160.3	5.64	25.0	764	30.6	5.43	7.15	16.25	90.7	-	-
LIBERIA:																		
20. Bong Range	-	M/F	1971	2.0	1	6060	4.57	155.6	6.1	29.4	1068	36.3	5.95	5.67	17.08	108.8	-	-
INDIA:																		
21. Noamundi	TISCO	F	1972	0.9	-	-	-	-		-	-	-	-	-	-	-	-	-
BELGIUM:																		
22. Clabecq	-	Mixed ore	1970	2.0	-	-	-	-		-	-	-	-	-	-	-	-	-

Sinter vs. Pellet

It is well known that pellets are usually produced near the source of iron ore and sinter is made at the smelting plant. Sinter production permits a much larger part of the added values to be credited to the country where the ore is processed into iron and steel than does pellet manufacture. This extra benefit usually favours the iron- and steelmaker, who therefore has a good reason for bias toward the use of sinter over pellets.

Technically, a good quality self- or superfluxed sinter having adequate strength and close-sizing, possesses same of sometimes, even superior metallurgical, physical and chemical properties to that of oxidized pellets. The choice of sinter or pellets as a burden material in similar circumstances, is usually a matter of personal preference, within constraints over which the operator has little control. Besides this, the choice is also dictated by the local conditions and characteristics of the ore.

Pellets are largely preferred in North America with a view to utilizing huge deposits of taconite. The concentrates produced are in finely divided state and are excellent feed material for pelletizing.

Japan imports huge quantities of high grade lumpy ore and fines. The fines are sintered and used in blast furnaces. However, captive pelletizing plants are being put up by Kobe Steels at their Kakagawa and Nadahama works based on imported fines and concentrates. This is reported to be mainly to avoid pollution problems about which there are stringent pollution control regulations.

Physical Form of Iron Ore Consumption

World Production ratios of sinter-pellets and pig iron as shown in Table 7 below, indicate the enormous efforts being made to improve the burden preparation.

Table 7: Relation between production of sinter/pellets and pig iron.

Country	1960 Sinter and Pellet/Pig Iron	1975 Sinter and Pellet/Pig Iron
Federal Republic of Germany	0.779	1.202
Austria	1.127	1.450
Belgium	0.337	1.130
Canada	0.774	1.380
United States	0.777	1.246
France	0.448	1.699
Hungary	-	1.996
Italy	0.788	1.270
Japan	0.670	1.309
Luxembourg	-	2.207
Netherlands	0.733	1.004
Poland	1.292	1.281
United Kingdom	0.398	1.139
U.S.S.R.	-	1.732

Source: U.N. and E.C. - Steel/GE. 3/R.3/Add. 1.

Table 8 shows the changing pattern of iron ore requirement. It may be seen that the proportion of sinter feed in the iron ore demand has generally remained unaltered, whereas the share lost by lumpy ore, is gained by pellets.

Table 8: Changing pattern of Iron Ore Requirement

(in per cent)

Type of Feed	1965	1970	1980	1985
Lumpy ore	39.4	33.4	22.0	20.0
Sinter feed	53.0	50.3	48.0	48.0
Pellet	7.6	16.3	30.0	32.0
	100.0	100.0	100.0	100.0

Source: Agglomeration "77".

Fig. 3 shows the growth pattern of consumption of lumpy ore, sinter and pellets in different regions of the world. It may be seen that sinter consumption predominates in Eastern and Western Europe, and in Japan. In the United States and Canada, the pattern was similar until the early 1960's, when pellets became the preferred iron burden material. In Latin America, lumpy ores are still the principal burden material, but sinter consumption is also steadily rising.

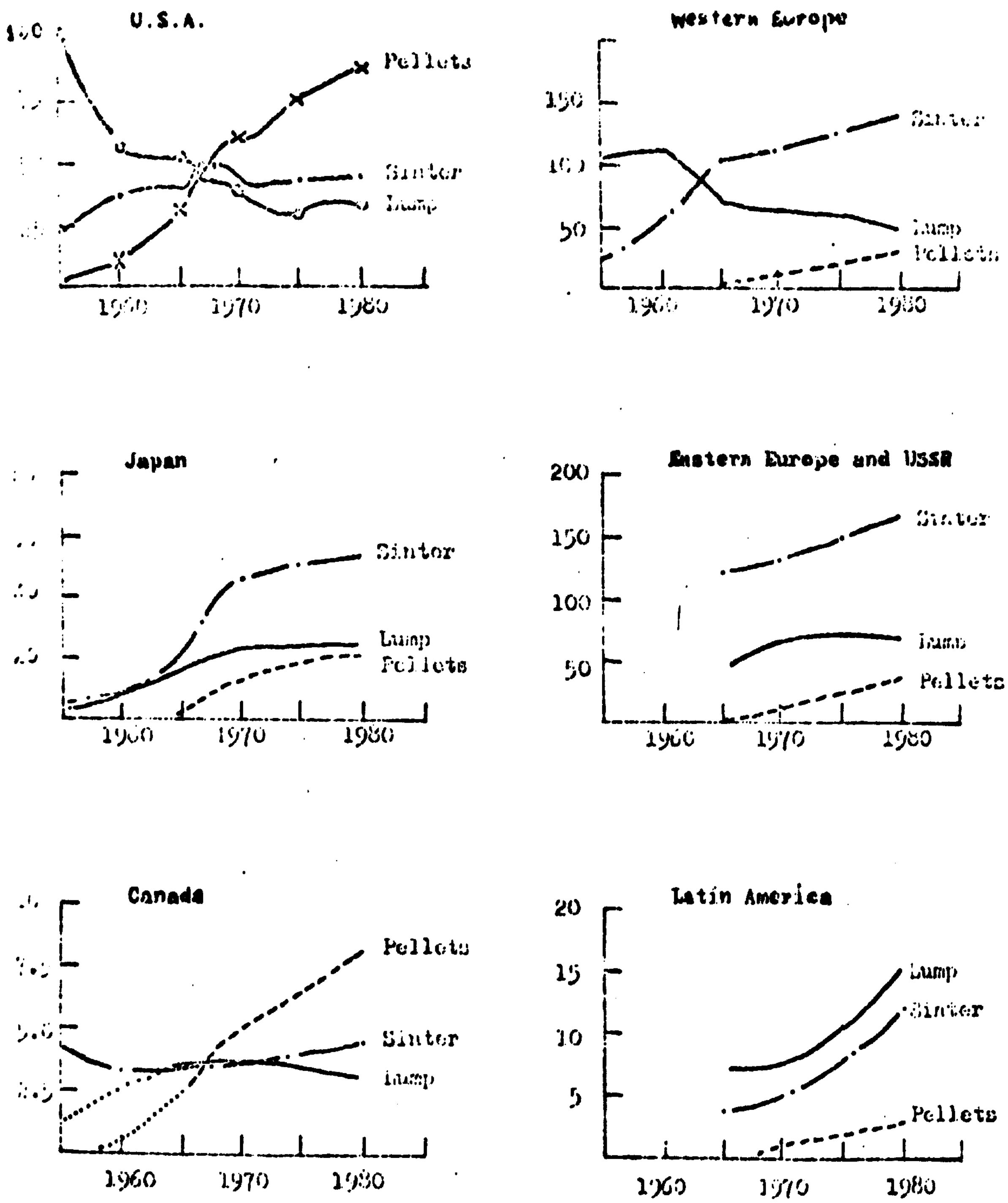


Figure 3 - Projection of iron-ore consumption tonnages by physical form (in million metric tons)

Source: Jack R. Miller - 3rd Interregional Symposium on Iron and Steel Industry, 1973; Brazil.

TECHNOLOGICAL PROFILE

ON

IRON MAKING

CONTENTS

1. Introduotion:

Pig iron is the intermediate form through which almost all iron must pass in the manufacture of steel. In addition to this, it is used in foundries for the manufacture of a wide variety of iron castings.

Most iron ores may be used to produce pig iron. In current iron making practice, the definition "iron ore" is applied to any iron-bearing material that can economically be used at a particular time and place for the manufacture of pig iron.

All the constituents in the ore that are undesired in iron making, are impurities. However, the mineralogy of iron ores often does not lend itself to the ready removal of many such impurities by known ore-treatments methods. It is therefore necessary to determine the nature and amount of impurities and accordingly to control the composition of the iron ores in the smelting furnace. The wide differences in structure and mineral content of ores from different deposits are responsible for the considerable variation in the beneficiation methods that have been developed to remove or to limit the impurities. However, some impurities, notably silica, alumina and lime, play important positive roles in scavenging other impurities from molten iron. Nevertheless, the ironmaker would prefer to use highgrade ores containing a minimum of these scavengers and to add them only as needed, in controlled amounts, or to blend ores containing known amounts of different impurities.

2. Influence of burden constituents:

Iron Ores:

I) Iron compounds: The iron content of ores that are used in blast furnaces varies widely from about 30% up to 71%. Hematites are easier to reduce in iron smelting than magnetites, in spite of the greater amount of oxygen combined with the iron in hematites. Ores with a high content of iron silicate minerals have a low degree of oxidation and are difficult to reduce in the blast furnace. Goethites and carbonate ores contain combined water and carbon dioxide which are removed in the upper part of the blast furnaoe.

In order to obtain low fuel consumption in the blast furnace, the ore should have a high iron content so that a smaller amount of slag is formed.

II) Silica: Silica is ore of the most important gangue mineral in an iron ore. Together with alumina, it is a main constituent of an aoid slag during the smelting operation. The amount of silica permissible in the ore is determined by the proper slag volume, which in turn, is determined primarily by the sulphur in the charge and, secondarily, by the necessity of having a slag fluid enough to recover the molten iron.

A decrease of about 1.5% in the silica content of the ore will produce a drop in slag volume of about 65 kg per ton of pig iron. It has been estimated that an inorease of 100 kg in the amount of slag per ton of pig iron, raises fuel consumption by about 40 kg of coke per ton of pig iron.

III) Alumina: The alumina content of the slag of a coke blast furnace should not be too low. About 10 - 15 per cent of alumina increases the fluidity of basic blast furnace slags and thus makes it possible to use a higher basicity which facilitates the removal of sulphur.

If the ore is high in alumina, its content in slag may be as high as 25 - 30 per cent. Such a slag requires a high temperature in the furnace to get the right fluidity, and produce high-silicon pig iron for foundry and Bessemer process as in Indian practice.

If slags contain 40 - 45 per cent alumina, then these can be used for cement or aluminium industries.

In case alumina content of the slag is low, desulphurization is not quite effective, which could be offset to some extent by raising the magnesia content.

IV) Lime: Lime is a dominant constituent of a basic slag. Its function is to form a fluid slag with coke ash, ore gangue and other burden impurities.

V) Magnesia: Magnesia, the other dominant constituent of slags, helps in reducing the viscosity of slag due to high alumina content. Dolomite is generally used in blast furnaces along with limestone.

VI) Manganese oxides: Most of manganese, if present in the ore, passes into the pig iron, and subsequently, a portion of this finds its way into the final steel.

VII) Phosphorus: Almost all phosphorus present in the burden will pass directly through the blast furnace and enter the pig iron. A high phosphorus content is a drawback, as extra lime is required for its elimination; thus slag volume and fuel consumption are increased and steel output decreased consequently.

VIII) Sulphur: Sulphur is contributed not only by iron ore but also by limestone and the coke used in the burden. Excepting a small percentage of sulphur which goes out as gas, it is divided between the slag and metal. Satisfactory removal of sulphur requires a basic slag low in iron, a high temperature and a large quantity of slag. The extent of sulphur removal, therefore, depends upon the temperature of the hearth and the ratio of basic oxides of lime and magnesia to the acid oxides of silica and alumina. High silicon in the pig iron is favourable, and a high manganese content is also regarded as an advantage.

IX) Titanium: In blast furnace smelting, most of the titanium oxide remains unreduced in the slag. It is a strongly carbide forming element, and the titanium carbide has a low solubility in molten pig iron. High titanium content give rise to blast furnace operating difficulties. However, in electric smelting, the operating difficulties are not many and so higher amounts of titanium can be tolerated.

X) Vanadium: About 70 - 90 per cent of vanadium present in iron ore passes into the pig iron. If the metal is not high in silicon or titanium, a large quantity of the contained vanadium can be oxidized quickly when refined by the Bessemer practice. A vanadium-rich slag is poured off for the production of ferro-vanadium, an important metallurgical agent.

XI) Zinc: If zinc content increases beyond 0.2 per cent, operating difficulties begin to appear.

XII) Copper: The entire amount of copper present in the burden, will pass into pig iron and ultimately into steel. Small percentages of copper in steel increases its corrosion resistance. But if its content increase beyond 0.3 to 0.4 per cent, rolling difficulties are encountered.

XIII) Chromium: Chromium content in pig iron is an advantage used for alloy steels. For ordinary steels, its presence is mainly a disadvantage.

XIV) Nickel: The entire amount of nickel will go into pig iron from which it cannot be removed by oxidation during steel making process. In some special cases, small amounts of nickel in steel may be of advantage in improving mechanical properties. But in most instances, its presence is undesirable.

XV) Arsenic: An excess of arsenic causes cold brittleness in steel produced from pig iron containing arsenic. However, upto 0.15 to 0.25 per cent, is acceptable in ordinary steels, and upto 0.05 to 0.10 per cent in steels for temper hardening.

XVI) Lead: Lead is rare in iron ores. It does not enter pig iron but damages refractory lining by penetrating into it.

XVII) Tin: The entire amount of tin present in the ore goes into pig iron and thence into steel. Even in relatively low amounts, it is harmful in steels in damaging the deep drawing properties and also causes brittleness. The steels should not contain more than 0.05 per cent of tin.

3. World Iron Ore Production:

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

Table 1 : World Iron Ore Production

Country	In million tons			
	1973	1974	1975	1976*
Algeria	3.130	3.792	3.300	3.200
Angola	6.048	4.980	3.360	3.300
Australia	83.568	96.688	97.365	92.400
Austria	4.211	4.246	3.833	3.784
Belgium	0.116	0.123	0.093	0.063
Brazil	55.019	79.973	88.493	70.000
Bulgaria	2.774	2.684	2.337	2.300
Canada	48.200	47.271	44.745	56.000
Chile	9.650	10.297	11.070	10.500
China	50.000	51.000	51.000	50.000
Colombia	0.442	0.500	0.623	0.600
Czechoslovakia	1.672	1.688	1.773	1.850
Denmark	0.012	0.006	-	-
Egypt	3.130	3.792	3.300	3.200
Finland	0.885	0.934	0.766	0.700
France	54.754	54.730	50.142	45.543
East Germany	0.520	0.250	0.590	0.500
West Germany	6.429	5.670	4.273	3.034
Greece	1.842	2.001	1.965	2.154
Guinea	-	-	-	-
Hungary	0.681	0.595	0.386	0.631
Hongkong	0.151	0.160	0.161	0.037
India	34.426	34.230	40.271	41.400
Iran	0.600	0.620	0.650	0.650
Italy	0.675	0.795	0.739	0.643
Japan	1.007	0.780	0.942	0.800
North Korea	8.100	8.100	8.200	6.100
South Korea	0.467	0.493	0.525	0.500
Liberia	34.620	36.000	36.500	35.000
Luxembourg	3.782	2.686	2.315	2.079
Malaysia	0.516	0.468	0.349	0.300
Mauritania	10.416	11.110	8.500	8.000
Mexico	5.736	4.902	4.621	3.500
Morocco	0.376	0.534	0.554	0.350
Netherland	-	-	-	-
Norway	3.970	3.918	4.064	4.291
Peru	8.964	9.563	7.753	7.000
Philippines	2.256	1.616	1.352	1.150
Poland	1.413	1.296	1.192	1.100
Portugal	0.057	0.024	0.045	0.043
Rhodesia	0.550	0.550	0.600	0.600
Romania	3.234	3.205	3.065	2.300
Sierra Leone	2.400	2.508	2.500	2.400
South Africa	10.955	11.734	11.191	15.684
Spain	6.901	8.613	8.617	7.700

Table 1 : continued - World Iron Ore Production

Country	In million tons			
	1973	1974	1975	1976*
Sudan	-	-	-	-
Swaziland	2.148	2.055	2.232	1.932
Sweden	34.727	36.153	30.867	30.526
Switzerland	-	-	-	-
Thailand	0.036	0.036	0.032	0.020
Tunisia	0.811	0.820	0.652	0.500
Turkey	1.861	1.531	1.990	1.000
U.K.	7.105	3.602	4.490	4.583
U.S.A.	88.800	85.917	81.351	81.200
U.S.S.R.	216.104	224.883	232.803	239.000
Venezuela	22.880	26.408	24.104	23.000
Yugoslavia	4.670	5.034	5.239	4.265
WORLD	851.200	899.100	895.700	875.300

*Estimated or provisional

Source: Metal Bulletin - Sept. 6, 1977

Table 2 : World Iron Ore Total and Potential Reserves

Country	P	M	G	S	PM	PC	GS	PS	MP	MS	PMP	MSP	MC	SP	PMG	PMS	Not classified and others
U.S.S.R.	29,025 (20,875)	38,325 (21,648)	106,363 (13,894)	1,258 (1,195)	36,255 (29,421)		522 (447)	9,316 (9,316)								300	82,937 (13,687)
Australia New Zealand Caledonia	(1,630)	(660)	(5,951)		(35)	(7,953)		(322)	(144)		(2)						
U.S.A.	3,561 (396)	12,969 (785)	907 (745)		65,555 (3,227)	6,139 (2,267)	343 (343)	50					313 (113)		1,742 (272)	10,254 (4)	3; PGS 30 (30); PMGS (3); 4428 (28); others 2 (2)
Canada, West Indies and Dominican Republic	12,235 (2,025)	32,411 (8,164)	(1)		55,875 (20,898)	8,370 (4,320)		600	20 (10)	1,000		1,675 (40)		735 (420)		6,020 (20)	1500; P (38); PI 1350 (350); PMI 320; PC 2000; PMG 25; GSC 1500
Middle East and Far East (incl. India)	19,427 (8,310)	7,751 (2,673)	3,206 (655)	41	12,824 (4,296)	566 (317)	2,545 (508)	129 (29)					4 (2)		275 (108)		24,3[illegible]; GSC (450) (88)
Africa	17,056 (2,405)	2,718 (373)	1,297 (262)	6 (6)	4,254 (603)	1,358 (27)	92 (20)	168 (168)		55 (15)	41 (41)		46 (46)		1,419 (1,250)	1,427 (432)	42; P 17; PPI (1); (42); PSI 279 (28); PMC 1000 [illegible]
South America	84,869 (32,262)	788 (251)	1,948 (301)		2,610 (411)	2,304 (929)							8				
Europe	777 (457)	3,122 (3,103)	1,264 (794)	1,900 (1,680)	2,498 (1,278)	839 (139)	9,460 (4,840)	775 (675)	50 (10)	50 (50)					440 (100)	2,240 (2,120)	1110; MT 50 (50); GC 5148 ([illegible]); (10); SC 10 (2); PSC 50 (30); [illegible] 680 (230); GSC 1853 (1048); PG[illegible] [illegible] (1640); PGS 38 (38)
Sweden		2,895			475												

Legend : 1) P - Hematite; M = Magnetite; G = Goethite; S = Siderite;
P = Pyrite; C = Chamosite; I = Ilmenite;

2) Figures without bracket indicate total reserves in million tons and those within bracket show potential reserves in million tons.

4. Coke:

Coke for blast furnace consumption must be sufficiently firm and strong to resist shattering by handling, and crushing by pressure exerted by the heavy blast furnace-burden. It should be free of dust and fines, and in pieces not too large for optimum speed of combustion.

With a good coking coal, these physical properties can be controlled only moderately by the coking process. As the coal is heated, it becomes plastic at 350° to 475°C, forming a fused mass irrespective of its form when charged into the retort. As bituminous coal is heated through this range of temperature, volatile matter is given off, rapidly at first, then slowly up to about 950°C. The coals making up a blend, so far as possible, should have about the same plastic range. Slow heating through the plastic range increases slightly the hardness of the coke. The size of the lumps of coke depends largely upon the thickness of the coal charge and whether or not it is heated from one or both sides.

As to the chemical composition, a good metallurgical coke will contain very little volatile matter - not over 2 per cent - and 85 to 90 per cent fixed carbon. The remainder is ash, sulphur and phosphorus. The phosphorus content, 0.018 to 0.040 per cent for making Bessemer iron, preferably should be low also for basic iron. Sulphur varies from 0.6 to 1.5 per cent, but is desired as low as possible because coke is the chief source of sulphur in the pig iron produced. Standard specifications for foundry coke call for a volatile matter content of 2 per cent, a maximum sulphur of 1 per cent, a maximum moisture of 3 per cent, and a minimum fixed carbon of 86 per cent.

Shatter and tumbler tests are also specified, but no standard for combustibility has been adopted. These requirements are controlled through selection of the coal, which should be low in sulphur, free from slate or removable refuse, and give and ash which has a moderably high fusion point in a reducing atmosphere.

There are three principal kinds of coke, classified according to the methods by which they are manufactured : low, medium and high temperature coke. All the coke used for metallurgical purposes must be processed in the high ranges of temperature if the product is to have satisfactory physical properties.

The most desirable blast furnace coke is made from mixtures of high-volatile and low-volatile coals, pulverized and blended and then coked in ovens capable heating the mass to an uniformly high temperature.

Manufacture of metallurgical coke:

There are basically two methods for manufacturing metallurgical coke, known as the (i) Beehive process and the (ii) By-product or Retort process.

(i) In the beehive process, air is admitted to the coking chamber in controlled amounts for the purpose of burning therein the volatile products distilled from the coal to generate heat for further distillation.

(ii) In the modern by-product method, air is excluded from the coking chambers, and the necessary heat for distillation is supplied from external combustion of some of the gas recovered from the coking process. The temperatur f coking is somewhat lower than in the beehive ovens. Besides metallurgical coke, coke breese, coke-oven gas, tar, ammonium sulphate, ammonia liquor and light oil, are the principal by-products. Refining of tar and light oil, yield a large variety of products such as benzene, naphtalene, pyrene, phenol, pyridine, etc., etc.

In order to reduce environmental polution, extensive successful studies have been made in U.S.S.R. on dry quenching of hot coke instead of wet quenching.

The world reserves of coking coals are given in Table 3.

Table 3 : World Coking Coal Reserves

A. Estimate by Shell Oil

Country	In billion tons	
	Hard Coking Coal	Soft Coking Coal
U.S.S.R.	166	107
U.S.A.	128	60
China	101	-
Europe	41	38
Oceania	14	11
Africa	12	-
India	11	1
Japan	1	-
South America	-	1
Rest of the regions	12	1
Total	476	219

B. Estimate by Dasturco

Country	In billion tons
Latin America	
Brasil	0.15
Mexico	0.21
Chile	0.07
Colombia	2.10
Asia	
China	9.50
India	10.077
Taiwan	0.07
Rest of the regions	407.565
Total	429.732

About 90 per oent of the total world reserve of ooking, exist in relatively a few locations in the world, mainly in the developed countries. Developing oountries, other than China, aocount only for some 2.3 to 2.5 per oent of the total world reserves.

The estimates of ooking ooal requirements in the world are given in Table 4. The figures foroast have taken into account the eoonomy of coke being effeoted by improved smelting teohnologies, like oil and pulverized ooal injection, oxygen enriohment of the blast, use of pre-reduoed ore, cto.

The figures are from a paper presented by Jaok Miller during UNIDO's Third Inter-regional Symposium on Iron and Steel Industry, held in Brazil in October 1973.

Table 4 : Estimate of Coking Coal Requirements

in million tons

Region	1975				1980				1985			
	No PR		With PR		No PR		With PR		No PR		With PR	
	for BF	Total	for BF	Total	for BF	Total	for BF	Total	for BF	Total	for BF	Total
North America	75.7	85.1	67.0	75.4	76.9	86.4	70.1	76.9	78.8	88.2	66.3	74.7
Latin America	16.3	17.8	15.2	16.5	24.0	26.2	20.2	21.9	24.3	26.8	19.3	21.2
Western Europe	89.4	129.5	83.5	121.0	107.0	147.0	91.0	125.4	111.0	144.5	87.3	113.6
Eastern Europe	94.6	132.8	85.8	119.8	108.8	117.1	92.4	123.6	117.1	145.8	89.5	112.0
Asia	75.0	94.3	67.6	85.4	79.8	91.5	69.9	80.3	87.5	108.9	66.2	96.4
Africa + Mid. East	5.6	6.6	5.4	6.5	7.4	8.7	6.9	8.1	9.4	10.9	7.2	8.4
Oceania	10.3	12.0	9.8	11.5	15.6	18.3	12.7	14.9	17.4	20.2	12.7	14.4
World	366.9	478.1	334.3	436.1	419.5	495.2	363.2	451.1	445.5	545.3	348.5	440.7

Legend : PR = Pre-reduction
BF = Blast Furnace

Coke production figures for some of the countries during 1974 are given in Table 5.

Table 5 : Coke Production

In million tons

Country	1974
Argentina	0.660
Australia	4.916
Austria	1.733
Belgium	8.050
Brasil	1.850
Bulgaria	1.308
Canada	5.233
Chile	0.315
China	28.000
Colombia	0.510
Czechoslovakia	10.898
Egypt	0.360
Finland	0.080
France	12.282
German Dem. Rep.	1.829
Federal Rep. of Germany	34.854
Greece	0.372
Hungary	0.766
India	8.199
Iran	0.065
Italy	8.566
Japan	45.632
Korea Dem. P. Rep.	2.300
Mexico	2.071
Netherlands	2.687
New Zealand	-
Norway	0.315
Peru	0.012
Poland	16.929
Portugal	0.196
Romania	1.525
South Africa	3.600
Southern Rhodesia	0.255
Spain	4.243
Sweden	0.481
Turkey	1.241
U.S.S.R.	82.641
U.K.	15.776
U.S.A.	60.487
Yugoslavia	1.323
World	372.750

5. **Formed Coke:**

Attempts to develop new processes for the manufacture of artificial solid fuel suitable for metallurgical use, have been mainly inspired by the desire to use otherwise unsuitable coal-base materials, and world-wide shortage of good coking coal. Experiments have been made for the development of a new coking process aimed at obtaining a solid product similar to metallurgical coke by means of blends partially or entirely made up of non-coking coals and named as "formed coke". Although many processes have been developed throughout the world, the majority of installed plants are based on two main processes:

a) degassification and transformation of the coal into semi-coke to be briquetted with the aid of a binder; and

b) hot briquetting of coal followed by distillation in special furnaces.

The main advantages that can be achieved with this new technology are:

i) enlargement of the quality range of the coals to be used

ii) better uniformity in coke size

iii) extensive automation in the operating plants

iv) better control of pollution problems,

v) continuity in the coking process from coal preparation up to the final product.

It is well known that one of the main conditions for lowering the coke rate and increasing productivity of the blast furnace, is a satisfactory permeability of the burden. The "formed coke", with its well balanced briquettes, is certainly more suitable than the conventional coke for this purpose.

Table 6 shows formed coke installations, experimental pilot plant scale as well as on commercial scale.

Table 6 : Formed Coke Operational Processes

Process	Country	Plant type	Output tons/year	End Product	Temperature range °C
1. Midland Coal Products	U.K.	Commercial	50,000	Domestic boiler fuel	900°
2. Caumore	Canada	Commercial	30,000	Metallurgical+Chemical	900°
3. Balfour	U.K.	Pilot	50,000	Smokeless domestic briquettes	700° - 900°
4. Otto	Germany	Pilot	1,000	Smokeless fuel	700° - 900°
5. Humphreys and Glasgow	Australia	Commercial	60,000	Metallurgical foundry coke	800°
6. Lurgi Spulgas	India+others	Commercial	380,000	Smokeless domestic briquettes	800° max
7. Phurnacite	U.K.	Commercial	1 mill.	Smokeless domestic briquettes	600° - 900°
8. National Fuel Corporation	U.S.A.	Pilot	35,000	Metallurgical	850°
9. H.B.N.P.D.C. (Soubrier)	France	Pilot		Metallurgical	850°
10. Iniex	Belgium	Pilot	40,000	Metallurgical	600° - 900°
11. Broken Hill Proprietary	Australia	Pilot	40,000	Metallurgical	550° - 900°
12. Schenok/ Wenzel/ Peabody	Germany/ USA	Pilot		Metallurgical and Chemical	600° - 900°
13. Food Machinery Corp.	U.S.A.	Commercial	70,000	Metallurgical	1000°

Table 6 : continued - Formed Coke Operational Processes

Process	Country	Plant type	Output tons/year	End Product	Temperature range °C
14. Lurgi	Germany	Pilot		Metallurgical	850°
15. B.W.V.	Germany	Semi-commercial	36,000	Cupola Coke	900°
16. Sapoznikow	U.S.S.R.	Commercial	140,000	Metallurgical	1000°
17. Bergbau Forschung Lurgi/BMV	Germany	Pilot	42,000	Metallurgical	500°
18. D.S.M.	Holland	Commercial	40 - 80,000	Smokeless domestic	600°
19. ChPW	Poland	Commercial	220,000	Cupola Coke	700°
20. Suncole	U.K.	Commercial	160,000	Domestic	600°
21. Consolidated Coke Co.	U.S.A.			Metallurgical	950°
22. BMV (Bergwerksverband)	Germany	Pilot	40,000	Domestic	650°

Source : Conti and Sacerdote - 3rd Interregional Symposium on Iron and Steel Industry, Brazil 1973.

6. Charocal;

Wherever oonditions are favourable, charcoal is used in smaller size blast furnace in place of coke. Since charoocal is virtually ash free compared with coke, one of the features of the operation is the extremely low slag volume produoed. It is unnecessary to use hign grade limestone beoause silioa must be added to the burden to make up minimum slag volume. This oan be obtained by the use of low grade high silica limestones.

Slag volume vary between 150 and 200 kg per ton, and all slag is tapped with the iron. Slag basicity is usually within the range 0.9 - 1.0 but sulphur oan be kept at 0.02 per oent maximum despite low volume. The charcoal produced is screened to +4mm before being charged to the furnace. The screen undersize after pulverization is injected though the tuyeres of the furnaoe.

Charcoal is highly reactive, but it is not strong and oannot withstand the abrasion of the oharge in a blast furnace of the usual height. It can therefore be satisfaotorily used in a shorter and smaller furnaoe of oapacity, say, upto 400 - 500 tons per day. With a well prepared burden of sinter or pellets, a ooke rate of 750 kg/ton iron should be possible. However, suoh a furnace would need stoves capable of heating the blast up to 1100°C.

As mentioned above, charcoal for iron smelting in relatively small blast furnaoes, is being used in several developing countries whioh have a good forest wealth and a forestation programme. In Brazil, about 3 million tons of pig iron is smelted in small blast furnaces using charcoal as the reduotant and for heat input. In western Australia at Wundowie, an iron smelting blast furnace using oharooal has been in operation for more than two decades. In India, the Viseshwaria Iron and Steel works at Bhadravati, has an operating oharcoal blast furnaoe for the past several years. In Malaysia, at the plant at Malayawata Steel, iron smelting has been successfully in operation for the last several years using charcoal made from rubber wood.

7. Crude Petroleum:

Reserves and production of crude petroleum for some of the countries is given in Table 7.

Table 7 : Reserves and Production -Crude Petroleum

Country	Reserves in million tons	Production in 1974 in million tons
Albania	10	2.2
Algeria	1,158	48.66
Angola	199	8.7
Argentina	344	21.139
Australia	336	19.595
Austria	25	2.238
Bahrain	34	3.363
Bolivia	27	2.112
Brazil	102	8.442
Brunei	267	9.284
Bulgaria	2	0.144
Burma	17	0.888
Canada	965	80.261
Chile	27	1.311
China	2,024	65.000
Colombia	89	8.686
Congo	127	2.455
Cuba	-	0.140
Czechoslovakia	3	0.149
Denmark	39	0.086
Ecuador	198	8.999
Egypt	386	7.472
France	11	1.080
Gabon	90	10.202
German Dem. Rep.	2	0.75
Germany, Fed. Rep. of	69	6.191
Greece	82	-
Hungary	29	1.997
India	122	7.490
Indonesia	1,614	67.979
Iran	9,315	300.852
Iraq	4,724	96.940
Israel	-	6.040
Italy	83	1.024
Japan	10	0.672
Kuwait	10,469	128.101
Libyan Arab Rep.	3,039	73.364
Malaysia	352	3.844
Mexico	433	29.560

Table 7 : continued (Reserves and Production - Crude Petroleum)

Country	Reserves in million tons	Production in 1974 in million tons
Morocco	-	0.024
Netherlands	44	1.461
New Zealand	26	0.163
Nigeria	2,655	111.578
Norway	739	1.706
Oman	450	14.488
Pakistan	4	0.432
Peru	112	3.756
Poland	6	0.550
Qatar	720	25.059
Romania	174	14.486
Saudi Arabia	14,780	421.397
Spain	14	1.982
Syrian Arab Rep.	402	6.426
Thailand	-	0.10
Trinidad and Tobago	92	9.641
Tunisia	69	4.139
Turkey	17	3.430
U.S.S.R.	6,607	458.948
United Arab Emirates	3,397	81.071
U.K.	1,641	0.87
U.S.A.	4,629	432.794
Venezuela	2,090	155.803
Yugoslavia	44	3.458
World	75,530	2,792.080

8. <u>Natural Gas:</u>

Reserves of natural gas and its production in 1974 are given in Table 8.

Table 8 : Reserves and Production of Natural Gas in 1974

Country	Reserves in thousand million cu.m.	Production in million cu.m.
Afghanistan	-	3,200
Albania	12	150
Algeria	2,837	5,621
Angola	50	-
Argentina	201	7,242
Australia	747	4,360
Austria	14	2,206
Bahrain	51	2,036
Bangladesh	-	850
Barbados	-	2
Belgium	-	63
Bolivia	132	1,735
Brazil	26	498
Brunei	193	5,000
Bulgaria	14	180
Burma	8	20
Canada	1,606	73,367
Chile	73	3,400
China	481	3,000
Colombia	43	1,700
Congo	179	19
Cuba	-	19
Czechoslovakia	13	669
Denmark	20	-
Ecuador	116	10
Egypt	142	60
France	155	7,628
Gabon	50	46
German Dem. Rep.	96	7,732
Germany, Fed. Rep. of	354	19,826
Greece	11	-
Hungary	86	5,094
India	68	717
Indonesia	425	5,732
Iran	10,602	22,126
Iraq	778	1,300
Israel	1	66
Italy	245	15,273
Japan	38	2,572
Kuwait	1,080	5,300
Libyan Arab Rep.	800	2,800

Table 8 : continued (Reserves and Production of Natural Gas)

Country	Reserves in thousand million cu.m.	Production in million cu.m.
Malaysia	323	-
Mexico	317	13,950
Morocco	-	59
Netherlands	2,180	83,703
New Zealand	168	303
Nigeria	1,423	574
Norway	549	-
Oman	68	-
Pakistan	439	4,600
Peru	37	530
Poland	136	5,528
Qatar	221	1,050
Romania	193	28,643
Rwanda	-	1
Saudi Arabia	1,726	3,200
Spain	11	1
Syrian Arab Rep.	76	180
Trinidad and Tobago	92	1,418
Tunisia	82	201
Turkey	1	-
U.S.S.R.	19,816	260,553
United Arab Emirates	768	1,800
U.K.	850	34,718
U.S.A.	6,715	586,531
Venezuela	1,215	11,633
Yugoslavia	42	1,447
World	59,195	1,255,250

9. Fluxes:

Limestone and/or dolomite are used as fluxes. The functions of these fluxes are :

i) to form a fluid slag with the coke ash, ore gangue, and any other charged impurities, and
ii) to form a slag of such chemical composition that it will provide a degree of control of the sulphur content of the pig iron.

Selection of the proper flux for a given process is chiefly a chemical problem requiring a knowledge of the composition and properties of all materials entering the process.

Almost all of the slag-forming compounds that enter into a smelting or refining process may be classed as either 'acids' or 'bases' by virtue of the fact that they will react with each other to form compounds which are similar to the salts formed in reactions taking place in water solutions. Since one of the functions of a flux is to react chemically with unwanted impurities to form a fusible slag, it will naturally follow that to remove 'basic' impurities, an acid flux will be required and to remove 'acid' components, a 'base' will be used as the flux.

i) Acid fluxes: Silica (SiO_2) is the only substance that is used as a strictly acid flux. For this purpose it is available as sand, gravel and quartz and also as siliceous iron-bearing minerals.
ii) Basic fluxes: The chief natural basic fluxes are limestone and dolomite ($CaCO_3$ and $Ca.Mg.CO_3$ respectively). Either dolomite or limestone may be used as a blast furnace flux, the proportions of each depending on the other constituents of the slag and the amount of sulphur that the slag remove.

Alumina: Although alumina is seldom employed as a flux, it is present in a large number of raw materials as an impurity and is therefore present in slag. In slags it may function as an acid or as a base, depending on the conditions. In highly siliceous slags it may form aluminium silicates while in the presence of an excess of a strong base such as lime, it may form calcium aluminates.
Fluorspar: For making slags more fusible, neutral substance like fluorspar (CaF_2) may be added.

10. Manufacture of Pig Iron:

Pig iron is the term applied generally to the metallic product of the blast furnace when it contains over 90 per cent of iron. This term is used to distinguish it from blast furnace products such as 'ferromanganese' and 'spiegeleisen' that are made from manganese ore or mixture of manganese and iron ores, and still other blast furnace products such as 'ferrophosphorus' and 'other ferro-alloys'.

Pig iron can be made in the following ways :

1) In blast furnace using coke
2) In blast furnace using charcoal
3) In electric smelting furnace
4) In cupola by melting steel scrap with excess of carbon.

However, most pig iron is made in blast furnace using coke and only small quantities are made by the other methods.

10.1 Blast Furnace:

The following different products are produced in blast furnace :

i) iron for steel making
ii) iron for castings
iii) ferro-alloys.

The chemical specifications for the above products are broadly given in Table 9.

Table 9 : Specifications of Metallic Products

Product	Composition Range				
	Silicon	Sulphur	Phosphorus	Manganese	Total Carbon
i) Iron for steel making					
Basic pig iron	1.50 max	0.05 max	0.04 - 0.90	0.40 - 2.0	3.50 - 4.40
Acid pig iron - Bessemer	1.00 - 2.25	0.045 max	0.04 - 0.135	0.50 - 1.0	4.15 - 4.40
Acid pig iron - Open Hearth	0.70 - 1.50	0.045 max	under 0.05	0.50 - 2.50	4.15 - 4.40
Oxygen steel making pig iron	0.20 - 2.0	0.05 max	0.40 max	0.40 - 2.50	3.50 - 4.40
ii) Iron for castings					
Low phosphorus	0.50 - 3.00	0.035 max	0.035 max	1.25 max	3.0 - 4.50
Intermediate phosphorus	1.00 - 3.00	0.050 max	0.036 - 0.075	1.25 max	3.0 - 4.50
Bessemer	1.00 - 3.00	0.050 max	0.076 - 0.100	1.25 max	3.0 - 4.50
Malleable	0.75 - 3.50	0.050 max	0.101 - 0.300	0.50 - 1.25	3.0 - 4.50
Foundry	3.5 max	0.050 max	0.301 - 0.900	0.25 - 0.75	3.0 - 4.50
iii) Ferro-alloys					
Spiegel	1.0 - 4.5	0.050 max	0.14 - 0.25	16 - 30	6.5 max
Standard Ferro-manganese	1.2 max	0.050 max	0.35 max	74 - 82	7.6 max
Ferro-silicon	5.0 - 17.0	0.060 max	0.30 max	1.0 - 2.0	1.5 max
Ferro-phosphorus	1.5 - 1.75	under 0.05	15 - 24	0.07 - 0.50	1.10 - 2.0

In the blast furnace process, iron-bearing materials like lumpy iron ore, sinter, pellets, mill scale, open-hearth or Bessemer slag, iron and steel scrap, etc., fuel (coke), and flux (limestone and/or dolomite) are charged into the top of the furnace. Heated air (blast) and in recent practices, gas, oil or pulverized coal, are blown from the tuyeres. The blast air burns part of the fuel to produce heat for the chemical reactions involved and for melting the iron while the balance of the fuel and part of the gas from the combustion remove the oxygen combined with the metal.

To produce one ton of pig iron, the following materials, on an average, are required :

a) Iron ore	-	about 1.7 tons
b) Coke and other fuels	-	500 - 660 kg
c) Fluxes	-	250 - 295 kg
d) Scrap	-	330 - 340 kg
e) Air	-	1.8 - 2.0 tons

Besides one ton of pig iron produced, nearly 0.2 - 0.4 tons of slag, 2.5 - 3.5 tons of blast furnace gas and about 0.05 tons of flue dust are also produced.

10.2 Changes in conventional blast furnace technology:

The depleting world coking coal resources, together with increasing cost of metallurgical coke, has necessitated considerable innovations in blast furnace technology in the recent times. The sharp rise in daily output capability has been accompanied by a steady fall in coke consumption per ton of iron. The average coke consumption has fallen in the U.K. from about 1100 kg to 650 kg per ton, in the U.S.A. from 940 kg to about 600 kg per ton, and in Japan from 900 kg to below 400 kg per ton.

Parallel with the improved fuel efficiency leading to reduced total coke consumption, there has been realization of the fact that a part of the coke can be replaced by hydrocarbon fuel injected at the tuyeres.

The various steps taken to reduce coke consumption and increase metal production are briefly described below :

a) Raw materials

i) Preparation of iron ore: The current modern practice is to use closely sized lumpy ore of generally 50 mm to 10 mm size. Studies at Nippon Kokan plant have shown that a 1% decrease of lumps of larger than 35 mm in the burden corresponds to a decrease in coke rate of about 2 kg per ton and a 1% decrease of -6 mm fines leads to a decrease in coke rate of 1 kg per ton. Larger furnaces in Japan now use -25+8 mm ore.

It is well known that the iron ore used should be of as high a grade as possible. Experiments in U.S.S.R. have shown that for increase b y 1% Fe in burden, productivity increases by 2% and coke rate decreases by 3%. It has also been estimated that for every 1%

reduction in the alumina content of the ore, the coke and flux rates decrease by 40 kg and 60 kg per ton respectively and the consequent increase in production of pig iron made would be about 2.0% - 2.5%.

ii) Sinter and its effect: Due to close sizing of iron ore and limiting the top size of ore for direct charging into the blast furnace, large quantities of ore fines are generated, both at mine sites and in iron works. These fines are usefully utilized after sintering.

In order to derive the maximum possible metallurgical advantages by use of sinter in iron making, it should have a suitable chemical composition, should be self-fluxing or still better super-fluxed and should have adequate physical strength to withstand handling without crumbling into fines. The sinter should neither have un-sintered particles nor a glassy structure and should be non-magnetic, that is, the FeO content should be as low as possible.

The modern blast furnace practice generally use large percentages of sinter in the burden, upto 70% - 80% and in some cases the burden exclusively consists of fluxed or super-fluxed sinter. Size of sinter used is generally 50 mm to 5 mm. Practice in Japan has shown that a 10% increase in sinter ratio in blast furnace burden corresponds to a reduction of coke rate of about 10 kg per ton and to a production increase of about 2%.

iii) Pelletizing: Pelletizing, the newest of the agglomerating processes, is being increasingly used in blast furnaces despite the unquestioned benefits of sinter on blast furnace performance. Pelletizing process is desirable for agglomeration of finely divided ore concentrates, blue dust, flue dust and the like. Fluxed pellets of uniform size and of adequate strength, crushing as well as tumbler, good porosity and reducibility and desirable swelling index, become ideal feed for iron making in blast furnace. The process enables use of a very high grade ore concentrate in the form of pellets which have advantages almost equal to those of self-fluxing sinters.

b) Blast-humidity control:

Changes in atmospheric humidity has an effect on furnace operation because of the endothermic reaction taking place when steam comes in contact with hot coke. With the modern practice of using high blast temperatures, humidity has also to be adjusted suitably to avoid furnace to hang and operate irregularly. The higher the hot blast temperature, the higher the moisture content of the hot blast has to be given to obtain a suitable flame temperature in the hearth zone.

The use of very high hot-blast temperatures together with addition of the proper amount of moisture in the blast, has made it possible to increase blast furnace production rates substantially. Moisture produces more reducing gas per unit volume than dry air does. However, the possibility of controlling the flame temperature at tuyeres to a certain level by the injection of fuel has almost eliminated the necessity of steam addition. The temperature of hot metal has since been controlled by fuel injection, in modern practice by the developed oountries like Japan.

c) Oxygen enrichment of blast:

Enrichment of blast with oxygen reduces the volume of gas required at the same daily productivity, and has therefore an effect identical to the use of a higher top pressure. However, if the blast air is enriched, the flame temperature increases so that with oxygen contents above 22%, moisture or hydro-carbon fuels must be added to control the flame temperature. It can broadly be assumed that for every one per cent of enrichment a production rate increase of about 3 to 4 per cent can be achieved. The higher the hot blast temperature the smaller the improvement in production rate for each per cent of increase in oxygen content.

In Japan's Nippon Kokan's blast furnace oxygen enrichment was first tried as early as 1959. It has been established that one per cent enrichment of oxygen brought about a 5 per cent increase in production and a slight decrease in coke rate. Nowadays, upto 3.8 per cent enrichment is being adopted.

In a 2000 m^3 blast furnace in the Soviet Union, oxygen in the blast when increased from 26.7 to 34.7 per cent plus natural gas injection increased from 8.6 to 14.3 per cent, the productivity increased by 15.3 per cent with lowering of coke rate from 484 to 445 kg per ton of pig iron with coke replacement factor by natural gas of 0.91 kg/m^3 (Nekrasov et al - Stal'Feb. 1973).

In another practice at Magnitogorsk Combine Blast Furnace, Babarykin et al report in'Steel in U.S.S.R.' - March 1976, that with blast containing 25 per cent oxygen and injection of 100-105 m^3/ton of natural gas, it was possible to increase daily pig iron production by 1.8 to 2.2 per cent in the 2014 m^3 blast furnace and a reduction of 2.4 per cent per one per cent of oxygen in coke consumption. With the actual relation between expenditure on coke, natural gas and oxygen, the greatest economic benefit was obtained with oxygen and natural gas consumption each of 90 m^3/ton of pig iron. It has also been established by the above researches that the limiting natural gas consumptions for blast oxygen contents of 21%, 25%, 30%, 35% and 40% calculated from practical data are respectively 20-65, 70-140, 100-210, 130-230 and 150-245 m^3/ton of pig iron. When combined blast is being used to obtain a greater lowering of coke consumption, it is essential to aim for a gas consumption closer to the upper limits and, if to obtain mainly a rise in productivity, one closer to the lower limit.

d) Fuel injection:

Fuel injection through the tuyeres is the most important practice next to raw material preparation in blast furnace operation. With the development of means for obtaining higher hot-blast temperatures and the need for controlling the flame temperature, it became apparent that oold hydro-carbon fuels could be injected into the blast furnace tuyeres for not only controlling the flame temperature but also to replace some of the ooke.

In the presence of large quantities of coke the hydro-carbon fuels can burn only to carbon monoxide and hydrogen; consequently they produce less heat than that produced by the hot coke they replace. As long as a blast furnace has the stove capacity for obtaining higher hot blast temperature, or as long as moisture must be added to the blast to lower the flame temperature, hydro-carbon fuels can be used to advantage because their endothermic effect provides a means of controlling the temperature in the hearth.

Generally when tuyere-injected fuels are used, the moisture content of the blast must be decreased. Natural gas, coke-oven gas, fuel oil, pulverized coal, tar and slurries of oil and coal have been used in this manner.

Fuel injection has the following favourable features :

i) Reduction of coke rate
ii) Stabilization of blast-furnace operation and production increase
iii) Compensation of shortage in coke oven capacity or saving of coking facilities
iv) Low investment in installing the injection equipment on blast furnace.

For the effective application of fuel injection, attention should be given to the following points :

i) Heat compensation capable of keeping the flame temperature at tuyere within a certain range
ii) Limit of combustion load for individual tuyeres
iii) Changes in permeability, heat exchange, and reducing reactions caused by varying volume of gas produced per ton of hot metal
iv) Injection method (engineering of atomizing, etc.)
v) Measures to cpoe with unexpected blow-off and other troubles.

Heat compensation and combustion load are the most important problems in injecting fuel. Reduction of coke rate brought by the fuel injection is related to the blast temperature.

According to the operating results of Nippon Kokan's Kawasaki no.4 blast furnace, the limit of oil injeotion is 30 kg/ton at a constant humidity, i.e., with a lower limit of 2000°C and an upper limit of 2200°C of the theoretical flame temperature and a blast temperature of 800°C. With a blast temperature of 1100°C, even an injection of 110 kg/ton is possible.

Limit of the ratio to the amount of oxygen necessary for the perfect combustion of oil is considered to be 1.1 - 1.2 and this would result in a limit of oil injection of 110 kg/ton and that of tar injection of about 90 kg/ton.

In recent operations of Nippon Kokan's Fukuyama blast furnaces, oil injection of about 80 kg/ton was applied in combination with oxygen enrichment to reduce the coke rate to about 400 kg/ton. It was however necessary to keep the theoretical flame temperature at rather a high level of 2300 - 2400°C. It was found to be possible to reduce the coke rate to 210 kg/ton by injecting reducing gas made from about 220 kg/ton oil in an experimental blast furnace.

Yarosherskii et al report in 'Steel in U.S.S.R. - June 1976' that injection of coal dust in 700 m^3 blast furnace at Donetsk, shows that with 200 kg of lean coal per ton of pig i. ~, altered the productivity and coke rates very substantially. T.e data obtained over a period of one year are as follows :

Change in productivity with coal injection	-	0.2 per cent
Reduction in coke consumption	-	45.1 kg/ton of iron
Percentual reduction in coke consumption	-	7.5 per cent
Reduction in pig iron production cost	-	about $1.3 per ton of pig iron.

e) High top pressure operation:

One of the limiting factors in attempting to increase the production rate of a blast furnace is the lifting effect that is caused by the large volume of gases blowing upward through the burden. This lifting effect prevents the burden from descending normally and causes a loss rather than an increase in production.

Increase in blast volume for raising blast furnace productivity reduces the passage time of gas through the furnace, i.e., the reaction time. This lowers the utilization ratio of gas resulting in rise in top temperature and increase in coke rate. Pressure drop in the furnace also increases. However, if the blast volume is increased over a certain limit, imbalance of permeability through the furnace would result in channelling and flooding.

To achieve a uniform ascent of gases and a satisfactory burden descent, it is necessary to keep the gas-flow velocity within certain limits. Use of higher gas pressure in the furnace leading to a decreased gas volume is very effective measure for this purpose.

Most of the newly constructed furnaces in Japan are operated with high top pressure. Top pressure has been gradually raised to the present level of 1.0 - 1.5 kg/cm^2 and some times up to 2.5 kg/cm^2 in bigger blast furnaces.

According to the results of Nippon Kokan's Fukuyama and other iron producers in Japan, high top pressure operation has the following effects :

i) Top pressure and permeability : With the increase in top pressure the permeability index increases proportionately.

ii) Effect on production rate : An increase in top pressure raises the productivity; a 0.1 kg/cm^2 increase in top pressure corresponds to an increase of about 1.5 per cent in productivity.

iii) Effect on coke rate : Increase in top pressure reduces solution loss whereas higher daily productivity results in an increased solution loss but the overall effect is a slight reduction in the coke rate.

iv) Decrease in dust loss : A higher top pressure leads to a better permeability and therefore reduces the number of slips.

Higher top pressure slows down the top gas velocity, thus reducing the dust lost.

f) Pre-reduced burden:

It has been established by the performance data of blast furnaces that coke consumption reduces and productivity increases when pre-reduced burden is used as shown in Figures 1 and 2 resp.

Fig. 1. Coke consumption vs. pre-reduced burden.

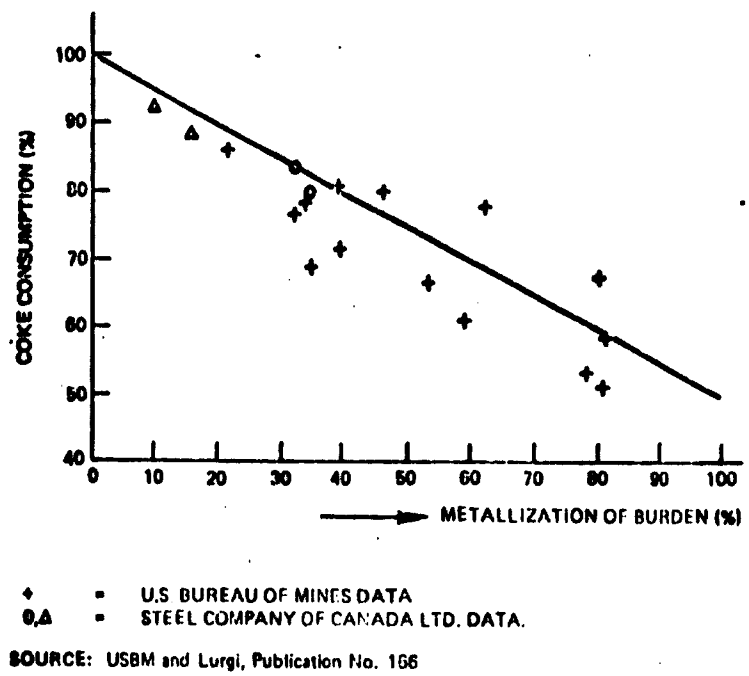
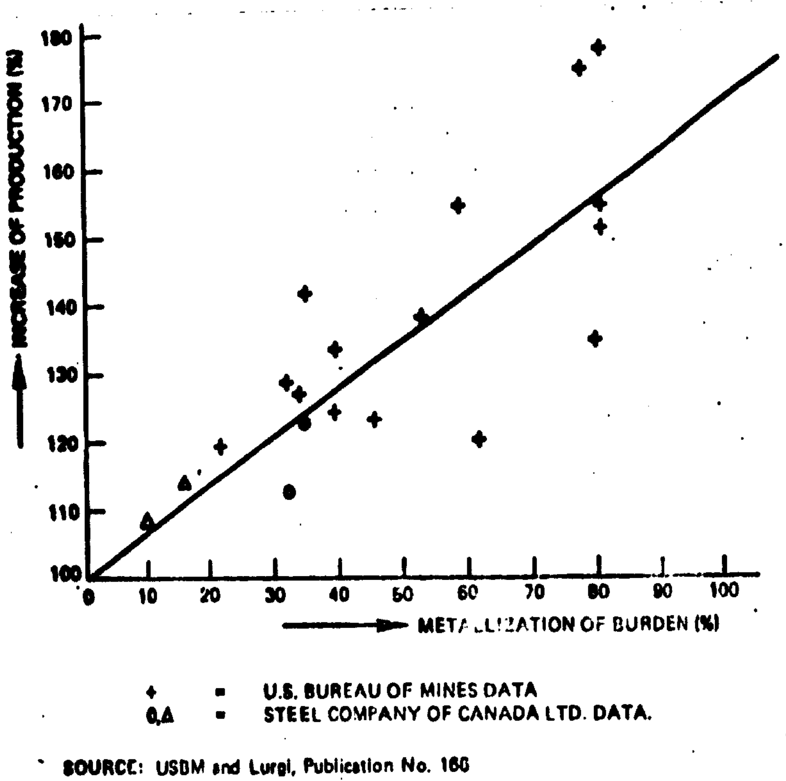


Fig. 2. Production vs. pre-reduced burden.



g) Large Capacity Blast Furnace:

Steel making in integrated iron and steel works has been changed from the open-hearth furnace process to the converter process. The high efficiency of the latter process and the expansion of unit capacity of rolling facilities have brought about the most economical annual production unit of iron works. To cope up with this trend towards larger facilities and the increasing demand for hot metal from converters, there is a strict requirement for a stable supply of large quantities of low cost hot metal to be produced in blast furnaces having increased capacities.

Comprehensive data on factors in operation of larger capacity blast furnace indicate that the production cost of hot metal is lowered. This advantage, though pronounced upto an inner volume of 2500 m^3, becomes less over the limit of about 4000 m^3 as has been studied by the Japanese Iron and Steel makers.

In deciding the size of a blast furnace, the properties of raw materials should be seriously taken into account. The requirements on the burden size and and the strength have recently beoome more and more stringent.

The blast furnace capacity is increased by enlarging the hearth diameter and other cross-sectional sizes, but not raising the furnace height too much. The top pressure for a larger capacity blast furnace is also proportionately increased.

Although the operating costs for a larger size blast furnace are higher than for a smaller size furnace, the investment costs are lower in the former case. The overall operating and investment costs are lower than those for smaller size blast furnace. In a larger blast furnace, the solution loss is higher because furnace height is not large enough in relation to the increase in inner volume acid hence the descent time for the burden is shortened. The labour cost is reduced with the increase in furnace capacity, but the operating cost of the blower increases accordingly as high top pressure operation is applied for a stable operation. Since the increase in blower operating cost exceeds the decrease in labour cost, the overall operation costs tend to be higher with the increase in furnace capacity.

The construction cost per ton of iron is inversely proportional to a third power of the inner volume. This results in the decrease in unit depreciation cost, interest on capital and running cost.

The above aspects are diagramatically shown in Fig.3.

Fig. 3. Inner volume of blast furnace and running and investment costs (source : UNIDO - ID/WG.146/25)

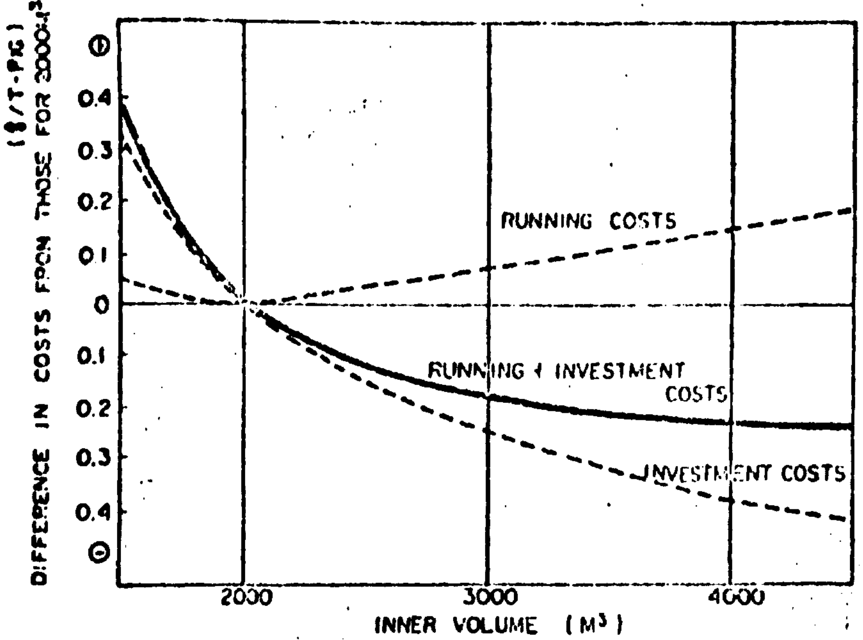
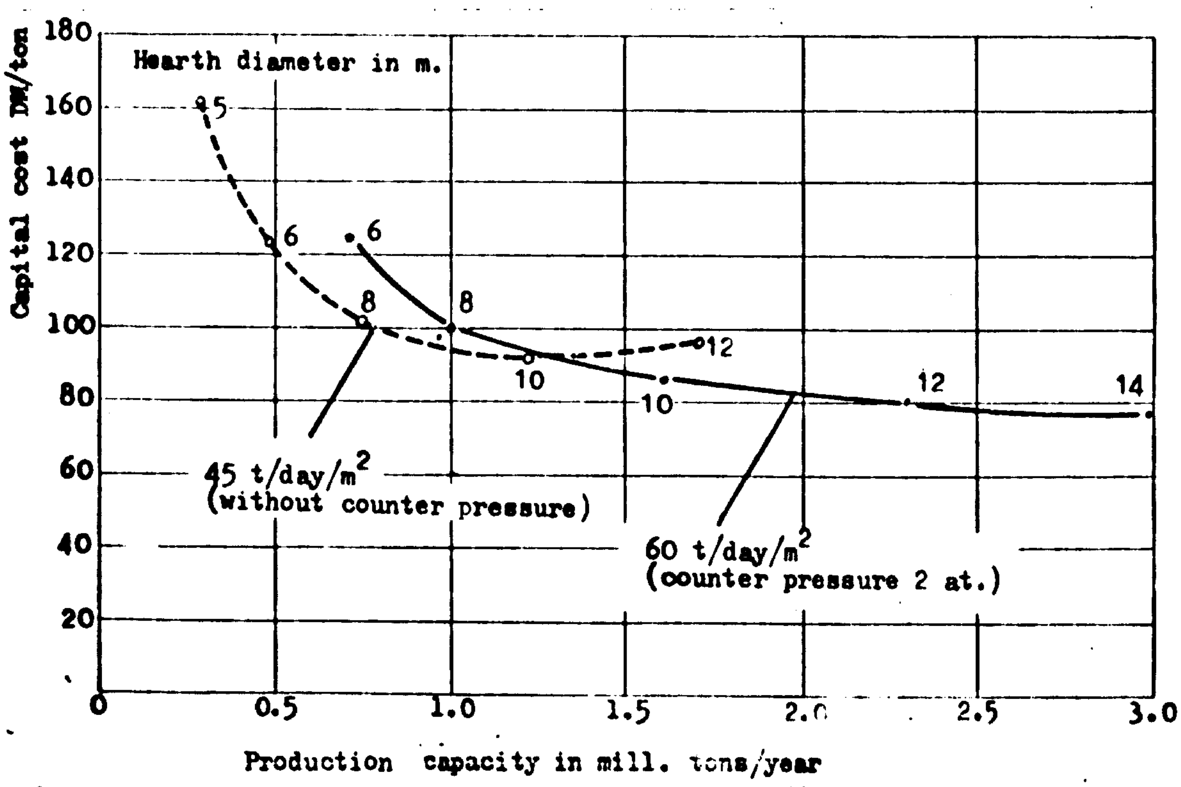


Fig.4 shows the capital cost per ton for different capacity blast furnace.

Fig. 4. Capital cost per ton - capacity of blast furnace (source : Stahl und Eisen, 90(1970), No.4)



The Industrial Environmental Research Laboratory of the U.S. Environmental Protection Agency in a study (EPA-600/7-76-034c, December 1976) has estimated the investment and running costs of a few sizes of blast furnaces in U.S.A. using oxidized and metallized pellets. These figures are given in Tables 10, 11, 12 and 13.

Fig.5 shows the relationship between cost of iron making and sulphur in iron produced.

Fig. 5. Relationship between cost of iron making and Sulphur in iron.

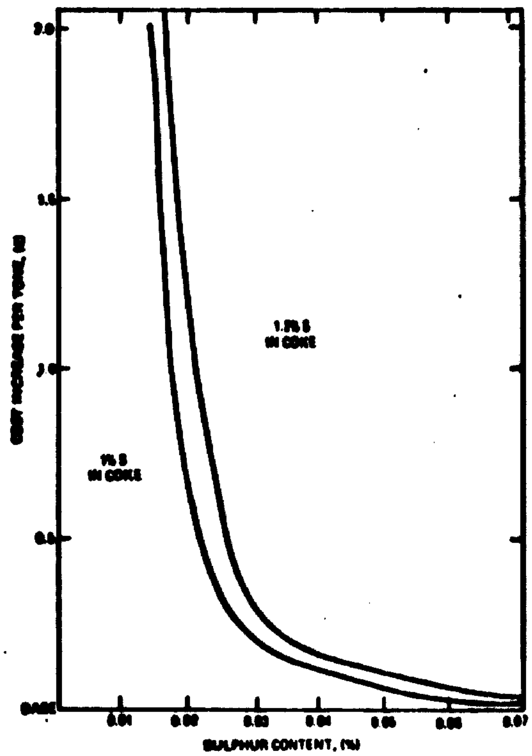


Table 10 : Cost Structure in New Blast Furnace Facilities

Annual Design Capacity: 1.22 x 10^6 tons of hot metal
Capital Investment: $90 million
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per Ton of Product	$/Ton of Product
Variable Costs				
Raw Materials				
Pellets	Btu	0.45	84.7	38.11
Limestone	ton	5.00	0.25	1.25
Energy (Details on Table B)				
Purchased Coke	ton	90.25	0.53	47.85
Electric Power Purchased	kWh	0.016	25.00	0.40
Energy Credits (Specify form)				
Blast Furnace	10^6 Btu	2.0	3.8	(7.60)
Water				
Cooling (Circulating rate)	10^3 gal	0.05	11	0.55
Labor (Wages) (1)	man-hr	7.00	0.15	1.05
Direct Supervisory Wages (s)	15% labor			0.16
Maintenance Labor and Material	5% CI			3.69
Labor Overhead	35% (L+S)			0.42
Misc.Variable Costs/Credits (a)				
Slag Sampling				0.25
Scrap Credit	ton	80.00	0.01	(0.80)
TOTAL VARIABLE COSTS				85.33
Fixed Costs				
Plant Overhead	65% (L+S)			0.79
Local Taxes and Insurance	2% CI			1.48
Depreciation 18 Years				4.06
TOTAL PRODUCTION COSTS				86.21
Return on Investment (pretax)	20% CI			14.76
TOTAL				106.42

Table 11 : Cost Structure in New Blast Furnace

Annual Design Capacity: 2.6×10^6 tons hot metal
Capital Investment (CI): $156 million
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per Ton of Product	$/Ton of Product
<u>Variable Costs</u>				
Raw Materials				
Pellets	ltu[a]	0.45	84.7	38.11
Limestone	ton	5.00	0.332	1.66
Energy				
Purchased Coke	ton	90.0	0.53	47.70
Electrical Power Purchased	kWh	0.016	25	0.40
Energy Credits				
Blast Furnace Gas	10^6 Btu	2.0	3.8	(7.60)
Water				
Process (Consumption)				
Cooling (Circulating Rate)	10^3 gal	0.05	11	0.55
Direct Operating Labor (Wages)L	man-hr	7.00	0.10	0.70
Direct Supervisory Wages +	15% labor			0.11
Maintenance Labor and Mat'l.S	5% Inv.			3.00
Labor Overhead	35% L+S			0.28
Misc.Variable Costs/Credits				
slag sampling				0.25
scrap credit	ton	80.00	0.01	(0.80)
TOTAL VARIABLE COSTS				84.36
<u>Fixed Costs</u>				
Plant Overhead	65% L+S			0.53
Local Taxes and Insurance	2% Inv.			1.20
Depreciation	5.55%			3.33
TOTAL PRODUCTION COSTS				89.42
Return on Investment (pretax)	20% CI			12.00
<u>Pollution Control</u>				4.57
TOTAL				105.99

[a] long ton unit - 22.4 lb of coal contained Fe.

Table 12: Cost Structure in New Blast Furnace (Reduced Coke Rate)

Annual Design Capacity: 2.6 x 10^6 tons hot metal
Capital Investment (CI): $152 million
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per ton of Product	$/Ton of Product
<u>Variable Costs</u>				
Raw Materials				
Pellets	ltu	0.45	84.7	38.11
Limestone	ton	5.00	0.225	1.12
Energy				
Purchased Coke	ton	90.00	0.515	46.35
Electric Power Purchased	kWh	0.016	24	0.38
Energy Credits				
Blast Furnace Gas	10^6 Btu	2.00	3.69	(7.38)
Water				
Cooling (Circulating Rate)	10^3 gal	0.05	10.6	0.53
Direct Operating Labor (Wages) L	Man-hr	7.00	0.10	0.70
Direct Supervisory Wages +	15% Labor			0.11
Maintenance Labor S				
Maintenance Materials and Supplies	5% Inv.			2.92
Labor Overhead	35% L+S			0.28
Misc. Variable Costs/Credits[a]				
Slag Sampling				0.25
Scrap Credit	ton	80.00	0.01	(0.80)
Total Variable Costs				82.57
<u>Fixed Costs</u>				
Plant Overhead	65% (L+S)			0.53
Local Taxes and Insurance	2% Inv.			1.17
Depreciation 18 years				3.25
TOTAL PRODUCTION COSTS				87.52
Return on Investment (pretax)	20% CI			11.70
<u>Pollution Control</u>				4.06
TOTAL				103.28

[a] long ton unit = 22.4 lbs of contained Fe.

Table 13 : Cost Structure in New Sponge Iron (93% Metallized) Facilities

Annual Design Capacity: 1,200,000 tons
Capital Investment: $168 x 10^6
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per Ton of Product	$/Ton of Product
Variable Costs				
Raw Materials				
Pellets	ltu	0.45	8.5	38.25
Limestone	ton	5.00	0.140	0.70
Energy (Details on Table B)				
Purchased Fuel	10^6 Btu	2.00		
Coal	ton	25.00	0.625	15.62
Purchased Steam	10^6 Btu	3.00		
Electric Power Purchased	kWh	0.018	56.0	0.90
Misc.				
Water				
Process (Consumption)	10^3 gal	0.50		
Cooling (Circulating Rate)	10^3 gal	0.05	4	0.20
Direct Operating Labor (Wages)(L)	man-hr	7.00	0.20	1.40
Direct Supervisory Wages (S)	L		15% L	0.21
Maintenance Materials and Supplies	4% CI			5.60
Labor Overhead	35% (L+S)			0.56
TOTAL VARIABLE COSTS				63.44
Fixed Costs				
Plant Overhead	65% (L+S)			1.05
Local Taxes and Insurance	2% CI			2.80
Depreciation 18 Years				7.84
TOTAL PRODUCTION COSTS				35.83
Return on Investment (pretax)	20% CI			28.00
TOTAL				102.88

Table 14 gives a list of some of the larger sise blast furnaces in the world.

Blast furnaces planned or under construction in different countries are listed in Table 15. Those furnaces which have been commissioned recently (sinoe January 1974) are given in Table 16.

The operating data of some of the larger blast furnaces in Japan and Soviet Union are presented in Tables 17 and 18 respectively.

Table 19 gives technical data of a recently commissioned blast furnace at the Linz Works of Voest Alpine A.G., Austria.

Table 14 : Large Blast Furnaces in the World

Blowing in	Country	Works	No.	Hearth Dia.m.	Inner Volume m^3
1964	Japan	Nagoya	1	9.8	2021
1965	Japan	Chiba	5	10.0	2142
1965	U.S.S.R.	Zidanov	4	10.3	2300
1966	Japan	Fukuyama	1	9.8	2004
1967	Japan	Wakayama	4	11.0	2535
1967	Japan	Mizushima	1	10.0	2156
1967	Japan	Nagoya	2	10.3	2166
1967	Japan	Sakai	2	11.2	2620
1967	U.S.S.R.	Krivoi Rog	8	11.0	2700
1967	Netherlands	Ijmuiden	6	10.0	2150
1968	Japan	Fukuyama	2	11.2	2626
1968	France	Dunkirk	3	10.2	2100
1968	Japan	Kimitu	1	11.5	2705
1969	Japan	Mizushima	2	11.5	2857
1969	Japan	Wakayama	5	11.0	2630
1969	Japan	Nagoya	3	11.7	2924
1969	U.S.S.R.	Cherepovets	4	11.0	2700
1969	Japan	Tobata	3	10.5	2338
1969	Japan	Fukuyana	3	11.8	3016
1969	Japan	Kimitu	2	11.6	2884
1969	U.S.S.R.	Nizhnij Tagil	6	11.0	2700
1969	U.S.A.	Burns Harbor	1	10.6	2427
1969	Japan	Wakayama	2	10.0	2147
1969	Italy	Taranto	3	10.6	2475
1970	U.S.S.R.	W. Siberian	2	11.0	2700
1970	Japan	Hirobata	4	11.0	2548
1970	W. Germany	Ruhrort	6	11.0	2226
1970	Japan	Kakogawa	1	11.6	2847
1970	Japan	Mizushima	3	12.4	3363
1971	Japan	Kashima	1	12.4	3159
1971	U.S.S.R.	W. Siberian	3		3000
1971	U.S.S.R.	Karaganda	2	11.0	2700
1971	Japan	Fukuyama	4	13.8	4197
1971	Japan	Kimitu	3	13.4	4063
1972	Japan	Oita	1	14.0	4158
1973	Japan	Fukuyama	5		4600
1976	U.S.S.R.	Krivoi Rog	9	14.7	5000
1976	Japan	Kashima	3		5050
1976	Japan	Oika	2		5070
	*U.S.S.R.	Krivoi Rog		15.1	5500

*under construction

Table 15 : BF planned or under Construction

Country/Company, Works	Date	No.	Volume m^3	Capacity m. t/y
Algeria				
SNS, El-Hadjar		2	2000	
Argentina				
Propulsora, Enseñada		182		
Austria				
Voest-Alpine, Linz	1976		2400	1.8
Belgium				
Sidmar, Gent		3		3.7
Brazil				
Barra Mansa		3		0.13
Cosipa Puacaguera	1975	2	2500	1.3
CSN, Volta Redonda	1976	3	3200	
Cia. Sid. Tubarao	1977	1	4500	
Canada				
Stelco, Nanticoke	1977	1		
Colombia				
Colar, Bogotá	1975/76	2		0.04
Egypt				
Egyptian Iron + Steel, Helwan	1975	4	1033	0.65
Finland				
Rantaruukki, Raahe	1975	2		
West Germany				
Krupp, Rheinhausen	1976			1.8
Peine-Salzgitter, Salzgitter				1.8
Italy				
Piombino	1977	4		
Japan				
NKK, Ohgishima (Keihin)	1976	1		
Kawasaki, Chiba	1976/77	6	4500	3.6
Kobe, Kakogawa	1976/77	3		
Amagasaki		3	4500	
Nippon Steel, Oita	1975	2	5000	
Kimitsu		4		
Tobata		5		
Nagoya		1	4000	
Sumitomo, Kashima	1976	3	5000	4.0
South Korea				
Pohang	1976	2	2254	1.48
Mexico				
Sicartsa, Las Truchas	1976	1	1700	1.4
Ahmsa, Monclova	1976	5		1.6
Poland				
Huta Centrum, Kotowice	1976	1	3200	
Lenin, Nowa Huta	1976/77	6	2000	

Table 15 : continued

Country/Company, Works	Date	No.	Volume m^3	Capacity m. t/y
South Africa				
Iscor, Vanderbijlpark		D		
Newcastle	1976		2060	1.64
Iscor+Partners, Saldanha Bay		182		
Sweden				
Norrbotten, Tulea		182	3000	2
Spain				
AHM, Sagunto		182		
Turkey				
Eregli	1975	2		
Iskenderum	1975	1	1386	0.55
U.K.				
BSC, Redcar		1	4573	3.65
U.S.A.				
Inland, Indiana Harbor	1978		4000+	
National, Portage	1976	1	3680	1.80
U.S.Steel, Fairfield				
U.S.S.R.				
Chereporets		5		
Karaganda		6		
Novo-Lipetsk	1976	6	5000	5.0
West Siberian		4	5000+	
Krivoi Rog		10		
Yugoslavia				
Smederovo	1980	2	1386	

Table 16 : Recently commissioned Blast Furnaces (January 1974)

Country/Company, Works	No. of furnace	Hearth dia.m.	Volume m^3	Capacity 1000 t/y
Argentina				
Somisa, San Nicolas	2	9.753	4500	1300
Altos Horros Zapla, Palpala	5	5.2		200
Brazil				
Usiminas, Belo Horizonte	3	11.5	2700	2160
Canada				
Algoma, Sault Ste. Marie	7	11.7		1800
Egypt				
Egyptian Iron + Steel, Helwan	3		1o33	650
France				
Solmer, Fos	1	10.1	1910	1440
West Germany				
Dillinger, Dillingen	4	10	1790	1000 (later 1400-1600)
Duisburger Kupferhütte, Duisburg		5.5	660	200
Italy				
Italsider, Taranto	5	14	3358	3500
Sweden				
Surahammar, Spannarhyttan	1	5.5	455	220
U.K.				
BSC, Llanwern	3	11.2	2289	1800
U.S.A.				
Bethlehem, Sparrows Point	L	13.716	3681	2880

Table 17 : Operating Results of Fukuyama, Japan, Blast Furnaces

	1 BF	2 BF	3 BF	4 BF
Blowing in	Aug.1966	Feb.1968	Jul.1969	Apr.1971
Inner volume, m^3	2004	2626	3016	4197
Hearth dia., m	9.8	11.2	11.8	13.8
Production, t/d	4639	6064	6834	10,017
Productivity, $t/d/m^3$	2.32	2.31	2.27	2.39
Coke rate, kg/t	469	469	465	437
Oilrate, kg/t	34	26	40	52
Fuelrate, kg/t	503	495	505	489
Sinterrate, %	70	64	76	80
Slag volume, kg/t	253	260	274	290
Blast volume, Nm^3/min	4073	5309	5842	7722
Blast pressure, kg/cm^2	2.24	2.61	2.93	3.61
Top pressure, kg/cm^2	0.59	0.99	1.36	2.10
Blast temp., °C	1112	1146	1159	1200
O_2 enrichment, %	0	0	0.6	1.4
Si% in pig	0.71	0.69	0.66	0.71
S% in pig	0.038	0.037	0.038	0.032
CaO/SiO_2 in slag	1.23	1.17	1.16	1.13
Coke ash, %	9.2	9.1	10.6	10.5
Drum index	92.4	93.2	91.8	92.0

Table 18 : Data on new Blast Furnaces in U.S.S.R.

	5000 m3 BF	5500 m3 BF
Inner volume, m^3	5000	5500
Hearth dia., m	14.7	15.1
Useful height, m	33.5	34.3
Daily production, t	12,900	14,000
Burden, kg/t pig iron		
Sinter	1,000	837
Pellets	680	810
Coke (dry)	375	370
Energy resources, m^3/t pig iron		
Blast (incl. 6% losses)	830	820
incl. process oxygen	158	156
natural gas (incl. 3% losses)	149	147
Blast volume m^3/min	7500	8000
Blast temperature, °C	1400	1400
Yield of smelting products, kg/t pig iron		
Slag	325	290
Top gas, m^3/t	1380	1370
Flue dust	25	25
Manganese in pig iron, %	1.2	1.2
Sulphur in pig iron, %	0.035	0.020
Top gas calorific value, kcal/m3	1190	1180
Top gas pressure, atm.	2.5	2.5

Table 19 : Technical Data - Linz Blast Furnace

Hearth diameter	11 m
Total volume	3,055 m^3
Utilizable volume	2,504 m^3
Maximum furnace gas pressure	2.5 atm. gauge
Maximum hot air temperature	1350°C
Maximum air quantity	360,000 Nm^3 per hour
Tuyeres	28
Pig iron taps	3
Slag taps	1
Daily pig iron output	5,500 tons
Coke consumption per day	2,300 tons
Burden rate per day	9,500 tons

10.3 Electric Iron Making Practice:

It was at the end of the last century that the first electric furnaces were built for smelting iron ore and producing liquid metal. Researches were carried out on three different types of furnaces :

i) the open-bath arc furnace
ii) the electric shaft furnace
iii) the low-shaft or submerged arc furnace.

A brief description of the above types of furnaces is as follows :

i) Open-bath arc furnace :
In these furnaces the electrode is in contact with the slag, but it is not immersed in the solid charge. This type of furnace is being used at the Quebec Iron and Titanium Corporation plant at Sorel, P.Q., Canada, for melting of ilmenite with selective reduction of iron and production of a low-carbon hot metal and titaniferous slag. It is also used by the Strategic Materials Corporation forming a part of the Strategic-Udy process.

ii) Electric shaft furnace :
This type of furnaces built and operated at Domnarvet and Trollhattan, Sweden, and Aoste, Italy, gave no better operating results that the open-bath or the submerged arc furnaces and hence were finally abandoned. There was not enough gas to pre-heat the charge in the shaft and so indirect reduction of iron oxides by the gas was impossible.

iii) Submerged arc furnaces :
This type of furnace is an intermediate type between the shaft and the open-bath furnaces. One of the first such furnaces was constructed by Heroult and used at Sault Sainte Marie, Canada. Later the submerged arc furnace was industrially developed by Tysland and Hole, Norway.

There are about 100 electric iron making furnaces with a total capacity of the order of 3 to 4 million tons per year of pig iron. Since the first 600 kw Tysland-Hole furnaces at Fiskaa and Christiana Spigerverk in Norway, the Electrokemisk firm has built a number of larger furnaces.

In Norway, four furnaces of 20 - 25 MW of Tysland-Hole type in Moi Rana and one unit of same size in Svelgen are in operation. The larger installations in different countries are given in Table 20.

Table 20 : Tysland-Hole Furnaces

Country	No. of furnaces	MW
Canada	1	10
Finland	1	10
India	2	20
Israel	2	29
Italy	13	102.5
Japan	2	13
Norway	6	108
Peru	2	20
Phillippines	2	20
Portugal	1	10
Spain	1	6.5
Sweden	6	54
Switzerland	1	8.5
Venezuela	9	180
Yugoslavia	3	30
	52	630.5

The Japanese steel works have independently developed electric pig iron smelting furnaces based on relatively small open furnaces of 1 to 10 MW capacities. Most of the units in operation smelt the locally available beach sand concentrates.

Including the Japanese furnaces and also the smaller open type of furnaces, the total smelting capacity is estimated at approximately 1000 MW producing 3 to 4 million tons of pig iron annually.

Consumption of electrical energy has averaged about 2200 kwh per ton of pig iron produced and electrode paste consumption between 8 and 15 kg/ton. About 1500 kg of sintered ore and 400 - 430 kg of coke are generally consumed to yield one ton of pig iron.

10.4 Pre-reduced Iron Ore Pellets for Smelting:

In the field of direct reduction processes a clear distinction exists between

(a) pre-reduced material for iron smelting in blast furnace or electric furnace or

(b) sponge iron for direct steel making in electric furnace.

In the former case, the endproduct is pig iron.

A brief review of the use of pre-reduced material for pig iron making is made in the following lines :

Since considerable pre-reduction takes place in the shaft of the blast furnace itself, the advantages of using a pre-reduced charge are not quite significant in blast furnace.

On the other hand use of pre-reduced charge for electric smelting results in substantial economy in consumption of coke, electrical power and fluxes. The productivity also tends to improve with the use of pre-reduced charge. The extent of improvements depends upon the degree of metallization of the pre-reduced iron ore.

Of the large number of processes for pre-reduction and sponge making the following are the most promising ones :

i) Solid reductants :
   External heating - (a) Echeverria
                      (b) Kinglor Metor
   Internal heating - (a) Krupp
                      (b) SL/RN

ii) Gaseous reductants :
   Shaft furnace - (a) Midrex (gas recycling)
                   (b) Purofer (gas recycling)
                   (c) Armco (no gas recycling)
   Fixed bed - HyL
   Fluidized bed - (a) HIB (under pressure)
                   (b) FIOR (under pressure)
                   (c) Novalfer (without pressure)

The processes in commercial production are briefly as follows :

<u>Rotary kiln process:</u> This process uses non-coking coals as the reducing agent and is a continous one. It is advantageous to those countries where coal is available in abundance along with good quality iron ore. Both, high grade lumpy iron ore or high grade pellets can be utilized.

<u>Midrex process :</u> This process uses a continous shaft furnace using reformed natural gas as the reducing agent. The recycling of gases together with the advantages of a continous process results in low energy requirements.

<u>HyL process :</u> This is a batch process using a fixed bed reactor and uses reformed natural gas as the reducing agent.

<u>Armco Process :</u> This process is similar to the Midrex process.

<u>HIB process :</u> The high iron briquette process is a fluidized bed reduction one using steam-reformed natural gas. The fine ore is first pre-heated, then reduced by steam-reformed natural gas at a temperature of about 700°C followed by hot briquetting and cooling.

11. Economic Considerations of Iron Making Processes:

In comparing the capabilities of electric reduction furnaces and blast furnaces it is difficult to conceive of an electric furnace plant having an iron-making capacity of 2 million tons or more; here is the domain of the blast furnace with its large output. For plants of about 1 million tons capacity the electric reduction furnace could be considered; and for plants of less than one-half million tons capacity. The electric furnaces would offer the advantage of greater flexibility than a large blast furnace.

It may, however, be noted that the trend toward larger electric furnaces employing pre-heated and pre-reduced charges will make possible the production of 500 tpd per furnace in the near future and with possibilities of higher tonnages of upto 1000 tpd. Such furnaces could be considered for 1.5 million tons plants, such as those projected for eastern Siberia or Africa where tremendous hydro-electric potentials exist in equatorial regions.

Concerning cpaital costs, there does not appear to be a great deal of difference between blast furnace and electric-reduction furnace plants of comparable capacity. For large - or medium - size plants costs per annual ton of iron capacity for either a modern blast furnace or an electric-reduction-furnace installation, each with ore preparation but without stocking facilities, coke-oven plants, power stations and mines, may be more or less equal.

If investment costs are comparable for blast furnace and electric furnace installation, then the choice between them is largely a matter of the relative cost of electrical eneergy and the cost and availability of coking coals. Studies in Soviet Union have shoen equivalent costs for the two processes when 1 kg of coke had equivalent value to 3.5 to 4 kwh employing 108,000 - 120,000 kva furnaces with six electrodes with an output of 1000 tpd.

In conclusion it may be pointed out that choice between the two processes would mainly be dependent on availability of cheap electrical energy and that of coal. Since developing countries have a dominant share of world resources of gas, oil and hydro-electric energy potential, and a good share of iron ores, they suffer a lack of coal, particularly coking coal. It would, therefore, be more desirable for many developing countries to consider adoption of electric furnace method which has the added advantages of flexibility of size and comparatively lower plant costs.

The substitution of charcoal for coke is an acceptable and fully feasible technology. However, its utilization will call for a programme of reforestation in order to ensure adequate supplies of charcoal on long term basis. The paramount importance of preserving environmental balance in developing countries can not be overlooked by delaying the replantation programme.

12. World Production of Pig Iron:

World's pig iron production and its output per capita are shown in Table 21. The data has been published in Metal Bulletin - June 10, 1977.

Table 21 : Pig Iron Production

Country	Production x 000 tons		Output per capita kg		% World
	1975	1976	1975	1976	Output 1976
Europe					
West Germany	30,074	31,849	486	517	6.53
Belgium	9,180	9,956	938	1,014	2.04
France	17,921	19,035	338	357	3.90
Italy	11,412	11,694	204	208	2.40
Luxembourg	3,889	3,756	10,655	10,151	0.77
Netherlands	3,970	4,266	291	310	0.87
Denmark	-	-	-	-	-
U.K.	12,131	13,859	217	248	2.84
EEC	88,577	94,415	343	364	19.35
Finland	1,368	1,240	290	260	0.25
Norway	638	630	159	156	0.13
Austria	3,056	3,325	406	444	0.68
Portugal	327	350	37	39	0.07
Sweden	3,309	2,600	404	315	0.53
Switzerland	35	35	5	5	0.01
Spain	6,842	7,000	193	196	1.43
Turkey	1,337	1,350	34	34	0.28
W.Europe	105,489	110,945	276	289	22.74
East Germany	2,456	2,460	146	147	0.50
Bulgaria	1,509	1,600	173	183	0.33
Yugoslavia	2,001	1,950	94	91	0.40
Poland	7,752	7,900	228	230	1.62
Rumania	6,602	6,650	312	312	1.36
Czechoslovakia	9,290	9,400	629	634	1.93
Hungary	2,219	2,200	211	208	0.45
Europe	137,318	143,105	268	278	29.33
U.S.S.R.	102,968	105,500	405	411	21.62
Asia					
Taiwan	470	550	29	34	0.11
China	22,500	23,000	27	28	4.71
India	8,353	8,730	14	14	1.79
Japan	86,877	86,500	793	757	17.73
N. Korea	3,100	3,100	195	191	0.64
S. Korea	1,194	1,500	36	44	0.31
Thailand	40	40	1	1	0.01
Asia	122,534	123,420	56	55	25.30

Table 21 : continued

Country	Production x 000 tons		Output per capita kg		% World
	1975	1976	1975	1976	Output 197
America					
Argentina	1,038	1,100	41	43	0.23
Brazil	7,260	7,700	68	70	1.58
Chile	417	400	41	40	0.08
Canada	9,150	9,750	401	421	2.00
Colombia	297	260	12	10	0.05
Mexico	2,961	3,000	49	48	0.61
Peru	307	220	19	13	0.05
Venezuela	535	480	45	39	0.10
U.S.A.	72,505	79,150	339	368	16.22
America	94,470	102,060	170	180	20.92
Africa					
Egypt	250	250	7	7	0.05
S. Africa	5,197	5,720	204	215	1.17
Rhodesia	310	310	48	46	0.06
Africa	5,757	6,280	13	15	1.29
Australasia					
Australia	7,476	7,500	553	548	1.54
Australasia	7,476	7,500	356	352	1.54
WORLD	470,500	487,900	119	122	100.00

TECHNOLOGICAL PROFILE

ON

STEEL MAKING

CONTENTS

1. Introduction:

Pig iron consists of the element iron combined with numerous other chemical elements, the most common of which are carbon, manganese, phosphorus, sulphur and silicon. Depending upon the composition of the raw materials used in ironmaking - principally iron ore (beneficiated or otherwise), coke and limestone - and the manner in which the furnace is operated, pig iron may contain 3.0 to 4.5 per cent of carbon, 0.15 to 2.5 per cent or more of manganese, as much as 0.2 per cent of sulphur, 0.025 to 2.5 per cent of phosphorus and 0.5 to 4.0 per cent of silicon. In refining pig iron to convert it into steel all five of these elements must either be removed almost entirely or at least reduced drastically in amount.

Modern steelmaking processes, including the pneumatic processes, are divided into two general classes from the chemical standpoint : acid processes and basic processes. Carbon, manganese and silicon can be removed with relative ease by any of the processes, either acid or basic. The removal of phosphorus and sulphur requires special conditions that oan be met only by the basic processes wherein lime is added to the chemical system to form a basic slag that is capable of forming compounds with phosphorus and sulphur during refining operations, thereby removing them from the metal.

2. Processes:

There are five different processes of steelmaking with several modifications in each of these :

2.1 Open Hearth processes
2.2 Pneumatic processes
2.3 Continuous Steelmaking processes
2.4 Electric Steelmaking processes
2.5 Atomic Energy and Steelmaking

(2.1) Open Hearth processes:

The open hearth furnace is both reverberatory and regenerative. The charge is melted on a refractory hearth, which is shallow in relation to the length of the hearth by a flame passing over the charge so that both, the charge and the relatively low roof above the hearth, built of refractory brick, are heated by the flame. The hot gases from the combustion of fuel pass out of the reverberatory furnace chamber through passages into regenerative chambers containing fire brick.

There are two types of open hearth processes :

(a) Acid open hearth process : The hearth of the furnace is of acid brick construction. The initial charge consists of cold pig iron or oold pig iron and scrap. No ore can be added with the charge for iron oxide being a base, would react with the acid refractory lining and destroy it rapidly. For the same reason the melting of scrap alone would be undesirable for its oxidation products would have a simila detrimental effect.

In this process only silicon, manganese and carbon are eliminated and only a trace of phosphorus and none of the sulphur are eliminated. In fact the finished steel may contain a slightly higher percentage of both of these elements than the average of the charge.

The specifications for acid open-hearth pig iron usually desire :

Silicon	-	less than 1.5 per cent
Manganese	-	1.0 to 2.5 per cent
P and S	-	under 0.045 per cent
C	-	4.15 to 4.40 per cent

The composition of acid open-hearth slag is generally as follows :

SiO_2	-	52 to 56 per cent
FeO	-	20.5 to 29 "
MnO	-	10 to 20.5 "
P_2O_5	-	0.02 to 0.045 "
Al_2O_3	-	3.1 to 4.2 "
CaO	-	0.7 to 5.4 "
MgO	-	0.12 to trace "

(b) Basic open hearth process : The hearth of the furnace for the basic process is lined with basic refractory material like magnesite and burned dolomite to permit charging of limestone and use of a basic slag for removal of phosphorus and sulphur.

The specifications for basic open-hearth pig iron usually are :

Silicon	-	under 1.5 per cent
Manganese	-	0.4 to 2.0 per cent
Sulphur	-	under 0.05 per cent
Phosphorus	-	under 0.9 per cent
Carbon	-	3.5 to 4.40 per cent

The operation of basic open hearth process has undergone changes during the course of time. The earlier "ore practice" has been changed to "oxygen roof lance practice". The use of oxygen increases flame temperature and the rate of heat transfer to the charge, thereby speeding up melting of high scrap charges. It also compensates for deficiencies in air supply and regenerator capacity. In modern oxygen roof-lance practice, the flow of oxygen to the furnace is begun immediately after the addition of hot metal and is continued throughout most of the refining period. It has been reported that there is a saving in heat time of 10 to 25 per cent and a decrease in fuel consumption of 18 to 35 per cent when oxygen roof-lancing is adopted.

(2.2) Pneumatic processes:

In common with other steelmaking methods there are two chemical types of pneumatic processes - acid and basic. In both types air, high-purity oxygen or combination of these and other oxidizing gases are blown under pressure through, onto or over the surface of molten pig iron to produce steel. If air is used for blowing its nitrogen content serves no useful purpose and actually removes heat from the system.

Nitrogen absorbed during blowing is considered as an undesirable impurity in the finished steel.

There are several ways in which the oxidizing gas oan be supplied to a pneumatic process :

(i) Bottom-blown Converter:

The bottom-blown converter had been the principal type used in both, the acid and basic air-blown pneumatic processes for steel production. The blast travels full length of the molten bath, thus representing the extreme of submerged blowing practices.

The bottom-blown acid process known as acid Bessemer process, earlier produced the majority of the world's steel supply. Iron of the correct chemical composition and temperature is required for the process conforming, generally, to the following composition :

Silicon	-	1.1 to 1.7 per cent
Manganese	-	0.4 to 0.7 per cent
Phosphorus	-	0.09 per cent max.
Sulphur	-	0.03 per oent max.
Carbon	-	4.0 to 4.5 per cent

The blow to produce steel lasts for a period of only 10 to 15 minutes and speed of operation is very rapid. The ratio of silicon to manganese in pig iron should be 2 to 2.5, as the former is a source of heat. Oxygen enrichment of air-blast helps in reducing blowing time and permits greater utilization of cold iron and scrap.

Bottom-blown basic process known as basic Bessemer process or Thomas or Thomas-Gilchrist process was never extensively adopted in view of the development of the basic open-hearth process.

A typical blast-furnace iron for bottom-blown basic Bessemer process generally contains :

Silioon	-	0.2 to 0.5	per cent
Manganese	-	0.6 to 1.0	"
Phosphorus	-	1.4 to 2.0	"
Sulphur	-	0.03 to 0.05	"

The chemical composition and properties of steels produced by this method more olosely approach the composition and properties of basio open hearth steels of similar grade than do comparable steels made by the aoid Bessemer process. But the nitrogen content of the bottom-blown basic pneumatic steels is definitely higher than that of basic open-hearth steel. For this reason, the properties of air-blown steels made by the basio Bessemer process, while more similar to basic open-hearth steels than are acid Bessemer steels, are still inadequate for certain applications because of their higher strength, lower ductility and susceptibility to strain aging.

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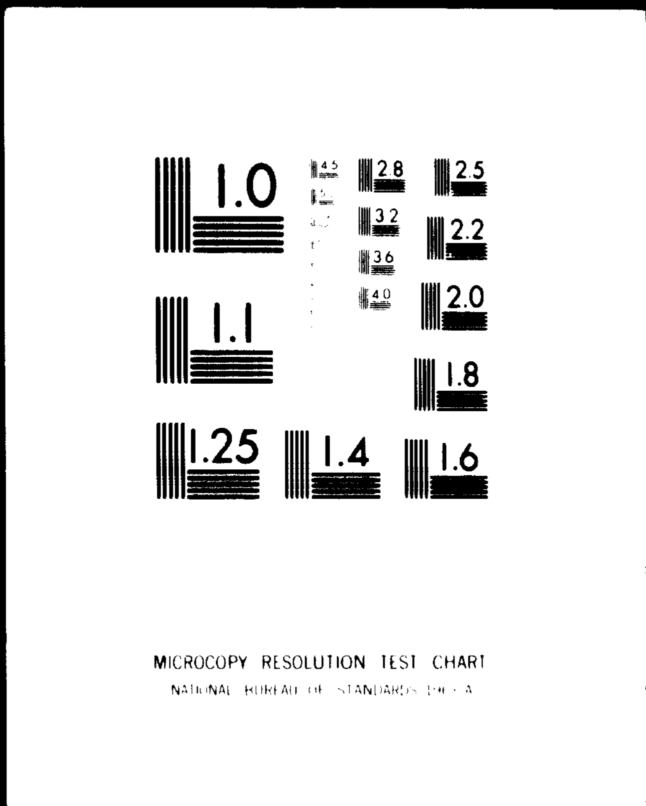
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

(ii) Side-blown Converter:

The chemical reactions which occur in the side-blown acid converter are similar to those occuring in the bottom-blown acid converter. However, in the former, all the tuyeres are above the liquid level of the bath and entering through the side of the vessel. The steel produced is much hotter from a similar iron charge than produced by the acid bottom-blown converter, and thus silicon content of the iron can be somewhat lower. Nitrogen content of the finished steel is obviously much lower than in the steel made by the bottom-blown acid process. By enriching the air blow by oxygen, the blowing time is reduced.

(iii) Stora-Kaldo process:

In this process oxygen is introduced at an angle with respect to the surface of the liquid metal bath contained in a tilted, rotating vessel. In contrast to bottom-blown Bessemer vessels and top-blown oxygen vessels, the Kaldo furnace is tilted at about 15 to 20 degrees from the horizontal while operating and can be rotated about its longitadinal axis at speeds upto 30 revolutions per minute.

As in all top-blown pneumatic processes, phosphorus is eliminated simultaneously with carbon, unlike in the basic Bessemer process where it is eliminated only after all the carbon has been removed.

(iv) Rotor Process:

The process developed in Oberhausen, FRG., and often referred to as Oberhausen process, employs the same rotary principle as the Kaldo process except that the speed of rotation is $\frac{1}{2}$ to 2 revolutions per minute. Another distinct feature is that two oxygen lances, one for high purity oxygen and the other for commercial variety of oxygen, are used. Tap to tap time for a 66 ton vessel is about 2 hours.

(v) LD Process:

In the basic oxygen process, substantially pure oxygen is introduced from above the surface of the bath in a basic-lined vessel. The LD process (Linz-Donawitz process) was developed in Austria and was initially designed to employ pig iron produced from local ores that are high in manganese and low in phosphorus contents. The basic oxygen process has readily been adapted to the processing of pig iron of medium and high phosphorus contents. The phenomenal growth of the LD process out-stripped steel production by the basic open-hearth process. All grades of steel including high carbon, low alloy and stainless, are now being produced by LD process.

The process has been extensively employed, particularly in Japan, USA and Europe. Continued improvement in this technology has enabled reduction of heat time to 30 to 40 minutes from earlier time of 50 to 60 minutes. This has been mainly possible due to intensified oxygen blowing rate and use of multi-hole lance. A 400-ton converter at August-Thyssen-Hütte employs a 7-hole lance capable of blowing about 1,4000 cubic meter of oxygen per minute. The tap to tap time is about 35 to 40 minutes.

To enable higher scrap usage in the LD process from the normal 20 to 30 per cent to 40 to 50 per cent, pre-heating of the scrap by oxy-fuel lance and using of silicon carbide and calcium carbide have been adopted.

Continuous improvements in the quality of refractory lining have increased lining life of 400 to 800 heats to, in some cases, upto about 2000 heats. Besides the quality of lining and use of dolomitic lime as part of the flux charge improved operating techniques and control of silicon content of the hot metal have influenced the lining life.

Table 1 shows a list of LD installations in the different countries.

Table 1 : World LD steel capacity

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m.tons raw steel) Existing	To be added
ALGERIA				
SNS:				
El-Hadjar	2x65	1972	0.45	
	3x85	1979		1.30
Siderurgie Ouest		1983/88		10.00
		TOTAL	0.45	11.30
ARGENTINA				
Somisa:				
San Nicholas	2x170	1973	1.60	
	1x170	1977		1.25
		TOTAL	1.60	1.25
AUSTRALIA				
BHP:				
Newcastle	2x220	1962	2.35	
	1x55	1967	0.35	
	1x70	1981		0.25
	2x225	1986		2.00
Whyalla	2x120	1965	1.24	
Port Kembla	2x260	1973	2.78	
Kwinana	1x65	1981		0.56
		TOTAL	6.72	2.81
AUSTRIA				
Linz	3x35	1952/56	0.60	
	3x55	1959/68	1.30	
Voest-Alpine	2x145	1973/76	2.00	
Donawitz	3x65	1953/74	1.30	
		TOTAL	5.20	
BELGIUM				
Cockerill:				
Chertal	3x165	1963/68	2.50	
Seraing	2x225	1965	2.00	
Marchienne	1x40	1965	0.20	
	1x70	1973	0.45	
Forges de Clabecq:				
Ittre	2x83	1964/69	1.30	
Sidmar: Gent	2x285	1967	3.20	
Hainaut-Sambre:				
Montignies-sur-Sambre	3x180	1969/72	3.50	
Boel: La Louviere	3x85	1967/71	2.00	
		TOTAL	15.15	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
BRAZIL				
Acesita: Timoteo	1x35	1972	0.18	
	1x80	1978		0.38
	2x80			0.78
Belgo-Mineira: Joao Monlevade	2x40	1957	0.50	0.10
Siderurgica Mannesmann: Belo Horizonte	2x30	1963	0.40	1.00
Volta Redonda	2x200	1977	2.48	
CSN:	1x200	1980		2.12
Piacuagera	3x85	1965/77	1.50	
Cosipa	3x120	1978/80		1.80
Siderurgica Tubarao: Tubarao	2x300	1980		2.70
Barra Mansa: Barra Mansa	2x15	1971	0.12	
Usiminas: Ipatinga	3x80	1963/73	1.60	
	2x160	1973	0.60	
		TOTAL	7.38	8.92
BULGARIA				
Kremikovtsi: Kremikovtsi	3x100	1966	1.70	
		TOTAL	1.70	
CANADA				
Algoma Saults Ste. Marie, Ont.	3x100	1958/64	1.32	
	2x227	1973	2.54	
Hamilton, Ont.	3x150	1954/66	2.80	
Dofasco:	1x300	1977		1.20
Hamilton, Ont.	3x127	1971	2.54	
Stelco: Nanticoke, Ont.	2x227	1980		1.18
		TOTAL	9.20	2.38
CHILE				
Cap: Talcahuano	2x110	1976	1.10	0.91
		TOTAL	1.10	0.91
CHINA				
Maanshan: Maanshan, Anwei	5x-	1970		
San-ming: San-ming, Fukien	3x6	1970		

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
CHINA, cont.				
Capital:				
Shih-Chingshan, Hopei	3x30	1965/66	0.50	
Hantan:				
Hantan, Hopei	x			
Wu-Han:				
Wu-Han, Hopei	1x-	1970		
Lienyuan:				
Lienyuan, Hunan	1x-	1969		
Huhehot:				
Huhehot, Inner Mongolia	x			
Paotou:				
Paotou, Inner Mongolia	2x-	1970	0.50	
Nanking:				
Nanking, Kiangsu	x			
Liu-Chow Municipal Foundry:				
Liu-Chow, Kwangsi	3x-	1970		
Canton:				
Canton, Kwangtung	2x-	1969/70		
Hainan:				
Hainan, Kwangtung	1x-	1970		
Anshan:				
Anshan, Liao-ning	2x(lge)		1.50	
Shanghai:				
Shanghai, Shanghai	3x35	1966	0.40	
	1x120	1970	0.70	
Tai-Yuan:				
Tai-Yuan, Shansi	2x55	1969	0.55	
Yen-T'ai:				
Yen-T'ai, Shantung	1x-	1968		
Sian:				
Sian, Shenhsi	1x3	1970		
Kunming:				
Anning, Yunnan	1x-	1970		
		TOTAL	4.15	
TAIWAN				
China Steel Corp.				
Kaohsiung, Taiwan	2x150	1977	1.50	
		TOTAL	1.50	
CZECHOSLOVAKIA				
East Slovak:				
Kosice	3x110	1966/67/80	2.20	0.80
	2x150	1974	1.50	
		TOTAL	3.70	0.80
EGYPT				
Egyptian Iron+Steel:				
Helwan	3x70	1974/76	1.20	
		TOTAL	1.20	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
FINLAND				
Koverhar:				
Lappohja	2x50	1971	0.55	
Rautaruukki:				
Raahe	3x75	1967/76	1.60	
		TOTAL	2.15	
FRANCE				
Acierie de Marpent et Hydraulique du Nord:				
Marpent	1x3	1961	0.01	
Acieries du Furan:				
Saint Etienne	1x2	1962	0.02	
Cockerill: Rehon	1x30	1963	0.16	
Creusot-Loire Usine des Dunes:				
Dunkerque	1x60	1971	0.40	
Pont-a-Mousson:				
Fumel	1x2	1963	0.01	
Sté Métallurgique de Normandie:				
Mondeville	1x65	1967	0.40	
	2x85	1977		1.00
Sté. Nouvelles des Acieries de Pompey:				
Pompey	2x85	1964	0.60	
Sacilor:				
Gandrange	2x250	1971	2.50	
Solmer:				
Fos-sur-Mer	2x200	1974	3.50	
Usinor:				
Denain	4x60	1964/71	1.80	
Dunkerque	3x160	1962	3.50	
	3x220	1972	4.50	
		TOTAL	17.40	1.00
WEST GERMANY				
Dillinger:				
Dillingen, Saar	2x200	1968	2.00	
Thyssen AG:				
Beeckerwerth	3x255	1962	6.60	
Bruckhausen	2x385	1969	5.45	
Ruhrort	4x125	1962/68	4.30	
Thyssen Henrichshütte:				
Hattingen	1x150	1970	1.50	
Krupp:				
Rheinhausen	2x300	1975	3.00	
	3x115	1964/67	2.00	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel)	
			Existing	To be added
WEST GERMANY, cont.				
Hoesch:				
Dortmund-Hoerde	3x180	1963/66	4.20	
Kloeckner:				
Bremen	2x275	1968	3.60	
Mannesmann:				
Duisburg-Huckingen	2x220	1966	2.76	0.24
	3x50	1967	1.20	
Rheinstahl:				
Hattingen	see Thyssen Henrichshütte above			
Peine-Salzgitter:				
Peine	3x50	1964	1.91	
Salzgitter	3x210	1968/77	4.50	
Roechling-Burbach:				
Burbach, Saar	2x110	1972/75	2.50	
Volkingen, Saar	3x140	1980		2.30
		TOTAL	45.52	2.54
GREECE				
Halyvourgiki:				
Efesis	2x45	1963	0.45	
	2x45	1970	0.45	
		TOTAL	0.90	
HUNGARY				
Danube:				
Dunaujvaros	2x110	1979		1.10
		TOTAL		1.10
INDIA				
Bokaro:				
Bokaro Steel City, Bihar	3x100	1973/76	1.28	
	2x100	)		4.00
	2x300	)		
Hindustan:				
Rourkela	3x50	1959/60)	1.60	
	2x60	1966/67)		
Maharashtra Elektrosmelt:				
Chandrapur, Maharashtra	2x15	1978		0.15
Visvesvaraya:				
Bhadravati	2x15	1965	0.08	0.03
		TOTAL	2.96	4.18
IRAN				
NISC: Aria Mehr	3x100	1972/76	2.00	
		TOTAL	2.00	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
ITALY				
Piombino:				
Piombino	3x100	1970	1.50	0.50
Italsider:				
Bagnoli	3x150	1964	2.40	
Taranto	3x310	1964	4.70	
	3x350	1973	5.80	
Cogne: Aosta	2x60	1970	0.22	
		TOTAL	14.62	0.50
JAPAN				
Kawasaki:				
Chiba No. 1	2x85	1970	1.15	
Chiba No. 2	3x150	1962/65	4.26	
Mizushima No. 1	3x180	1967/69	4.90	
Mizushima No. 2	3x250	1970/73	7.40	
Kobe:				
Kobe	3x80	1961/66	2.30	
Amagasaki	2x40	1960	0.70	
Kakogawa	3x235	1970/73	6.00	3.00
Nakoyama:				
Funamachi	2x65	1975	0.90	
Mizuo	3x90	1960/62	1.65	
NKK:				
Fukuyama No. 1	3x200	1966/68	5.50	
Fukuyama No. 2	3x275	1969/71	7.60	
Fukuyama No. 3	3x330	1973	4.40	
Ogishima	3x275	1976/79	3.00	3.00
Nippon Steel:				
Yawata No. 1	1x150	1974	1.50	
Yawata No. 2	3x150	1962/70	4.30	
Yawata No. 3	2x75	1966/67	2.00	
Yawata No. 5	2x60	1957/64	0.70	
Muroran No. 1	2x50	1964/67	0.60	
Muroran No. 2	3x110	1961/67	3.60	
Muroran No. 3	2x270	1977		2.60
Kamaishi	2x90	1965	1.40	
Hirohata No. 1	2x100	1960/65	1.50	
Hirohata No. 2	3x100	1968/73	2.70	
Nagoya No. 1	3x160	1964/67	3.80	
Nagoya No. 2	2x250	1969	3.20	
Sakai	3x170	1965/67	4.50	
Kimitsu No. 1	3x220	1968/69	5.90	
Kimitsu No. 2	2x300	1971	[illegible]	
Oita	3x340	1972/76	[illegible]	
Tokai Special Steel:				
Nagoya	2x75	1968	0.80	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel)	
			Existing	To be added
JAPAN, cont.				
Nisshin:				
Shunan	2x45	1970	0.33	
Kure	3x90	1965	2.70	
	1x150	1977		2.60
Osaka Iron + Steel:				
Nishijima	2x40	1964	0.50	
Sumitomo Metal Industries:				
Kokura No. 1	2x70	1961	1.04	
Kokura No. 2	3x70	1970/76	2.08	
Wakayama No. 1	1x70	1968	0.60	
Wakayama No.2	3x160	1963	3.83	
Wakayama No. 3	3x160	1967	4.64	
Kashima No. 1	3x250	1971	6.00	
Kashima No. 2	2x250	1974	3.00	
		TOTAL	122.78	11.20
LUXEMBOURG				
Arbed:				
Dudelange	1x77	1962	0.98	
Esch-Schifflange	1x80	1976	0.96	
	1x80	1978		0.96
Esch-Belval	2x150	1976	2.00	
Differdange	1x160	1973	2.10	
Rodange-Athus:				
Rodange	1x25	1965	0.10	
		TOTAL	6.14	0.96
MALAYSIA				
Malayawata:				
Prai/Penang	2x15	1967	0.18	
		TOTAL	0.18	
MEXICO				
Ahmsa:				
Monclova	3x80	1971/74	1.40	
	1x125	1976	0.80	
Fundidora Monterrey:				
Monterrey	2x150	1975	1.50	
Sicartsa:				
Lazaro Cardenas, Mich.	2x100	1976	1.30	
	2x200	1979		2.35
	1x200	1988		2.35
	1x100	1990		1.30
		TOTAL	5.00	6.00
MOROCCO				
Sonasid: Nador	2x105	1980		1.00
		TOTAL		1.00

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel)	
			Existing	To be added
NETHERLANDS				
Hoogovens:				
Umuiden	3x100	1958/61	2.45	
	3x300	1968/76	4.70	
		TOTAL	7.15	
NORWAY				
Norsk Jernverk:				
Moi Rana	2x70	1976	0.70	
		TOTAL	0.70	
PERU				
Siderperu:				
Chimbote	2x35	1966	0.33	
	2x180	1982		1.80
		TOTAL	0.33	1.80
PHILIPPINES				
National Steel Corp.:				
Iligan City	1x25	1979		0.12
Tagoloan, Misamis Or.	2x200	1982/83		2.00
		TOTAL		2.12
POLAND				
Huta Im. Lenina:				
Krakow	3x120	1966/71	3.50	
Katowice:				
Katowice	3x350	1976/79	4.50	4.00
		TOTAL	8.00	4.00
PORTUGAL				
Siderurgia Nacional:				
Seixal	2x45	1961	0.50	
		TOTAL	0.50	
RUMANIA				
Galati: Galati	3x150	1968/69	3.50	
	3x150	1975	3.50	
	3x150	1979/80		3.50
		TOTAL	7.00	3.50
SOUTH AFRICA				
Highveld:				
Witbank	2x60	1968	0.60	
	3x60	1977/78		0.75
Iscor:	2x300	1987/88		3.00
Newcastle	3x150	1974/75	2.80	
Vanderbijlpark	3x150	1974/75	3.29	
	3x150	1985/86		3.29
Pretoria	3x160	1990/91		3.50
		TOTAL	6.69	10.54

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
SOUTH KOREA				
Pohang: Pohang	3x100	1973/76	2.20	
		TOTAL	2.20	
SPAIN				
AHV:				
Sestao	3x70	1967/69	1.50	
Sagunto	3x40	1969/76	1.00	
Aviles	3x65	1966	1.45	
Ensidesa:	3x100	1969/-	1.20	1.13
Gijon, Verina	3x125	1971	2.43	
		TOTAL	7.58	1.13
SWEDEN				
Fagersta: Fagersta	2x40	1962/69	0.17	
Granges:				
Oxelosund	1x180	1977		1.80
Norrbotten: Lulea	2x105	1972/75	1.80	
		TOTAL	1.97	1.80
TUNISIA				
Elfouladh:				
Menzel-Bourgiba	2x15	1965	0.18	
		TOTAL	0.18	
TURKEY				
Eregli: Eregli	3x90	1965/76	1.80	
Turkiye Demir ve Celik Isletmeleri:				
Iskenderun	3x130	1977/80	1.10	1.30
Karabuk	2x100	1980		1.00
		TOTAL	2.90	2.30
UNITED KINGDOM				
BSC, General Steels:				
Scunthorpe	3x300	1973	4.50	
Normanby Park, Scunthorpe	2x85	1964	1.00	
BSC, Teeside:				
Consett	2x165	1968/73	1.30	
Lackenby	3x260	1971/72/-	2.11	2.56
BSC, Scottish:				
Motherwell	2x125	1964/-	1.20	2.00
BSC, Welsh:				
Ebbw Vale	3x50	1963	0.70	
Llanwern	3x170	1962	3.50	
Port Talbot	2x320	1969	3.00	
		1981/85		3.00

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
UNITED KINGDOM, cont.				
BSC, Tubes:				
Corby	3x130	1965	1.30	
		TOTAL	18.61	7.55
USA				
Alan Wood:				
Conshohocken, Pa.	2x150	1968	1.25	
Allegheny Ludlum:				
Natrona, Pa.	2x80	1966	0.60	
Armco:				
Ashland, Ky.	2x180	1963	2.00	
Middletown, Ohio	2x210	1969	2.00	
Bethlehem:				
Lackawanna, N.Y.	3x300	1964/66	4.70	
Sparrow Point, Md.	2x215	1966	3.20	
Bethlehem, Pa.	2x270	1968	2.70	
Burns Harbor, Ind.	2x300	1969	4.30	
	1x300	1978		1.00
Johnstown, Pa.	2x200	1978		2.30
CF + I:				
Pueblo, Colo.	2x120	1961	1.30	
Crucible:				
Midland, Pa.	2x105	1968	0.90	
Ford Motor:				
Dearborn, Mich.	2x250	1964	2.90	
Inland:				
East Chicago, Ind.	2x255	1966	4.00	
	2x210	1974	2.20	
Interlake:				
Chicago, Ill.	2x75	1959	0.96	
Jones + Laughlin:				
Aliquippa, Pa.	2x80	1957	1.00	
	3x190	1968	3.00	
Cleveland, Ohio	2x205	1961	2.25	
Kaiser:				
Fontana, Calif.	3x120	1958	1.50	
	2x220	1978		2.30
McLouth:				
Trenton, Mich.	5x110	1958/69	2.80	
National Steel:				
Great Lakes Div.:				
Ecorse, Mich.	2x285	1962	3.60	
	2x235	1970	2.00	
Weirton Steel Div.:				
Weirton, W.Va.	2x360	1967	4.00	
Granite City:				
Granite City, Ill.	2x235	1967	2.20	

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
USA, cont.				
Republic:				
Warren, Ohio	2x190	1965	2.50	
Gadsden, Ala.	2x180	1965	1.50	
Cleveland, Ohio	2x245	1966	2.80	
Buffalo, N.Y.	2x130	1970	1.00	
Sharon:				
Farrell, Pa.	1x150	1974	1.00	
US Steel:				
Duquesne, Pa.	2x215	1963	2.60	
Gary, Ind.	3x215	1965	4.40	
South Chicago, Ill.	3x200	1969	4.10	
Lorain, Ohio	2x225	1971	2.80	
Braddock, Pa.	2x230	1972	2.60	
Wheeling-Pittsburgh:				
Monessen, Pa.	2x200	1964	1.80	
Steubenville, Ohio	2x285	1965	2.70	
Wisconsin Steel:				
South Chicago, Ill.	2x120	1964	1.20	
Youngstown:				
East Chicago, Ind.	2x285	1970	3.00	
	SHORT TON TOTAL		89.36	5.60
	EQUIVALENT METRIC TON TOTAL		81.06	5.10
USSR				
Dnepropetrovsk, Ukraine	3x50	1967/68	0.80	
Krivoi-Rog, Ukraine	3x100	1958	1.80	
	3x130	1965/71	2.60	
Yenakiyevo, Ukraine	3x130	1968/69	2.60	
Iyich: Zhdanov, Ukraine	3x100	1964/65	2.00	
	1x250		2.00	
Azovstal:Zhdanov, Ukraine	2x350			3.50
Dzerzhinsk, Ukraine	2x450			4.00
Makeyevskiy:				
Kirov (Central Russia)	2x270		3.00	
Cherepovets (")	2x400			4.00
Novolipetsk:				
Lipetsk, Cetral Russia	3x160	1966	3.50	
	3x300	1974/78	3.00	3.00
Magnitogorsk, Urals	3x350			7.00
Novo-Tagil:				
Nizhniy-Tagil, Urals	3x100	1963/67	2.00	
	2x300			3.00
Chelyabinsk:				
Chelyabinsk, Urals	3x125	1969	2.20	
West Siberian:				
Antonovskaya, W.Siberia	3x130	1969	2.20	
	3x300	1973/77	3.00	3.00
	2x270			2.70

Table 1 : continued

Company L/D plant location	No. of Converters output per heat (tons raw steel)	Start up date	Annual capacity (mill. m. tons raw steel) Existing	To be added
USSR, cont.				
Kuznetski:				
Novokuznetsk, W.Siberia	2x300			3.00
East Siberian:				
Svobodnij, E.Siberia	2x300			3.00
Karaganda, Kazakh	3x250	1970/72	4.50	
	3x250			4.50
	3x300		5.00	
Kazakhsk:				
Temir-Tau, Kazakh	2x350			3.50
		TOTAL	40.20	44.20
VENEZUELA				
Zulia: Maracaibo	3x300			6.00
		TOTAL		6.00
YUGOSLAVIA				
Skopje: Skopje	2x110	1967/-	0.70	0.70
Zenica: Zenica	2x110	1976	1.10	
Smederevo:				
Smederevo	3x100	1975/80	0.90	0.80
		TOTAL	2.70	1.50
		WORLD TOTAL	366.459	148.38

Source : Metal Bulletin Monthly - August 1977

(vi) Bottom Blowing Oxygen Process:

(a) OBM Process:

It had been felt that blowing pure oxygen through the converter bottom would have the inherent advantages of a quieter blow and better mixing. The OBM (Oxygen Bottom Maxhütte) process was developed by Eisenwerk-Gesellschaft Maximilianshütte mbH. in FRG, jointly with L'Aire Liquide of Montreal, Canada, and the first heat was made in December 1967. By March 1968, regular production was started. The unique feature of the process is shielding of the oxygen tuyere by a larger diameter pipe through the annulas of which hydrocarbons, such as propane or natural gas, is blown. The endothermic decomposition of the hydrocarbon at the mouth of the tuyere effectively cool the tuyere. With this concentric tuyere, pure oxygen could be introduoed into a steel bath without excessive refractory erosion.

The vessel for OBM process is similar to the Bessemer converter except for only six to fifteen tuyeres as against 250 to 300 in the Thomas converters. The inner oxygen tube is made of copper and the outer tube is of stainless steel. The converter shell is lined with dolomite bricks and the bottom is rammed with tar dolomite. Oxygen with lime powder is injected through the inner pipe and natural gas through the outer tube. The incoming of natural gas is about 9 kg per cm^2, whioh is reduced to about 4 kg per cm^2 and the flow rate is about 300 m^3 per hour. The line pressure of oxygen is about 15 kg per cm^2 which is reduced to about 13 kg per cm^2 in the converter. The oxygen flow rate can be varied from 4,000 to 10,000 m^3 per hour. The ratio of oxygen to natural gas for ignition is approximately 9:1 and during the blowing period this is reduced to 30:1. Natural gas consumption averages 6 m^3 per ton of steel and oxygen consumption about 64 m^3 per ton.

OBM vs. LD processes:

The advantage of the OBM process in comparison with the oxygen top-blowing processes are mainly as follows :

(i) Unlike the oxygen top-blowing process, only about a quarter of the iron is evaporated; consequently, less red fumes are developed.

(ii) The iron oxide content of the slag which in contrast with other steelmaking methods, approaches equilibrium with the metal bath, is substantially lower.

Due to (i) and (ii) above, the yield is increased by about 2.5 per cent compared with the oxygen top-blowing processes which means a decisive economic advantage of the OBM prooess.

(iii) The intense agitation of the bath by the introduction of the refining gas through the bottom leads to a more rapid dissolution of the scrap, whereby the total refining time in the converter is reduced to 10 minutes.

(iv) The simultaneous introduction of lime powder and oxygen permits to obtain a completely slopping-free refining which is far-reaching and independent of the pig iron composition. Besides advantages relating to process control, also the design of the gas-cleaning equipment is affected thereby in a favourable way.

(v) The amount of scrap to be processed by the OBM process is increased by about 35 per cent compared with the oxygen top-blowing processes. The reasons are: the lower iron evaporation losses; the elimination of cooled lances; shorter refining time; and the possibility of pre-heating the converter during charging operation by introducing through tuyeres oxygen and natural gas in stoichiometric ratio.

(vi) OBM plants require only two thirds of the building height than for oxygen top-blowing processes. For this reason, OBM converters are particularly suitable to be installed in existing open-hearth steel plants.

(vii) Due to the short blowing periods and the completely slopping-free blowing behaviour, a considerable increase in production can also be achieved in case of large OBM converters in comparison with LD converters.

(b) <u>LWS Process:</u>

A variation of OBM process is the LWS process (Creusot-Loire and Wendel-Sidelor with Sprunck and Co.). In LWS process fuel oil is used for shielding the oxygen stream instead of natural gas. The first commercial operation started in 1971 in a 30-ton converter and the process, like OBM, is used for refining high-phosphorus iron. The use of oil in LWS process ensures better safety in operation compared to the use of propane or natural gas. The process is expected to be attractive in places where natural gas is not available and propane is expensive.

(c) <u>Q-BOP Process:</u>

The OBM process was adopted by U.S. Steel to large furnaces and was termed as Q-BOP process. The letter 'Q' stands for 'quiet, quick, quality' and emphasizes the advantages of the oxygen bottom-blowing process.

The metallurgical performance of the Q-BOP has proved to be excellent. Phosphorus could be removed to low level. The ability to introduce powdered lime into the steel bath results in good desulphurization and steels with S content of 0.02 per cent are produced from hot metal containing 0.07 per cent sulphur. Nitrogen levels at turndown are generally below 0.0025 per cent and hydrogen content as about 2.6 ppm.

The process developed for treating low phosphorus iron and for adoption on large converters for high tonnages has elaborated tuyere-gas control system to ensure that the different gases are supplied in the right quantity and sequence to the converter. The blowing time for a 200-ton Q-BOP converter is about 12 minutes, as against 17 minutes for LD converter.

(d) SIP Process:

The submerged injection process SIP is an offshoot of the OBM process and was developed by the Sydney Steel Corporation, Canada, on their 200-ton tilting open-hearth furnace. The tuyeres are located below the bath on the back slope of the hearth. The refining time is reduced to some 12 minutes for an oxygen rate of about 900 m^3 per minute.

Advantages claimed for SIP are high production rates, 2 to 4 per cent increase in yield and less particle content in the waste gases due to quiet bath conditions. Since the endburners as in the conventional open-hearth are retained, the scrap melting ability of SIP is more than the other processes and there is no difficulty in melting upto 60 per cent scrap in the charge. Results of experimental heats in U.S. Steel's 30-ton Q-BOP converter indicate that rimmed and mechanically-capped low carbon steels of both hot and cold rolled quality; deep drawing tin-plate and other tin mill products including corrosion resistance types; structural quality plates including carbon-manganese steels and low alloy high strength steels, as well as high carbon rail steels are comparable to similar products from conventional open-hearth furnace or LD converter.

It has been estimated that the capital investment on bottom-blowing installation is expected to be lower than that on LD plants. A study recently completed by Dasturco, India, has shown the revamping and augmenting the capacity of a Thomas converter shop in Egypt, could be achieved at half the cost for OBM converter as against with revamping with installation of LD converter. Similarly, the conversion of existing open-hearth shops by installation of bottom-blown converters is expected to be more economical than LD.

Currently, the capacity of the oxygen bottom-blowing installations is about 18 million tons. The worldwide list of oxygen bottom-blowing converter installations is given in Table 2.

Table 2 : World Oxygen Bottom-Blown Plants

Country and Company	Location	Process	Start up	No.	Converters Heat tons	Capacity Crude Steel mill. tons
FRG						
Eisenwerk-Gesellschaft Maximilianshuette GmbH.	Salzbach-Rozenberg	OBM	1967	6	35	1.10
Stahlwerke Roechling-Burbach GmbH.	Voelklingen	OBM	1969	2	45	0.55
France						
Societé des Acieries et Trafileries de Neuves-Maison	Chatillon	OBM	1969	4	35	0.60
Wendel-Sidelor	Valenciennes	OBM	1970	3	80	0.90
	Hagondange	LWS	1973	2	50	0.60
	Rombas	LWS	1971	1	35	0.30
Cockerill-Ougre-Province	Rehon	OBM	1973	2	25	0.40
Societé des Hauts Fourneaux de las Chiers	Longwy	LWS	1973	2	25	0.40
Union Siderurgique du Nord et L'est de la France (USINOR)	Longwy	OBM	1970	2	45	0.40
Belgium						
Cockerill-Ougre-Province	Marchienne	OBM	1971	2	40	0.44
Forges de Thy-Marcinelle et Monceau	Monceau	OBM	1971	4	40	0.88
Luxembourg						
Miniere et Metallurgique de Rodange	Rodange	OBM	1970	4	30	0.66
South Africa						
South African Iron and Steel Industrial Corp. Ltd.	Pretoria	OBM	1971	1	40	0.30

Table 2 : continued

Country and Company	Location	Process	Start up	No.	Converters Heat tons	Capacity Crude Ste mill.tons
United States U.S.Steel Corporation	South Works Chicago	Q-BOP	1971	1	30	
	Fairfield Works	Q-BOP	1974	2	200	3.50
	Gary Works	Q-BOP	1973	3	200	5.00
Canada Sydney Steel Corp.	Sydney	SIP	1971	3	225	1.25
Sweden Surahammars Bruks AB	Surahammar	OBM	1974	1	40	0.15
		TOTAL				17.43

Source : SEAISI - Jan. 1976

Table 3 gives the trend of development of oxygen processes during the last decade in the different regions of the world.

Table 3 : Development of Oxygen Processes
(in million tons)

Year and Process	Canada and USA	Latin America	Eastern Europe	Western Europe	Middle East	Africa	Austral-asia	Total: In mill.tons	Total: Per cent
1965									
LD	26.39	0.99	4.59	30.67	0.50	-	29.41	92.55	93.7
Kaldo	0.90	-	-	3.33	-	-	0.30	4.53	4.6
Q-BOP	-	-	-	-	-	-	-	-	-
Others	-	-	-	0.75	-	0.90	-	1.65	1.7
Total	27.29	0.99	4.59	34.75	0.50	0.90	29.71	98.73	100.0
1970									
LD	70.27	2.58	29.58	78.30	0.63	0.56	86.58	268.50	96.6
Kaldo	0.95	-	-	4.85	-	-	-	5.80	2.0
Q-BOP	-	-	-	2.11	-	-	-	2.11	0.8
Others	-	-	-	0.30	-	1.25	-	1.55	0.6
Total	71.22	2.58	29.58	85.56	0.63	1.81	86.58	277.96	100.0
1975									
LD	90.07	7.66	61.77	132.09	2.27	7.14	129.16	430.16	94.7
Kaldo	-	-	-	4.20	-	-	-	4.20	0.9
Q-BOP	8.00	-	-	10.42	-	-	-	18.42	4.1
Others	-	-	-	-	-	1.36	-	1.36	0.3
Total	98.07	7.66	61.77	146.71	2.27	8.50	129.16	454.14	100.0

It can be seen that despite metallurgioal advantages of Kaldo and Rotor processes there has been no development for these processes owing to their complexity. The Q-BOP process is becoming increasingly popular.

(2.3) Continuous Steelmaking Processes

Considerable experimental work has been carried out on the continuous steelmaking processes. The following are the different processes which are under development stage :

(i) IRSID process
(ii) WORCRA process
(iii) HEARTH process
(iv) BISRA process
(v) NRIM process

(i) IRSID process:

In this process the actual refining takes place in a reaotor fed with regular and known flow of hot metal by means of oxygen supplied through a vertical lance, which also injects fluxes for slag formation. The metal-slag mixture flows into a second vessel where separation takes place. Oxygen consumption is about 48 m^3 per ton of steel and the yield of metal is around 96 per cent.

(ii) WORCRA process:

The process developed in Australia consists of continuous conversion of iron ore to steel by fast smelting of composite pellets in a low shaft furnace with sequential refining of the molten hot metal in a launder-like furnace. The iron yield is reported to be 99 per cent. Lime consumption is said to be 40 to 50 per cent less than that of LD converter and oxygen consumption is less by 15 to 20 per oent.

(iii) HEARTH process:

Steelmaking is carried out by this prooess developed in USSR in a system of open baths. The flow of metal from bath to bath occurs by gravity because of difference in levels and the capacity of each bath is 35 kg. Eaoh bath carries out some specific part of steelmaking process. The furnace is fired with natural gas using pre-heated air for combustion. Oxygen (10 to 25 m^3 per ton of iron) is injected into the bath means of lances.

(iv) BISRA process:

In the spray steelmaking process developed jointly by BISRA and Million Iron Works in U.K., a stream of molten pig iron is exposed to intimate oxidation reaction with oxygen jets. Slag formation is achieved by injecting powdered lime with oxygen. Oxygen oonsumption is reported to be about 55 m^3 per ton of steel.

(v) NRIM process:

The process, in experimental stage, consists of multi-stage trough-type furnaces and has been developed in Japan.

(2.4) Electric Steelmaking Processes:

Electric current can be used for heating in two ways : (i) by utilizing the heat generated in electrical conductors by their inherent resistance to the flow of current and (ii) by utilizing the heat radiated by the electric arc.

(i) Resistance method - two general methods of heating by resistance are possible : (a) the indirect method in which the charge is heated by radiation and conduction from separate resistors through which current is passed. This method, however, is impracticable for steelmaking; (b) the direct method in which the current is passed through the metal charge or bath itself. A high-voltage low-amperage current is transformed to low-voltage high-amperage current and passed through the bath or charge. The bath acts as a secondary circuit for the current which is generated from a primary circuit by induction. This method is therefore called induction heating.

(ii) Electric arc method - arc heating may be applied in two general ways : (a) the arcs may be made between electrodes supported above the metal in the furnace which thus is heated solely by radiation from the arc. This is commonly known as indirect-arc heating; and (b) the arc may be made between the electrodes and the metal. This method, known as direct-arc heating allows current to flow through the bath, so that heat developed by the electrical resistance of the metal is added to that radiated from the arcs. This system using a non-conduction bottom, has been successful in steelmaking in electric furnaces.

There are three different types of furnaces used for steelmaking:

(i) the open-bath arc furnace which is comparable to an open-hearth furnace
(ii) the electric shaft furnace which is the electrical version of the blast furnace
(iii) the low-shaft or submerged arc furnace which lies between the first two.

(i) Open-bath furnaces: In open-bath furnaces, the electrode is in contact with the slag, but it is not immersed in the solid charge. The furnace operates as on isothermal zone where the reactions are limited to the direct reduction of the oxides, the eventual carburization of the liquid metal and the formation of slag.

A recent development of the furnace is the Lubatti furnaoe whose bath is not actually open but is rather covered by a very small layer of charge material.

The Strategic-Udy process employs this type of furnace using preheated highly reduced material. A 33,000 kva industrial unit has been commissed in Venezuela sometime back.

(ii) Electric shaft furnace: A few furnaces of this type were made (500 - 600 kw at Domnarvat, Sweden), but the performance was not quite satisfactory in comparison to that of open-bath or the submerged arc furnaces. The furnaces did not become popular and were finally abandoned.

(iii) Submerged arc furnaces: One of the first furnace of the submerged arc type was made by Heroult. These designs were later industrially developed by Tysland and Hole. Today, most of the electric ironmaking plants make use of the submerged arc furnace. Tysland-Hole furnaces of 50,000 kva capacity or more are operating in several parts of the world. A 60,000 kva furnace has been constructed and is operating at Mo-i-Rana.

From the time of its invention, the electric furnace has been devoted to the making of special steels and has therefore been characterized by modest heat size and low hourly output. Its potential increased towards the 1960s, which led to the UHP (Ultra high power) concept. The main features of this technique are :

(a) an increase in transformer power, making possible the regular attainment of specific power levels of 500 to 600 kva/ton. Ugine's 100-ton furnace at Fos and the one of Sanyo Steel's 80-ton furnace at Himeji have capacities of 77 MVA and 60 MVA respectively.

(b) thermal efficiency is much improved using short, stable ores and high voltage and power, the power factor falling from 0.9 to 0.71.

Furnaces in the 80-100 ton range are quite common in many countries. The U.K., U.S.S.R., U.S.A., Italy, South Africa, etc. have furnaces of 150-ton capacity or more. The North Western Steel and Wire Company has a furnace of 400-ton and another of 700-ton capacity.

Auxiliary heating arrangements are made outside the furnace for reasons of economy in electric power and to enhance the productivity.

(2.5) Atomic Energy and Steelmaking:

The application of atomic energy to steel production would involve the use of a reactor to generate both electricity and the hot reducing gas needed in the direct reduction process. Two methods have been considered feasible :

(a) using the heat from a high-temperature gas-cooled reactor (HTGR), to reform hydro-carbon gas for the direct reduction of iron ore, the temperature being indirectly supplied by the hot helium from the reactor. The direct reduction sponge iron thus obtained would be refined to steel in an electric furnace powered by heat from the reactor.

(b) using reactor heat to obtain hydrogen (by splitting water) which is then used for the direct reduction of iron ore obviating the use of fossil fuel.

The over-riding problem at present is to design a safe, long-life catalystic reformer that can be heated by hot helium gas from the reactor. West Germany, Japan, Switzerland, U.S.A. and the U.S.S.R. are active in developing this technology. U.K., Belgium, France and Italy have also joined together to develop nuclear steel-making technology.

However, it is expected that first use of nuclear fission in steelmaking would not be there earlier than 1985-90, and may be, even later by 5 to 10 years.

(2.6) Share of each Process in Steel Production:

Steelmaking has undergone a substantial transformation in the last two decades or so, owing to the introduction on an industrial scale of pure-oxygen melting processes, the development of electric furnaces for the production of ingot steel and the introduction of metallurgical processing downstream of the steel production furnace.

This development is summarized in Table 4 and the forecast of the share of each process by the end of the century is given in Table 5.

Table 4 : Worldwide Share of Each Process

	1950		1955		1960		1965		1970		1975	
	%	million tons	%	million tons	%	million tons	%	million tons	%	million tons	%	million tons
Oxygen Converter	0.0	0	0.3	0.8	4.1	14.2	17.7	80.8	41.1	243.9	50.8	330.0
Open Hearth	78.7	147.9	77.9	210.5	71.8	248.6	61.0	278.4	39.4	233.8	30.8	200.0
Bessemer, Thomas Converter	14.1	26.5	13.8	37.3	13.1	45.4	8.6	39.3	4.3	25.5	1.5	10.0
Electric Furnace	7.2	13.5	8.0	21.6	11.0	38.1	12.7	58.0	14.7	87.2	16.9	110.0
Total	100.0	187.9	100.0	270.2	100.0	346.2	100.0	456.4	100.0	593.5	100.0	650.0

Source : 1950 - 1973, **Statistisches Bundesamt, Aussenstelle, Düsseldorf**
1975, **Mitchel Hutchins Inc.**

Table 5 : Forecast of Share of Each Process

Region	Basic Oxygen Process			Electric Furnace			Open Hearth, Bessemer, Thomas and others		
	1974	1985	2000	1974	1985	2000	1974	1985	2000
World	50.6	70	57	17.4	20	41	32.0	10	2
Developing Countries	24.7	58	61	21.9	28	35	53.4	14	4
Africa	22.2	35	30	40.7	65	70	33.1	–	–
Asia	21.1	60	65	17.5	20	28	61.4	20	7
Latin America	32.8	60	65	28.9	35	35	38.3	5	–

Note – All figures are in per cent

Source : World figures for 2000 are from UNIDO, ID/WG.146/58
Figures for other regions for 2000 and 1985 are UNIDO estimates on data from Mitchell Hutchins Inc.

The output of steel of some of the countries shows striking differences in the choice of technology. This is due to the particular infrastructure facilities of the steel industry in these countries.

Table 6 shows country-wise share of different processes.

Table 6 : Country-wise share of Each Processes
(in per cent)

Country	Year	Thomas	Open Hearth	Electric	Oxygen	Output in million tons
Federal Republic of Germany	1960	43.8	47.3	6.4	2.5	34.032
	1970	8.2	26.5	9.4	56.7	45.041
	1975	1.4	16.9	11.2	70.4	40.415
Austria	1960	-	31.3	12.6	56.1	3.163
	1970	-	16.3	12.1	71.6	4.078
	1975	-	7.4	11.8	80.8	4.068
Belgium	1960	91.1	5.8	3.1	-	6.698
	1970	41.6	2.2	3.6	52.6	12.607
	1975	-	1.4	5.8	92.8	11.584
Bulgaria	1960	-	90.0	10.0	-	0.260
	1970	-	26.1	20.1	53.8	1.800
	1975	-	22.8	21.3	55.9	2.265
Canada	1960	-	89.2	10.8	-	5.164
	1970	-	86.6	13.4	-	11.212
	1975	-	23.6	18.6	57.8	13.025
Spain	1960	13.8	-	71.4	14.8	1.938
	1970	-	26.4	35.2	38.4	7.429
	1975	-	9.8	36.1	54.1	11.242
United States of America	1960	1.2	87.0	8.5	3.3	90.067
	1970	-	36.5	15.3	48.1	122.120
	1975	-	19.0	19.4	61.6	108.250
Finland	1960	-	39.9	60.1	-	0.278
	1970	-	13.8	22.3	63.9	1.169
	1975	-	8.7	17.0	74.2	1.618
France	1960	60.9	29.9	8.7	0.5	17.181
	1970	42.2	18.8	9.8	29.2	23.774
	1975	15.5	7.2	12.8	64.5	21.530
Hungary	1960	-	90.2	9.8	-	1.887
	1970	-	90.7	9.3	-	3.110
	1975	-	90.8	9.2	-	3.671

Table 6 : continued

Country	Year	Thomas	Open Hearth	Electric	Oxygen	Output in million tons
Italy	1960	5.5	55.9	38.6	-	8.461
	1970	-	28.0	40.5	31.5	17.277
	1975	-	11.3	43.0	45.7	21.836
Japan	1960	-	68.0	20.1	11.9	22.138
	1970	-	4.1	16.8	79.1	93.322
	1975	-	1.1	16.4	82.5	102.314
Luxembourg	1960	98.0	-	2.0	-	4.084
	1970	60.6	-	1.8	37.6	5.462
	1975	28.5	-	1.4	70.1	4.624
Poland	1960	-	92.3	7.7	-	6.661
	1970	-	81.2	4.8	14.0	11.750
	1975	-	65.9	8.7	25.4	15.007
Portugal	1960	-	-	24.7	75.3	0.968
	1970	-	-	18.9	81.1	0.385
	1975	-	-	22.0	78.0	0.430
Romania	1960	-	89.1	10.9	-	1.671
	1970	-	62.0	9.3	28.7	6.517
	1975	-	49.9	12.7	37.4	9.549
United Kingdom	1960	8.0	84.9	6.9	0.1	24.571
	1970	-	48.3	20.0	31.7	28.316
	1975	-	22.0	27.6	50.3	20.198
Sweden	1960	14.0	34.0	48.0	4.0	3.219
	1970	3.8	24.4	39.5	32.3	5.497
	1975	-	15.7	40.9	43.4	5.611
Czechoslovakia	1960	3.9	83.8	12.3	-	6.768
	1970	2.0	68.3	11.7	18.0	11.480
	1975	1.1	64.2	10.9	23.9	14.324
U.S.S.R.	1960	2.7	88.4	4.5	4.4	56.627
	1970	1.0	72.6	9.2	17.2	115.889
	1975	0.7	64.7	10.0	24.6	141.325
Yugoslavia	1960	-	92.0	8.0	-	1.442
	1970	-	73.9	19.3	6.9	2.228
	1975	-	62.4	26.4	11.2	2.916

Source : U.N.E. and S.C. Steel/GE.3/R.3/Add.1

3. Factors affecting Process Selection:

Of the many different steel production processes employed in the past, only a few have survived in the face of stiff competition. Many decisions have to be made when formulating plans for the establishment of a new iron- and steelworks, or when considering a major expansion of an existing works. One of the most important of these is the process route by which the available raw materials are to be converted into the required product mix.

If the general location of the steelworks is already decided upon, certain parameters will already be fixed, such as the local market demand and its pattern of growth which in turn determines the size of works and its range of products, cost of the services available, etc.

The choice of processes is influenced strongly by :

(i) The cost and availability of iron ore and steel scrap;

(ii) The cost and availability of coking and steam coal, oil, natural gas, electricity, charcoal and other fuels;

(iii) The cost and availability of capital for the purchase and construction of facilities;

(iv) The availability of trained operative and technical staff;

(v) Transportation facilities available to move the large tonnages of raw materials involved;

(vi) Environmental considerations, primarily the disposal of water and waste rock from mining, and slag from smelting and refining operations;

(vii) The possible risk involved in choosing a particular technology which may be at various stages of development;

(viii) The cost of capital available.

(3.1) Optimum Works Scale:

With the increasing size of most production units, the optimum size of an integrated steelworks has risen accordingly. There is no general law governing the economics of works size. Each individual case must be carefully examined to determine the optimum solution. To arrive at a suitable works scale, the most economical rolling mill capacities to match the current and forecast market demands, are first chosen. Then working backwards through the prooess stages, optimum capacities of all other production units are determined.

Table 7 lists the approximate range of economic viability for the capacities of some of the major units, illustrating the complexity of the balancing problem.

Table 7 : Approximate Range of Economic Viability of some of the Major Units

Production Unit	Capacity Range - million tons/year
Blast Furnace	1.0 to 4.0 iron
Sinter Plant	up to 8.0 sinter
Coke Ovens Battery	up to 2.0 coke
LD Steelmaking Shop	up to 10.0 raw steel
Slab Mill	2.0 to 6.0 raw steel
Bloom Mill	1.5 to 6.0 raw steel
Continuous Slab Caster	up to 2.0 raw steel
Continuous Bloom Caster	up to 1.0 raw steel
Continuous Billet Caster	up to 0.5 raw steel
Plate Mill	0.5 to 3.0 steel product
Hot Strip Mill	1.0 to 6.0 steel product
Cold Strip Mill	0.1 to 2.5 steel product
Structural Mill	0.3 to 1.5 steel product
Bar Mill	0.01 to 1.0 steel product
Rod Mill	0.1 to 1.0 steel product

Source : SEAISI Quarterly, Jan. 1977

(3.2) Cost Data:

(i) Besides the technical advantages of OBM process over LD process mentioned earlier in this paper, Dasturco, Consultants, India, have estimated that the capital investment on bottom-blowing installation is expected to be lower than that on LD shop.

In another study made by the above consultants it has been indicated that the cost of modifying existing Thomas converters at the Helwan Steel Plant in Egypt to OBM would be approximately at half the cost compared to that required for revamping with installation of LD converters. Similarly, the conversion of open-hearth shops by installation of bottom-blown converters is likely to be more economical than LD plants.

The consultants have also estimated the following relative investment costs for different steelmaking processes inclusive of cost of oxygen plant, ingot casting facilities and calcining plant. These cost figures are given in Table 8.

Table 8 : Relative Investment Costs
Basis: 1 million ingot tons per year

Process	Investment per annual ingot ton US$	Relative Investment Index
Open Hearth	75	100
LD	47	63
OBM/LWS(Q-BOP)	42	60
Electric Arc Furnace	56	75

Source : SEAISI Quarterly, Jan. 1976

(ii) A study of estimated capital costs of some new steel producing facilities made by Paul Marshall in 1976 is summarized in Table 9.

Table 9 : Estimated Capital Costs

Process Sequence	Capacity in tons/year		Cost in $/ton		Total in million dollars
	Raw Steel	Finished Steel	Raw Steel	Finished Steel	
(a) 35 t. EF, Cont. Caster, hot mill	50,000	47,000	240	255	12
(b) DR-35 t. EF, Cont. Caster, hot mill	50,000	47,000	340	361	17
(c) 70 t. EF, Cont. Caster, hot mill	100,000	94,000	230	245	23
(d) 70 t. EF, Ingot Casting, hot mill	100,000	85,000	210	247	21
(e) 2-150 t. EF, Cont. Cast. merchant mill	500,000	450,000	320	355	160
(f) DR,2-150 t.EF, Cont. Cast.,merchant mill	500,000	450,000	426	475	213
(g) 2-150 t.EF,Ingot Casting,primary and merchant mills	500,000	375,000	370	500	185
(h) 1-150 tpd BF,Coke oven,1-100 t BOF, Cont.Cast.,merchant mill	500,000	450,000	610	670	305
(i) 3-200 t.OH,Cont.Cast merchant mill	500,000	450,000	340	380	170
(j) 3-200 t.EF,Cont.Cast hot mill,merchant mill	1,000,000	900,000	346	385	346
(k) DR,3-200t,EF,Cont. Cast.,hot mill,heavy structural mill	1,000,000	900,000	606	670	606

Table 9 : continued

Process Sequence	Capacity in tons/year		Cost in $/ton		Total in million dollars
	Raw Steel	Finished Steel	Raw Steel	Finished Steel	
(l) 3-200t.EF, Ingot casting, primary mill, hot mill, merchant mill	1,000,000	750,000	390	520	390
(m) 1-6000 tpd BF, Sinter plant, coke plant, 2-150t BOF plant, Cont. Cast., hot mill, merchant mill	2,000,000	1,600,000	477	600	955
(n) DR, 6-200t, EF, Cont. Cast. hot mill, cold mill, galvanizing	2,000,000	1,600,000	482	603	965
(o) Fully integrated plant, BF, Coke plant, BOF, Cont. Cast. for merchant, bar and structural mills, Cont. hot mill, hot and cold sheet mills, coated products, plate mill	8,000,000	6,000,000	675-750	900-1,000	6,000

Source : UNIDO/ICIS.25

The above Table shows a wide range of capital cost variations, namely between $210 and $750 per ton of raw steel at 1975 prices.

Table 10 gives comparison between index of capital costs for BF-BOF and DR-EF installations for different plant capacities.

Table 10 : Index of Capital Costs BF-BOF and DR-EF plants

Plant Capacity in million tons	Index of Capital Cost	
	BF-BOF	DR-EF
0.2	213	170
0.3	180	145
0.4	164	131
0.5	155	121
0.6	146	114
0.7	140	111
1.0	129	109
2.0	115	108
3.0	110	107
5.0	100	

Source : UNIDO/ICIS.25

As shown in Table 10, capital cost decreases by about 48 per cent and 37 per cent as plant capacities increase from 0.2 to 3.0 million tons for BF-BOF and DR-EF plants, respectively.

Tables 11 and 12 show capital costs for a 3 million tons BF-BOF plant and for 0.5 million tons DR-EF plant, respectively.

Table 11 : Capital Costs 3 million tons BF-BOF Plant

	Millions of dollars	Installed Steel-making capacity (dollars/ton)	Capital Cost Structure (per cent)
Coke Plant	168,0	56.0	8.6
Blast Furnace	225.0	75.0	11.6
Basic Oxygen Furnace	130.0	43.0	6.6
Continuous Casters	131.0	43.0	6.6
Mixed Rolling Facilities	563.0	188.0	29.0
General Facilities	125.0	42.0	6.5
Sub-total, fixed assets	1,342.0	447.0	68.9
Engineering, procurement and inspection (5% fixed assets)		22.0	3.4
Administration, advisory and expediting costs (6% of fixed assets)		27.0	4.2
Pre-operating expenses (3% of fixed assets)		13.0	2.0
Sub-total, project implementation and pre-operating expenses		62.0	9.6
Fixed capital costs		509.0	78.6
Infrastructural Investments		72.0	11.1
Sub-total, fixed capital costs plus infrastructure		581.0	89.7
Working Capital (15% of fixed assets)		67.0	10.3
Interest paid during implementation		42.0	
Grand Total		690.0	100.0

Source : UNIDO/ICIS.25

Table 12 : Capital Costs 0.5 million tons DR-EF Plant

	Millions of dollars	Installed Steel-making capacity (dollars/ton)	Capital Cost Structure (per cent)
D.R. (350,000 t)	38.4	77.0	25.5
Electric Furnace (500,000 t)	20.0	40.0	13.2
Six-Strand Caster (500,000 t)	22.5	45.0	14.9
Merchant Bar Mill (450,000 t)	31.5	63.0	20.9
Sub-total, fixed assets	112.4	225.0	74.5
Engineering, procurement and inspection (5% of fixed assets)		11.0	3.6
Administrative, advisory and expediting costs (3% of fixed assets)		7.0	2.3
Pre-operating expenses (3% of fixed assets)		7.0	2.3
Sub-total, project implementation		25.0	8.2
Fixed Capital Costs		250.0	82.7
Infrastructural Investment (15% of fixed assets)		34.0	11.3
Sub-total, fixed capital costs plus infrastructure		284.0	94.0
Working Capital (8% of fixed assets)		18.0	6.0
Total		302.0	100.0
Interest paid during implementation		10.0	
Grand Total		312.0	

Source : UNIDO/ICIS.25

The estimates given in Tables 11 and 12 do not take into account costs for mining, power, housing, contingencies and interest paid during construction period.

(iii) In a study conducted by the UNIDO, the operating cost for a 3-million tons BF-BOF installation, located in the U.S.A., Brazil, Western Europe and Japan, has been estimated at $134.70 per ton.

The percentage distribution of the inputs in relation to the total operating costs, is shown in Table 13.

Table 13 : Cost Structure - BF-BOF
(in per cent)

	Blast Furnace Shop	Basic Oxygen Steel-making
Raw Materials and Primary Energy	84.7	93.0*
Utilities	1.9	1.0
Labour	5.2	0.8
Overhead	3.3	0.5
Maintenance (4% of investment)	2.0	2.9
Local taxes and insurance	0.1	0.4
Depreciation (5.5% of investment)	2.8	1.4
Total Costs	100.0	100.0

*Liquid metal from the previous process and transfer costs.

Source : UNIDO/ICIS.25

(iv) The capital investment and operating cost for a 1.71 million tons per year new electric furnace are given in Table 14. Cost figures for a similar capacity new oxygen furnace are given in Table 15.

Table 14 : Cost Structure in New Electric Furnace Shop

Annual Design Capacity: 1.71 x 10^6 tons
Capital Investment: $65 million
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per ton of Product	$/Ton of Product
Variable Costs				
Raw Materials				
reduced pellets	ton Fe	102.88	0.75	77.16
scrap	ton	80	0.32	25.60
Energy				
Electric Power Purchased	kWh	0.016	600	9.60
Electrodes	lb	0.55	10	5.50
Water				
Process (Consumption)				
Cooling (Circulating Rate)				
Direct Operating Labor (Wages)	man-hr	7.00	0.3	2.10
Direct Supervisory Wages	15% Labor			0.32
Maintenance Labor and Materials	6% CI			2.27
Labor Overhead	35% (L+S)			0.85
Misc. Variable Costs/Credits				
Refractories				2.00
Fluxes, Oxygen, misc. nonmetallics				1.90
Metallic Additions				1.50
TOTAL VARIABLE COSTS				127.90
Fixed Costs				
Plant Overhead	65% (L+S)			1.57
Local Taxes and Insurance	2% CI			0.76
Depreciation 18 years				2.10
TOTAL PRODUCTION COSTS				131.83
Return on Investment (pretax)	20% CI			7.56
TOTAL				139.89

Source : EPA-600/7-76-034c-Industrial Environmental Research Laboratory, USA.

Table 15 : Cost Structure in New Basic Oxygen Process

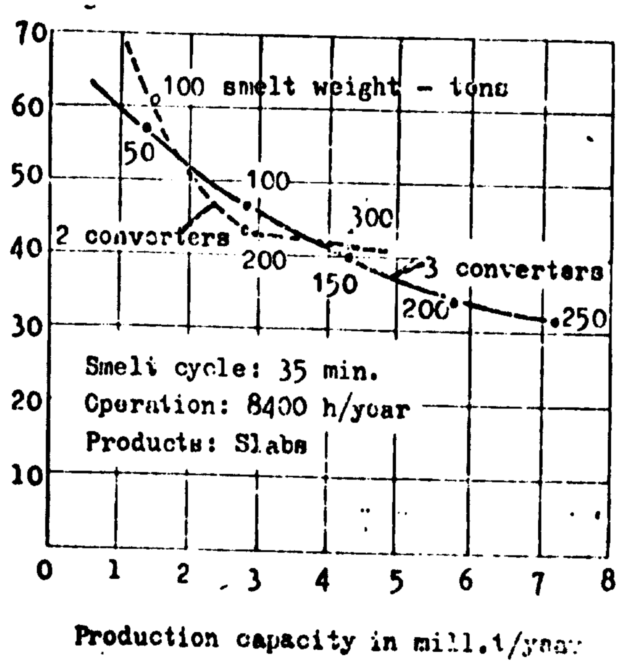
Annual Design Capacity: 1.71 million tons steel
Capital Investment: $45 million
Location: Great Lakes

	Units Used in Costing or Annual Cost Basis	$/Unit	Units Consumed per ton of Product	$/Ton of Product
Variable Costs				
Raw Materials				
Hot Metal (93% Fe)	ton	106.42	0.83	88.33
Scrap	ton	80.00	0.35	28
Energy				
Electric Power Purchased	kWh	0.016	30	0.48
Energy Credits (Specify term)				
Carbon monoxide	10^6 Btu	2.00	0.44	(.88)
Water				
Cooling (Circulating rate)	1000 gal	0.05	2	0.10
Direct Operating Labor (Wages)	man-hr	7	0.25	1.75
Direct Supervisory Wages	15% labor			0.26
Maintenance Labor and Materials	8% CI			2.09
Labor Overhead	35% (L+S)			0.70
Misc.Variable Costs/Credits				
Oxygen	ton	10	0.08	0.80
FeMn, Lime, Spar				3.00
Slag Disposal, Hot Metal, Scrap Treatment				1.00
TOTAL VARIABLE COSTS				125.63
Fixed Costs				
Plant Overhead	65% (L+S)			1.31
Local Taxes and Insurance	2% CI			0.52
Depreciation 18 years				1.45
TOTAL PRODUCTION COSTS				128.90
Return on Investment (pretax)	20% CI			5.23
TOTAL				134.14

Source : EPA-600/7-76-034c-Industrial Environmental Research Laboratory, USA.

(v) Capital cost per ton of steel made by the basic oxygen process for different capacity plants is shown diagrammatically in Fig. 1.

Fig. 1. Capital cost per ton - capacity of basic oxygen furnace



Source : Stahl und Eisen, 90 (1970), No. 4.

(vi) A recent study made by Jack R. Miller, Iron and Steel Industries Consultant, USA, has shown that for a one million tons per year plant for producing low-carbon billets, (a) the estimated capital costs of a DR-EF combination plant were 32 per cent lower than an equivalent BF-BOF combination, but 28 per cent higher than a steel-scrap-electric furnace (SS-EF) installation; and (b) production costs were lowest and profitability highest for the DR-EF operation. The profitability in this case was 14 per cent compared with 7.5 per cent for the BF-BOF and 8.4 per cent for the SS-EF processor.

Each of the above process combinations is strongly sensitive to changes in the availability and price levels of the main raw materials they consume. For the BF-BOF process, the dependency is primarily on coking coal or coke; for the DR-EF process, the reductant fuel; and for the SS-EF process, the scrap. The effect of fuel cost changes on profitability is more critical in the BF-BOF process than in the DR-EF combination.

The consultant considers DR-EF route to be either equal to or better than the other two combinations with respect to product quality, environmental pollution control and flexibility in the choice of plant site locations.

4. World steel production during 1975 and 1976, along with different country's percentage contribution to world production are given in Table 17.

Table 17 : World Raw Steel Production

Country	Production x 000 tons		Output per capita kg		% World Output 1976
	1975	1976*	1975	1976*	
Europe					
West Germany	40,415	42,415	654	688	6.23
Belgium	11,584	12,146	1,183	1,238	1.78
France	21,530	23,226	407	436	3.41
Italy	21,836	23,416	341	415	3.44
Luxembourg	4,624	4,566	18,163	12,341	0.67
Netherlands	4,826	5,185	354	377	0.76
Denmark	559	723	110	142	0.11
U.K.	20,198	22,268	361	398	3.27
Irish Republic	81	58	26	18	0.01
Finland	1,618	1,646	344	345	0.24
Greece	700	700	77	77	0.10
Norway	919	894	230	222	0.13
Austria	4,068	4,478	541	598	0.66
Portugal	430	428	49	48	0.06
Sweden	5,611	5,213	684	632	0.76
Switzerland	420	520	66	82	0.08
Spain	11,242	11,058	313	310	1.62
Turkey	1,464	1,770	38	44	0.26
W. Europe	152,125	160,710	398	418	23.59
East Germany	6,480	6,650	385	396	0.98
Bulgaria	2,265	2,450	260	280	0.36
Yugoslavia	2,916	2,712	134	126	0.40
Poland	15,007	15,450	438	450	2.27
Rumania	9,549	10,500	451	492	1.54
Czechoslovakia	14,324	14,550	970	981	2.14
Hungary	3,671	3,650	348	344	0.54
Europe	206,337	216,672	402	420	31.80
U.S.S.R.	141,325	144,900	555	565	21,27
Asia					
Bangladesh	100	100	1	1	0.01
Burma	40	40	1	1	0.01
Taiwan	847	1,000	63	61	0.15
China	25,000	26,000	30	31	3.82
Hongkong	70	80	16	18	0.01
India	7,989	9,313	13	15	1.37
Indonesia	100	100	1	1	0.01
Iran	551	550	18	16.	0.08

TECHNOLOGICAL PROFILE

ON

STEEL CASTING INCLUDING

CONTINUOUS CASTING

Contents

1. Introduction

A brief account of different processes for steel castings, including continuous casting, has been given in the following pages. Information about the various continuous casting machines installed in the different countries, has also been included. The criterial for selection of a process including cost data, have also been mentioned.

2. Steel Casting

As regards mechanical properties are concerned, steel castings are inferior to wrought-steel products. However, steel castings cover a very large field and include steelmill service items like charging boxes, blast furnace bells, cinder pots, rolls for certain type of rolling mills, etc., transport industry items such as casting for couplings, journal boxes, brake-shoes, cylinders, valves, engine beds, etc., and several hundred other items of use in chemical, petroleum, mining, agricultural and construction industries, etc.

There are two classes of castings, static castings, and centrifugal castings. The static castings are made by using proper type of moulds and make use of atmospheric pressure and gravity to form castings when molten steel is poured into the moulds. The centrifugal castings make use of centrifugal action to perform the function of gravity in static casting for flow of liquid metal. By the horizontal centrifugal casting techniques where the mould rotates on a horizontal axis, tubes, pipes, bushings, sleeves, etc. are manufactured. Gears, piston rings, impellars, propellers, turbine diaphragms, etc. are produced by the vertical centrifugal casting method. Centrifugal castings are more sound and have fewer inclusions than those of static castings. The yield is also higher in the former case.

The mechanical properties of cast steels can be developed by suitable heat-treatment and addition of alloying elements. Nickel, chromium, manganese, molybdenum, and vanadium are the alloying elements commonly used for improving the properties of the castings.

The common heat-treatment applied to steel castings are:

Annealing - This treatment relieves the tensile and yield strength and increases ductility. Machinability is also improved.

Normalizing - The treatment is similar to the annealing process. Harder steel with higher yield and tensile strength is obtained. Internal streesss are removed by tempering the normalized steel.

Quenching and Tempering - These treatments are confined principally to high-carbon and alloy-steel castings where high strength and resistance to impact and/or abrasion is required. The steel is, first annealed or normalized, reheated and quenched. Tempering treatment follows immediately.

Flame hardening - If the casting is required to have different hardnese in two different zones of the casting, such as a pinion gear which should have wear-resistant teeth with a machinable bore, flame hardening technique is adopted. The casting is first annealed or quenched and then only the surfaces to be hardened are heated to the hardening temperature by a torch or induction-heating apparatus. The heated parts are then quenched in water.

3. <u>Ingot Casting:</u>

After a heat of steel is properly refined, the liquid steel is tapped into a refractory lined open-top steel laddle. Additions of alloying materials and deoxidizers are made during tapping of a heat. The molten steel is poured or teemed into a series of moulds of the desired shape and dimensions, and after solidification, the ingot is stripped off the mould.

Ingot moulds are of two principal types:

(a) Big-end down; and

(b) Big-end up.

The big-end down moulds are further classified as (1a) open-top; and (2a) bottle-top. The big-end up moulds are also similarly classified as (1b) open-bottom; (2b) closed-bottom; and (3b) plug-bottom. The moulds are made of cast iron, the inner walls of which may be plain sided, corrugated, or fluted.

The rate of solidification of molten steel in the mould depends on thickness, shape and temperature of the mould; the amount of super-heat of the liquid steel; the type of steel and its chemical composition, etc. Presence of pipe and blowholes, segregation, internal fissures, cracks and non-metallic inclusions, etc. are some of the factors which are controlled by appropriate steps.

The ingot steel after reheating in soaking pits, is rolled into bloom, slab or billet. These rolled primary products are then further rolled in the desired shapes and cross-section.

4. Bottom Pressure Casting

A process to by-pass the ingot and primary mill stages in the production of wrought steels, is the bottom pressure casting method. A laddle filled with mother steel is placed in a pressure vessel. This vessel is covered with a lid in which a pouring tube is inserted that dips down into the mother steel almost to the bottom of the laddle. A gooseneck connects the pouring tube to the mould in the casting position. When air-pressure is applied to the pressure vessel, molten steel rises in the pouring tube and gooseneck and enter the mould. The rate of casting is controlled by regulating the pressure of air.

The mould is enclosed in a flaste which has a gate that retains the molten metal in the mould after the cast is completed. The gate is closed after the mould has been filled and the pressure vessel is then exhausted to the atmosphere. After the casting has solidified the mould is removed by stripping machine. Where the drag and the casting are separated from the oope. The casting is then separated from the oope by special maohines and placed on the oooling oonveyor.

5. Continuous Casting

Until recently, steel in the form of blooms, slabs, and billets, was produced mainly by hot rolling of ingots to produce blooms and slabs. Billets resulted from the further hot rolling of blooms. However, some blooms and slabs are still produced by other means of hot working, such as forging by hammering or pressing.

Researches and development in many countries, resulted in industrialisation of the method of continuous casting of molten steel directly into the form of slabs and billets, by-passing the ingot stage and the necessity for hot rolling operations.

The attractiveness of casting molten steel continuously into useful shapes, led to a long series of attempts to develop various designs of machines. The problems posed due to high melting point, high specific heat and low thermal conductivity of steel, were gradually overcome.

When molten steel comes into contact with the walls of the water-cooled mould, a thin solid skin forms. Due to thermal contraction, the skin separates from the mould shortly after solidification. The rate of heat abstraction from the casting being slow, molten steel persists within the interior of the section for some distance below the bottom of the mould. The thickness of the skin increases due to the action of water sprays as the casting moves downward and, eventually the entire is solid.

The mass of solid steel casting is supported as it descends by driven pinch rolls that also control line speed by controlling the rate of withdrawal of the casting from the mould. Oscillation of the mould up and down for pre-determined distances at controlled rates during casting eliminate tendency of sticking of the casting in the mould.

The successful application of the continuous casting process in a steel plant is dependent upon many factors other than just mechanical equipment and the feasibility. Some of the important factors which would determine the number of casting strands or laddle position, are:

(i) tons of liquid steel per heat; or in other words, size of the furnace

(ii) tap to tap time of the furnace

(iii) possibility to programme the tapping time

(iv) total tons of steel to be cast per day

(v) shape of cast product

(vi) casting rate.

The tapping temperature of steel is generally between 1650°C and 1690°C for concast operation depending on the life of the furnace refractory and tap hole condition. This is about 30°-40°C hotter as compared to steel tapped for small ingot-making.

The desired physico-chemical properties of billets produced by the conventional method is attained by close control of the process beginning from the ingot making stage, soaking and rolling. During the soaking and rolling stages, homogenity of cast structures are obtained by diffusion processes. On the other hand, the physico-chemical properties of billets produced by the continuous casting process exhibit properties on the as cast condition. For obtaining properties of finished products using continuous cast billets comparable to those products using conventionally produced billets, the following factors must be carefully examined as necessary tools in accomplishing the above mentioned objectives:

(a) Surface configuration which include among others, deformation and bending

(b) Surface defects such as pinholes and oscillation marks

(c) Scum

(d) Cracks - internal, longitudinal and transverse

(e) Segregation of components

(f) Kinds and distribution of non-metallic inclusions

(g) Reduction of cross-sectional area

(h) Grain size

(i) Fatigne

The following are the principal types of continuous casting machines in commercial use:

(i) Vertical type: The casting is supported in a vertical position and the continuous length of casting is parted by gas cutting in the vertical position. The cut-off piece is received by a tilting basket mechanism that lowers it to a horizontal position. Since the machine height is 17 m or more, this type of continuous caster require a tall building or deep pit.

(ii) Curved type: In this machine, the solidified product after cooling by water spray is bent by a series of rollers, from vertical to horizontal position. Cutting off is accomplished on the horizontal casting. The machine height is thus reduced to about 10 m and consequently the building height.

(iii) Bow type: Curved mould is employed in this type of machine, which is in oscillation. The cooling chamber is also curved. The height of this machine, is therefore, reduced to one-third or less than that of the vertical type of machine.

Pre-heated and insulated laddles and tundish are used. The latter may have one or more nozzles that feed the metal to the mould which is made of copper and is cooled by copious amounts of water.

5.1 Growth pattern of Continuous Casting

The growth of continuous casting has been phenominal during the last two decades. Vertical machines requiring buildings of great height, are now coupled with bending and straightening devices and curved-mold assembly. The speed of withdrawal has risen to 1.5 - 2.0 m per minute for slabbing machines and from 2 to 4 per minute for square sections. Thus hourly outputs per strand are 200 tph for flats and 15-36 tph for square sections. Uninterrupted series of more than 200 heats have been possible with the usage of improved distributor refractories, rapid changeover systems for closing mechanisms and proper synchronization of processing furnaces and casting machines.

Table 1 shows the trend in the growth of continuous casting.

Table 1: Growth of Continuous Casting

Year	World Steel production in million tons	World Casting Capacity in million tons	Annual Growth in per cent	Percentage Share of Continuous Casting in Steel Production
1955	266	0.38		0.1
1960	325	1.65	34	0.5
1970	599	57.40	42	9.6
1975	646	140.00	20	21.5

Source: ECE - Steel Committee/GE 3/R.3

It is estimated that by 1980 nearly one third of all the steel production in the world, will go through the continuous casting route. Over 50 per cent of the machines now in use produce billets, about 20 per cent are for blooms and the rest make slabs.

Continuous casting accounted for 30 per cent of the steel output in Japan in 1975, and 20 per cent in Italy, Spain, and the F.R.G., 15 per cent in France and less than 10 per cent in the USA and USSR. There were 651 countries in 1976. It has been estimated that by the end of

1977, there will be 734 mills in 66 countries.

The utilisation rate (output/production capacity ratio) on global basis, has risen from 38.5 per cent in 1970 to 64 per cent in 1974.

5.2 Continuous Casting Installations:

There are more than twenty manufacturing firms, marketing continuous casting machines of basically one of the three major types but incoporating special design features of their own. More than half the number of machines in operation, are of Concast make, followed by Demag, Danieli, Mitsubishi/Olsson, Vöest-Alpine, Koppers, etc.

Table 2 lists the continuous casting machines in the world indicating number of strands, casting dimensions, capacity, maker's name, products made, etc.

Table 2 : Continuous Casting Plants

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Others details
ALGERIA							
Sté Nationale de Sidérurgie, El Hadjar	3 x 2	slabs			200,000	USSR	vertical
ARGENTINA							
Acindar, Villa Constitución	4	billets	carbon, alloy	100,130 sq.		Concast 1974	
Aceros Bragado, Buenos Aires	3	billets		75,140 sq.		Danieli 1971	
Dalmine Siderca, Campana	4	billets	carbon, alloy	75,100 sq.; 100,120,140 dia.	70,000	Concast 1968	
Gurmendi SA, Avellaneda	2 x 4	billets	structural (standard commercial grade)	100 sq.	400,000	Demag 1971	
Somisa, San Nicolas	2 x 6	blooms	carbon	190,230 sq.		Concast 1973	
AUSTRALIA							
BHP Ltd., Newcastle NSW	4	billets	carbon, alloy	90,115,140 sq.		Concast 1967	S-type
Port Kembla, NSW	2	slabs	general structural				
Port Kembla, NSW		slabs		650-1600x150-304	1,100,000 2,000,000	Demag 1976 Demag/Nippon Steel 1977	bow-type
AUSTRIA							
Eisenwerk Breitenfeld, Wartberg, Mürstal	2	small slabs	structural (standard commercial grade), spring tool	200 x 50, 210 x 50, 275 x 65	14,500	Demag 1953	
Wartberg, Mürstal	3	billets + small slabs	structural (standard commercial grade)	90 sq, 210x90, 275x65	36,000	Demag 1962	vertical

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Others details
AUSTRIA, cont. VEW-Vereinigte Edelstahl Werke, (formerly Gebr.Böhler), Kapfenberg	1/2	billets, blooms and small slabs	structural (standard commerical grade)	100-200 dia.; 90,110,120, 140 sq. 175 x 50; 330 x 100; 370 x 170; 480 x 140; 500 x 110; 1,000x125/165	7,500	Demag 1952	
			ball-bearing, cold heading, spring	90,110,120, 140 sq.			
			stainless	90,110,120,140 sq. 370 x 170; 1,000x165			
			tool	90,140 sq.			
Kapfenberg	2	blooms, billets and small slabs	structural (standard commercial grade)	90,110,120, 140 sq. 175 x 50; 330 x 100; 370 x 170; 480 x 140; 500 x 110	7,500	Demag 1964/67	bow-type
			ball-bearing cold heading spring	90,110,120, 140 sq.			
			stainless	90,110,120,140 sq. 370 x 170			
			tool	90,140 sq.			
Kapfenberg		billets		140 sq.		Voest-Alpine 1967	in-line reduction stands

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Others details
AUSTRIA, cont.							
Kapfenberg		blooms		200–480x140–220		Voest-Alpine	bow-type
Voest-Alpine, Linz		slabs		1,000–1,600 x 140–250		Voest-Alpine 1968	
Linz		slabs		1,000–1,600 x 165–290		Voest-Alpine 1972	
Linz		slabs		1,000–1,600 x 165–290		Voest-Alpine 1974	
Linz	4	billets		80,120 sq.		Voest-Alpine 1977	in-line reduction
Linz	2	blooms and billets		120,200 sq.		Voest-Alpine 1977	in-line reduction
Stahlwerk Ybbs, Ybbs/Donau	1	billets	carbon, alloy	100,105,120 sq.	14,000	Concast 1961	vertical with bending
BELGIUM							
ALZ, Genk	1	slabs	stainless	800–1,850 x 160–250		Concast 1976	S-type
Cockerill, Seraing	3	blooms	carbon	142,159,175 187 sq.; 237,287 octagonal	115,000	Concast 1973	S-type
Hainaut-Sambre	2					Fives-Lille-Cail	
Forges de Thy-Marcinelle et Monceau SA,	4	billets	carbon	100 sq.		Concast 1974	S-type
Monceau-sur Sambre	6	billets	carbon	120 sq.		Concast 1976	
Usines Gustave Boël, La Louvière	1	slabs	mild carbon, general structural, heat-treatable	875–1,725 x 150–250	550,000	Demag 1975	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
BRAZIL							
Acesita, Timoteo	1	slabs	stainless, alloy	900-1,600 x 125-200		Concast 1976	S-type
Siderúrgica Barra Mansa SA, Barra Mansa	2	billets	structural (standard comm. grade), spring stainless	80,100 sq.	90,000	Demag 1972	bow-type
Cofavi, Vitória	2	billets	carbon	80,100,130 sq.	100,000	Concast 1973	S-type
Vitória	2	billets	carbon	75-130 sq.		Concast 1975	S-type
Cosigua, Porto Alegre	4	billets	carbon	120 sq.		Concast 1975	S-type
CSN, Volta Redonda	2	slabs			1,125,000	USS/Okura 1975	vertical
Siderúrgica Dedini SA, Piracicaba	3	billets	carbon	75,100,125 sq.	144,000	Concast 1968	S-type
FI-EL Korf, São José dos Campos	2	blooms and billets	alloy	80-160 sq.		Concast 1975	S-type
Cia.Industrial Itauense, Itaúna	2	billets	carbon	75-130 sq.		Concast 1975	S-type
Lafersa, Belo Horizonte	2	billets	carbon	100 sq.		Concast 1975	S-type
Cia.Siderúrgica Pains, Belo Horizonte	2	billets	carbon	80,100 sq.	120,000	Concast 1972	S-type
Siderúrgica Riograndense SA, Porto Alegre	2	billets	structural (standard comm.) grade)	95 sq.	37,500	Demag 1961	vertical
Usiba	6	billets			300,000	Fives-Lille-Cail 1973	curved
Usiminas, Belo Horizonte	2 x 2	slabs	mild carbon general struct.	940/1,250x160 1,000/550x160, 1,000/1,900 x 200, 1,000/1,900 x 300	2,000,000	Demag [illegible]	bow-type
CANADA							
Algoma Steel Corp., Sault Ste. Marie	4	blooms	carbon	355/320-230 x 265		Concast 1967	S-type
Sault Ste. Marie	2	beam blanks and other sections	carbon	760 x 150		Concast 1968	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
CANADA, cont.							
Sault Ste. Marie	2	slabs	mild carbon general struct.	1,016x152/254, 1,524x152/254, 2,150x152/254	850,000	Demag 1975	bow-type
Atlas Steels Co., Tracy	1	slabs	stainless	1,270/1,065/990 x 125		Concast 1965	S-type
Welland	1	slabs and blooms	carbon, alloy, stainless	140-215 sq. 520 x 165		Concast 1954	vertical
Burlington Steel, Hamilton	3	billets	carbon	100 sq., 150x100		Concast 1963	S-type
Hamilton	3	billets	carbon	100,125 sq. 100,150 sq.		Concast 1970	S-type
Ivaco Industries Ltd., l'Original, Que	4	blooms and billets	carbon	100,152,203 sq.		Concast 1975	
Manitoba Rolling Mills, Selkirk	2 x 2	blooms and billets	carbon, alloy	100-200 sq.		Concast 1966	S-type
Questeel, Longueuil	3	blooms and b.	carbon, alloy	76-205 sq.	140,000	Concast 1974	S-type
Longueuil	3	billets	carbon	115-155 sq.		Concast 1975	S-type
Sidbec, Contrecoeur	6	blooms and billets	carbon	90-190 sq.		Concast 197?	S-type
Contrecoeur	6	billets	carbon	90,115 sq.		Concast 1975	S-type
Montreal	4	billets	carbon, low-alloy	75-160 sq.	173,000 (short)	Concast 1965	S-type
Montreal	1	slabs		685-1,520 x 170-250		Vöst-Alpine/ Allis Chalmers 197?	bow-type wi straight mould cast.
Stelco, Contrecoeur	4	billets	carbon, alloy	90-152 sq.		Concast [illegible]	S-type
Edmonton	2	billets	carbon, low-alloy	100-150 sq.		Concast [illegible]	vertical wit bending
Hamilton	6	billets	carbon	100 sq.		Concast 1966	S-type
Hamilton	2	slabs	mild carbon, general struct.	760/1,880 x 250	1,225,000	Demag 1976	bow-type
Nanticoke		slabs				1977	
Sysco, Sydney, NS	1 x 2	slabs		1,250-2,134 x 204-315		Vöest-Alpine/ Allis Chalmers 1975	alternativ. 3-strand caster for blooms 406 x 279

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
CHILE							
Aza SA, Santiago de Chile	1	billets	carbon	80 sq.		Concast 1969	S-type
Cap, Talcahuano	1	slabs	carbon, low-alloy	585-1,050x145-155		Concast 1977	S-type
CHINA							
Shanghai Works							
Wuhan Works	3 x 1	slabs	carbon	700-1,300 x 170/210/250, 1,000-1,600 x 170/210/250		Concast 1977	S-type
COLOMBIA							
Acerias Paz del Rio, Belencito		blooms				(before 1981)	
CZECHOSLOVAKIA							
East Slovak Iron and Steel Works, Kosice					1,000,000	USSR 1977/78	
DENMARK							
Det Danske Staalvalsevaerk, Frederiksvaerk	1	slabs	carbon	900/2,100 x 150/320 900/1,700x 150 900/1,700 x 210 1,300/2,100x260 1,300/2,100x320	500,000	Demag 1975	bow-type
DOMINICAN REPUBLIC							
Metaldom, Santo Domingo	2	billets		3 3/16x3 3/16 in.	60,000	Koppers [illegible]	low-head
FINLAND							
Outokumpu Oy, Tornio		slabs	stainless (austenitic and ferritic)	800-1,600 x 130-200		Voest-Alpine 1976	
Ovako, Imatra	3	billets	carbon, alloy	100 sq.		Concast 1965	S-type
Koverhar	2 x 4	billets	carbon	100 sq.		Concast 1971	S-type
Rautaruuki Oy, Raahe	3 x 1	slabs			850,000	USSR	vertical

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
FRANCE							
Forges d'Allevard, Le Cheylas	2	billets	carbon, alloy	55-120 sq.		Concast 1962	tilting ladle, vertical with bending
Alpa, Porcheville	4	billets	carbon	120 sq.	180,000	Concast 1974	S-type
Anzin, Saint-Saulve	4	tube rounds		120-210 dia		1975	
Châtillon-Commentry-Biache, Isbergues	1	slabs	transformer and dynamo, stainless	1,300 x 145, 1,300 x 165	300,000	Demag 1972	bow-type
Sté des Hauts Fourneaux de la Chiers, Longwy	3	blooms	carbon	200 x 130		Concast 1975	S-type
Fives Lille-Cail, Denain	4	blooms	structural (stand. comm. grade) spring	165,240 sq.	60,000	Demag 1954	vertical
Iton-Seine, Bonnière-sur-Seine	3*	billets		80,140 sq.		Danieli 1973	
Sté des Acières de Montereau, Montereau	4	billets	carbon	75-130 sq.		Concast 1975	S-type
Safe, Hagondange	4	blooms + billets	struct. (standard comm. grade), ball-bearing, cold-heading, spring	120,200 sq.	75,000	Demag 1960	vertical
Solmer, Fos-sur-Mer	2	slabs	carbon	850-1,550 x 220-240	1,000,000	Concast 1975	S-type
Sudacier SA, Toulon	4	billets		100,140 sq.		Danieli	
Usinor, Dunkirk	2	slabs	general struct.	1,000x150/200/250/300, 2,000 x200/250/300	510,000	Demag 1971	bow-type
Dunkirk	3 x 2	slabs	mild carbon	950/1,650x200/250	3,200,000	Demag 197[illegible]	bow-type
Dunkirk		slabs			700,000	Five Lille-Cail	
Dunkirk		slabs			800,000	Five Lille-Cail	
EAST GERMANY							
VEB Stahl- und Walzwerk Wilhelm Florin, Hennigsdorf	2 x 4	billets	struct. (standard comm. grade)	160x98-110, 145x98-110	[illegible]	Demag 1971	bow-type strand reduction
VEB Stahl- und Walzwerk Riesa, Riesa/Elbe							

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
WEST GERMANY							
ATH, Ruhrort	1	slabs	carbon,alloy	1,500-2,100x 180-250	600,000	Concast 1969	S-type
Beeckerwerth	2	slabs	carbon,general struct.,heat-treatable	1,200/2,050x 200/275	1,200,000	Demag 1974	bow-type
Duisburg-Hamborn	6	blooms	struct.(standard comm.grade),ball-bearing,cold-heading, spring,tool	250x320	840,000	Demag 1975	bow-type
Badische Stahlwerke,Kehl	4	billets	structural(stand. comm.grade)	100 sq.	240,000	Demag 1968	bow-type
Kehl	4	billets	struct.(standard comm.grade)	100 sq.	240,000	Demag 1970	bow-type
Walzwerk Becker KG,Berlin	3	billets	struct.(standard comm.grade)	80,90,100,120 sq.	100,000	Demag 1971	bow-type
Paderwerk Gebr.Benteler Schloss Neuhaus	2	blooms	carbon	450/420/380x 100,120,140,160 sq. 200,230,260,290,310 octagonals		Concast 1958	vertical with bending
Gebr. Benteler,Lingen	2	slabs,blooms + octagons		350-670x115-180; 220-350x220-280; 220-310; o.d.		Sack 1974	
Best.Augsburg	4	billets		90,140 sq.		Danieli 1972	
Augsburg	4	billets		140,200 sq.		Danieli	
Dillinger Hüttenwerke,Dillingen	1	slabs	carbon	1,000x180,1,600x250		Concast 1964	S-type
Dillingen	2	slabs	carbon	750-1,600x170-250		Concast 1963	vertical with bending
Dillingen	2	slabs	carbon	1,500-2,200x200-300		Concast 1975	vertical with bending
Eschweiler Bergwerks-Verein Eschweiler-Aue	4		struct.(standard comm.grade) ball-bearing spring	125,135,190,150, 210 dia;92,100 sq. 87 sq. 100 sq.	90,000	Demag 1965	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (t/y)	Maker and date	Other details
WEST GERMANY, cont.							
Hamburger Stahlwerke GmbH., Hamburg-Finkenwerder	2 x 4	billets	carbon	100,110,120 sq.	600,000	Concast 1971	S-type
Hoesch Hüttenwerke AG, Dortmund Hörde	2	slabs	carbon, low-alloy	1,000x150–1,650x320	600,000	Concast 1972	S-type
Dortmund	2	slabs	mild carbon; general struct.; heat-treatable; transformer and dynamo	800–1,650x 150/320	750,000	Demag 1976	bow-type
Klöckner-Werke AG, Bremen	2	slabs		900–2,150x 160–310		Vöest-Alpine 1973	high speed sequence cast.
Fried. Krupp Hüttenwerke, Rheinhausen	2	slabs	carbon	500/700x150; 500/700x220; 900/1,650x150; 900/1,650x220	1,000,000	Demag 1971	bow-type
Rheinhausen	2	slabs	mild-carbon general struct.	850/1,650x 200/300	1,600,000	Demag 1975	bow-type
Mannesmann, Gelsenkirchen	4	slabs	general struct., transformer and dynamo	1,500x130/150, 900x150	300,000	Demag 1962	vertical
Duisburg	1	slabs	carbon, general struct.	1,000/2,050x 205	250,000	Demag 1964	bow-type
Duisburg	2 x 2	slabs	mild-carbon, general struct.	1,500x205; 2,100x205	1,200,000	Demag [illegible]	bow-type
Gelsenkirchen	8	billets, blooms and small slabs	struct. (standard comm. grade)	214, 280 sq.	300,000	Demag [illegible]	vertical
Duisburg	4	billets, blooms + small slabs	struct. (standard comm. grade)	145,260,275,300 dia 180x140; 240x200; 330x330; 390x130		Demag	vertical
Maxhütte, Sulzbach-Rosenberg	3	billets	carbon	110 sq.	200,000	Concast 1970	S-type
Sulzbach-Rosenberg	3	blooms	carbon	140,160,180 sq.	100,000	Concast 1970/73	S-type

Table 2 : Continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
WEST GERMANY, cont.							
Moselstahlwerk, Trier	3	billets		90,120 sq.		Danieli 1971	
NRS-Niederrhein Stahl, (Formerly F.Meyer-Dinslaken)	3	blooms + billets	struct.(standard comm.grade)	125,150,170 hexagons;100, 120,160 sq.	75,000	Demag 1962	vertical
Dinslaken	2		stainless struct.(standard comm.grade)	100,120,160 sq. 160,240 hexagons; 100,160 sq.	240,000	Demag 1971	vertical
Peine-Salzgitter, Salzgitter	2	slabs	carbon,general struct.,heat-treatable	900x210; 1,250x210; 1,450x210;1,650 x210;1,950x210	1,000,000	Demag 1973	bow-type
Röchling-Burbach, Völklingen	6	blooms + billets	struct.(standard comm.grade),cold-heading,spring, stainless,ball-bearing,tool	100,240 sq.	150,000	Demag 1967	bow-type
Völklingen	4	billets	carbon	240 sq. 100 sq.	360,000	Concast 1971	S-type
Thyssen Henrichshütte, Hattingen/Essen (formerly Rheinstahl Hüttenwerke)	2 x 1	slabs	carbon,alloy stainless	1,000-1,700x 160-250; 1,350-2,100x 160-300		Concast 1967	S-type
Theodor Wuppermann, Leverkusen		slabs			480,000	Krupp [illegible]	The caster has been built at Fried.Krupp's Rheinhausen works,which will supply liquid steel
GREECE							
Metallurgiki Halyps,Tsingelli	3	billets	carbon	75-130 sq;360x110		Concast 1975	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
GREECE, cont.							
Halyvourgia Thessalias, Volos	3	billets	struct.(standard comm.grade)	80,110,130 sq.	120,000	Demag 1974/75	bow-type
Halyvourgiki Inc.,Eleusis	6	billets		80,120 sq.		Danieli 1966	
Eleusis		slabs		800-1,600x 140-250		Voest-Alpine 1972	sequence casting
Eleusis		slabs		800-1,600x 140x250		Voest-Alpine 1974	sequence casting
Heliniki Halyvourgia SA, Athens	3	billets	carbon	80-160 sq.		Concast 1975	
Steel Works of Northern Greece SA, Saloniki	2	billets	carbon	100 sq.		Concast 1965/67	S-type
Saloniki	3	billets	struct.(standard comm.grade)	100,120 sq; 100x140; 120x160; 100x180	100,000	Demag 1971	bow-type
HONG KONG							
Shun Fung Iron Works Ltd., Kowloon	1	billets	carbon	100 sq.		Concast 1975	S-type
HUNGARY							
Csepel Steel and Tube Works, Csepel Island Danube Works, Dunaujváros							
Ozd Works, Ozd	6	billets	carbon	80,100,120 sq.	350,000	Concast 1973	S-type
INDIA							
Bihar Alloy Steels Ltd., Ranchi	2	blooms + billets	struct.(standard comm.grade)	120,150,190 sq.	100,000	Demag 1975	bow-type
			ball-bearing, cold-heading, spring, stainless, tool	150,190 sq.			
Canara Workshps Ltd., Mangalore	1	billets	carbon, alloy	90,120 sq.		Concast 1965	vertical with bending; tilting ladle

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
INDIA, cont.							
Modi Industries Ltd., Modinagar	2	billets	carbon	100 sq.		Concast 1975	S-type
Mukand Iron + Steel Works Ltd., Thana, Maharashira	2	billets	carbon low-alloy	80,100,120 sq.		Concast 1965	S-type
Rathi Alloys+Steel Ltd., Ghaziabad	2	billets	carbon	100 sq.	50,000	Concast 1976	S-type
Steel Complex Ltd., Feroke, Kerala	2	billets	carbon	100 sq.		Concast 1975	S-type
Tamil Nadu Steels, Arkonam	4	billets	carbon, low-alloy	75,100 sq.		USSR	vertical
INDONESIA							
PT Krakatau Steel, Jakarta	2 x 4	billets	carbon	75–130 sq.		Concast 1976	S-type
IRAN							
Shahryar Steel Plants Co., Teheran	4	billets	carbon	90,100,130 sq.		Concast 1972	S-type
Shoosh Steel Plants Co., Teheran	4	blooms	carbon	130,150,180 sq.		Concast 1973	S-type
IRAQ							
Khor Al Zubair Steelworks, Zubair	2 x 6	billets	carbon	80–160 sq.		Concast 1976	S-type
ITALY							
Afem, Campofelice di Roccella, Palermo	2	billets		140,160 sq.		Concast 1971	S-type
Afim, Nave	4	billets	carbon	140 sq.		Concast 1972	S-type
Alfa, Brescia	3	billets	struct. (standard comm. grade)	130 sq.	144,000	Demag 1971	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
ITALY, cont.							
Alfa, Brescia	2	billets	struct.(standard comm.grade)	130 sq.	61,000	Demag 1971	bow-type
Acc.Ferr.Alpine SpA, Borgone di Susa	2	billets	carbon	115 sq.		Concast 1971	S-type
Aveg, Vicenza	4	blooms + billets	high-alloy	100-140,180 sq.		Continua 1975	
Industria Siderurgica Azionaria Ospitaletto	4	blooms	carbon	200 sq.		Concast 1976	S-type
Ospitaletto	6	billets	carbon	120 sq.		Concast 1976	
Acc.Ferr.Busseni, Nave	4	billets		80,160 sq.		Danieli	
Offlaga	8	billets		80,160 sq.		Danieli	
Acc.e Ferr.del Caleotto, Lecco	3	billets	struct.(standard comm.grade) cold-heading	80,100,130, 160 sq. 130,160 sq.	130,000	Demag 1974	bow-type
Ferriera di Ceto, Ceto	2	billets		90,140 sq.		Danieli	
Acc.di Civitate al Piano, Cividate al Piano	3	billets	carbon	115 sq.		Concast 1975	S-type
Cortenuovo SpA,Bergamo	2 x 4	billets	struct.(standard comm.grade)	120 sq.	300,000	Demag 1975	bow-type
Sta.Nazionale Cogne,Aosta	3	blooms		240 sq.180x240, 200x280		Voest-Alpine 1976	bow-type with straight mould
Acc.Ferr.Trafilerie Cravetto, Turin	2	billets	carbon	100,115 sq.		Concast 1968	S-type
Turin	3	billets	carbon	100 sq.		Concast [illegible]	S-type
Acc.di Darfo,Darfo,Brescia	3	billets	carbon	120 sq.		Concast [illegible]	S-type
Acc.e Ferr.Lombarde Falck, Milan	1	slabs	carbon	1,350x160, 1,700x250, 2,100x300	250,000	Concast [illegible]	S-type
Milan	2	slabs	carbon,low-alloy	320-640x125-160		Concast 1976	S-type
Acc.Ferr.Fenotti + Comini, Nave, Brescia	3	billets		80,120 sq.		Danieli 1968	
Nave Brescia	3	billets		80,120 sq.		Danieli 1970	
Montichiari	3	billets	carbon	120 sq.		Concast 1973	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
ITALY, cont.							
Feralpi, Lonato	3	billets	carbon	115 sq.		Concast 1973	S-type
Lonato	3	billets	carbon	115 sq.		Concast 1974	S-type
Acc.Feretti Spa,Gianico,Bresc.	5	billets		120 sq.		Continua	
Acc.Ferrero SpA, Turin	2	billets	carbon	115 sq.		Concast 1972	S-type
Ferrotubi SpA, Genoa	3	blooms + billets	struct.(standard comm.grade)	100-150 dia.	150,000	Demag 1972	bow-type
	2		struct.(standard comm.grade)	100-250 dia.			
Off.e Fond.Galtarossa,Verona	4	billets		100,160 sq,180x120		Danieli 1968	
Verona	4	billets		90,160 sq.		Danieli	
Verona	4	billets		90,160 sq,180x120		Danieli	
Ilfo-Industria Laminati	3	billets	carbon	115 sq.		Concast 1968	S-type
Ferrosi Odolese, Odolo	3	billets	carbon	115 sq.		Concast 1973	S-type
IRO-Industrie Riunite Odolese, Odolo	2	billets	carbon	120 sq.		Concast 1969	S-type
Odolo	3	billets	carbon	120 sq.		Concast 1973	S-type
Italsider SpA,Taranto	2	slabs	carbon,general structural	1,500x140, 2,200x300	1,200,000	Demag 1971	bow-type
Taranto	2 x 2	slabs	carbon,low-alloy	900-2,200x160-300		Concast 1974	S-type
Acc.Ferr.del Lazio, Pomezia, Rome	3	billets		90,120 sq.		Danieli 1970	
Acc.e Ferr.Luigi Leali, Odolo	2 x 2	billets	struct.(standard comm.grade)	115,130 sq.	200,000	Demag 1968	bow-type
Acc.di Loreo, Loreo	4	billets	carbon	75-130 sq.		Concast [illegible]	S-type
Ind.Sid.Lucana,Potenza	4	billets		90,130 sq.		Danieli	
Acc.Lucchini, Sarezzo	4	billets		90,140 sq.		Danieli	
Settimo Torinese	4	billets		120,160 sq,180x120		Danieli	
Settimo Torinese	4	billets		100,150 sq,180x120		Danieli 1971	
Sarezzo	4	billets		100,150 sq,180x120			
Acciaierie Megara, Augusta,Catania	3	billets	carbon	125 sq.		Concast 1973	S-type
Siderurgia Meridionale Stefana Antonio, Termoli	4	blooms + billets	struct.(standard comm.grade)	120,220 sq., 120-200 dia.	250,000	Demag 1974	bow-type
Acc.Ferr.e Fond.Modena, Modena	3	billets		100,190 sq.		Danieli	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
ITALY, cont.							
Siderurgica Montirone, Brescia	4	billets	carbon	115 sq.		Concast 1973	S-type
ORI Martin, Brescia	2 x 2	billets	carbon, alloy	115, 130 sq.		Concast 1965	S-type
Brescia	3		carbon, alloy	115, 130 sq.		Concast 1971	S-type
Fratelli Orsenigo SpA, Milan	4	billets	struct. (standard comm. grade), cold-heading	140 sq.	150,000	Demag 1975	bow-type
Ferr. Fratelli Pasini di Alessio, Odolo	3	billets	carbon	115 sq.		Concast 1975	S-type
Acc.e Ferr. Pietra, Brescia	3		struct. (standard comm. grade)	max. dia. 200	108,000	Demag 1971	bow-type
Brescia	6	billets		100, 180 sq.		Danieli	
Acc. di Piombino, Piombino	6	billets	struct. (standard comm. grade)	100, 135, 140, 150 sq.	270,000	Demag 1970	bow-type
Piombino	2	slabs		300-550x120 (or 900-1,550x135-250)		Voest-Alpine 1974	high-speed
Acc. di Pisogne, Pisogne	3	billets	struct. (standard comm. grade)	140 sq.	90,000	Demag 1974	bow-type
Acc. di Porto Nogaro Srl, S. Giorgio di Nogaro	3	billets	carbon	75-130 sq.		Concast 1975	S-type
Acc. Ferr. Predalva, Piancamuno	2 x 4	billets		100, 150 sq.		Danieli 1969	
Piancamuno	6	billets		100, 160 sq.		Danieli	
Ferriera Preo + Figli, Marghera	2	billets		80, 120 sq.		Danieli 1966	
Prolafer, Trino, Vercelli	4	billets		90, 140 sq.		Danieli 1973	
Prosider, Sabbio Chiese	3	billets	struct. (standard comm. grade)	120 sq.	100,000	Demag [illegible]	bow-type
Carlo Raimondi SpA, Rescaldina	2	billets	carbon	120 sq.		Concast 1975	S-type
Acc.e Ferr. Riva SpA, Caronno	3	billets		100, 140 sq.		Danieli 1964	
Caronno	4	billets		90, 140 sq, 180x120		Danieli 1968	
Caronno	5	billets		90, 160 sq.		Danieli 1972	
Acc. di Rubiera, Rubiera Regio Emilia	3	billets		100, 160 sq.		Danieli 1971	
Luciano Rumi SpA, Montello Bergamo	6	billets		80, 140 sq.		Danieli 1971	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
ITALY, cont.							
Montello, Bergamo	6	billets		80,140 sq.		Danieli	
Metallurgica San Bonifacio, Bredina	3	billets	carbon	115 sq.		Concast 1975	S-type
Siderurgica Santo Stefano, Pero	2	billets	carbon, low-alloy	75–130 sq.		Concast 1975	S-type
Ferr.Acc.Sarde, Cagliari	2	billets		90,140 sq.		Danieli 1969	
Ferriera Sarda SpA, Porto Torres	2	billets	carbon	100 sq.		Concast 1973	S-type
Off.Laminatori Sebino, Pisogne, Bres.	5	billets		100,150 sq.		Danieli 1975	
Siderurgica Settimo, Settimo Torinese	3	billets	carbon	115 sq.		Concast 1975	S-type
Sideral SpA, San Zeno Naviglio	4	billets		100,160 sq.		Danieli 1971	
San Zeno Naviglio	3	billets		100,140 sq.		Danieli 1972	
San Zeno Naviglio	4	billets		100,140 sq.		Danieli 1972	
Siderman. Grottammare	3	billets		90,140 sq.		Danieli	
Sider[illegible], Osoppo, Udine	5	billets		90,130 sq.		Danieli 1975	
SiMo, Monfalcone	3	billets		80,140 sq.		Danieli 1971	
Sisma, Villadossola	4	billets		90,150 sq.		Danieli 1968	
Villadossola	4	billets		100,195 sq.		Danieli	
Acc.Ferr.A Stefana, Coniochio, Brescia	2	billets		90,140 sq.		Danieli 1967	
Stefana Antonio SpA, Nave	2	billets	struct.(standard comm.grade)	120 sq.	60,000	Demag 1975	bow-type
Acc.E.Ferr.Fratelli Stefana, Nave	2	billets	carbon	100 sq.		Concast 1970	S-type
Nave	4	billets	carbon	100,120 sq.		Concast 1971	S-type
Nave	2	billets	carbon	100 sq.		Concast 1973	S-type
Acc.del Sud, Casoria, Naples	3	billets		90,140 sq.		Danieli 1975	
Modica, Ragusa	2	billets		90,130 sq.		Danieli	
Acc.Tanaro SpA, Lesegno	4	billets		90,140 sq, 180x120		Danieli 1968	
Terni SpA, Terni	8	billets	struct.(standard comm.grade)	140 sq.	105,000	Demag 1958	vertical
Ferriera Valsabbia Srl, Odolo	3	billets	carbon	115 sq.		Concast 1971	S-type
Acc.Valsugana SpA, Valsugana	2	blooms		320 sq, 320x400		Continua	
Valsugana	4	billets		90–130 sq.		Continua	
Acc.Fond.Venete, Padua	2 x 4	billets		90,140 sq, 180x120		Danieli 1968	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
ITALY, cont.							
Padua	6	billets		90,140 sq.		Danieli	
JAPAN							
Azuma Seiko, Sendai	4	blooms	Struct.(standard comm. grade),cold heading,tool	280x350	330,000	Demag 1974	bow-type
Chiyoda Kohtetsu Kogyo, Ayase works, Tokyo	2		carbon		72,000	Hitachi 1969	vertical
Ayase works, Tokyo	3	billets	carbon	120 sq.		Concast 1974	S-type
Chiyoda Iron+Steel Co., Saitama	3	billets	carbon	95,120 sq.		Mitsubishi/ Olsson 1975	low-head
Daido Steel Co., Nagoya	1	billets	ball-bearing, cold-heading, spring,stainless,tool	170 sq.	60,000	Demag 1972	bow-type
			struct.(standard comm. grade)	155x215, 170 sq.			
Daiishi Seiko Co.Ltd., Nagoya	3	billets	carbon	120,140 sq.		Mitsubishi/ Olsson 1972	low-head
Daitetsu Steel Industry Co., Osaka	4	billets	carbon	110,140 sq.		Mitsubishi/ Olsson 1973	low-head
Daiwa Denki Seiko,Amagasaki	2	billets	carbon	145 sq.		Concast 1972	S-type
Amagasaki	2	billets	carbon	145 sq.		Concast 1973	S-type
Fujisawa Seiko Co., Sendai	3	billets	carbon	120 sq.		Mitsubishi/ Olsson 1974	low-head
Sendai	3	billets	carbon	120 sq.		Mitsubishi/ Olsson 1975	low-head
Funabashi Steel Works Ltd., Funabashi No. 1	4	billets	carbon	100,125,155 sq.		Mitsubishi/ Olsson 1971	low-head
Funabashi	8	billets	carbon	125 sq.		Mitsubishi/ Olsson 1975	low-head
Hokuetsu Metal Co., Niigata	4	billets	carbon	115,130 sq.		Mitsubishi/ Olsson 1972	low-head

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Jonan Seiko, Kawaguchi	3	billets		100-130 sq.		Continua/ Kawasaki 1974	
Kansai Steel Corp., Sakai	2	blooms	carbon	200x330/240/150		Mitsubishi/ Olsson 1971	Low-head
Kawasaki Steel Corp., Mizushima	8	blooms	carbon	200x220/300, 250x250/300	1,000,000	Concast 1968	S-type
Mizushima	2	slabs	carbon, low-alloy	max. 2,200x305	1,200,000	Concast 1971	S-type
Chiba	1	slabs	carbon, low-alloy	800x200, 1,700x260	480,000	Concast 1971	S-type
Mizushima	2	slabs	carbon, gen. struct. heat-treatable	1,900x350			
Mizushima	4	blooms + beam blanks	carbon	400x240/300, beam blanks 460x400x120		Concast 1973	S-type
Chiba	2	slabs		900x1,900x 200-305		Vöest-Alpine/ IHI 1974	
Mizushima	2	slabs	carbon, low-alloy	1,600-2,500x 220-310		Concast 1975	vertical with bending
Kishiwada Steel, Kishiwada	2	billets		140 sq.		Vöest-Alpine IHI 1972	in-line re- duct. stands
Kiyomoto Tekko Co., Saga	3	billets	carbon	105,130 sq.		Mitsubishi/ Olsson 1973	low-head
Kobe Steel Ltd. Kobe Works, Nadahama	8	blooms			246,000	USSR/Kobe	
Kobe Works, Nadahama	6	blooms			330,000	USSR/Kobe	
Amagasaki	2 x 2	blooms				USSR/Kobe	
Kakogawa	2	slabs				USSR/Kobe	
Kohkuku Kinzoku Kogyo, Sakai	2	billets	carbon	105 sq.		Concast 1972	S-type
Kohzai Kogyo, Yokohama	3	billets	carbon	95,130 sq.		Concast 1973	S-type
Kokko Steel Works Ltd. Osaka	2	blooms	carbon	130,190 sq.		Concast 1966	S-type
Kotobuki Industry Co. Ltd. Hiroshima	1	billets	carbon	110 sq.		Mitsubishi/ Olsson 1972	low-head
Kumamoto Kyoeu Kogyo, Uto-City	3	billets	carbon	130 sq.		Concast 1974	S-type
Kyoei Seiko, Tsukuda	3	billets	carbon	110,120 sq.		Concast 1974	S-type
Urazoe	2	billets	carbon	115 sq.		Concast 1974	S-type
Kyoei Seitetsu, Tsukuda	2	billets	carbon	105 sq.	140,000	Concast 1970	S-type
Hirakata	4	billets	carbon	105 sq.		Concast 1971	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Mitsubishi Heavy Industries Ltd., Hiroshima	1	slabs,blooms + billets	carbon	75,120,200 sq. 120x420		Mitsubishi/ Olsson 1968	low-head test machine (in-line reduction mill)
Mitsubishi Steel Mfg. Co.Ltd., Tokyo	1	billets	carbon	115,130 sq.		Mitsubishi/ Olsson 1973	low-head
Mukoyama Kojo, Kawaguchi	2	billets	carbon	100 sq.		Mitsubishi/ Olsson 1967	progressive bending
Saitama	4	billets	carbon	120 sq.		Mitsubishi/ Olsson 1975	low-head
Nakayama Steel Products Co., Osaka	4	billets	carbon	100,130 sq.		Mitsubishi/ Olsson 1972	low-head
Nakayama Steel Works Ltd., Nagoya	1	slabs	carbon	400-600/650-800 x150(twin mould)		Concast 1973	S-type
Funamachi	4	billets	carbon	80-135 sq.		Concast 1975	S-type
Osaka	4	blooms	carbon	150 x 225, 190 x 235		Mitsubishi/ Olsson 1975	low-head
Nanbuseiko, Tokyo	6	billets		130 sq.		Continua/ Kawasaki 1974	
NKK, Tsurumi (Keihin)	1	slabs	carbon,general structural	1,600x200	480,000	Demag 1967	bow-type
Fukuyama	2	slabs	carbon,general structural heat-treatable	950 x 220, 1,260 x 220, 1,570 x 220. 1,910 x 220/300	750,000	Demag 1970	bow-type
Fukuyama	2	slabs	carbon,low-alloy	max.1,600x300		Concast 1971	S-type
Fukuyama	2	slabs	carbon,general structural heat-treatable	950/2,100 x 220/300	1,000,000	Demag 1971	bow-type
Ogishima	2					Kobe	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Ogishima	4	slabs	carbon, low-alloy	1,600-1,900x200, 1,800-2,300x250/300		Concast 1976	
Nippon Metal Industry, Sagamihara	1	slabs	stainless	130 x 960, 130 x 1,300		Mitsubishi/ Olsson 1968	straight
Kimuura	1	slabs	stainless	960/1,045/1,270 x 130,1,270/1,585x165		Concast 1972	S-type
Nippon Steel Corp., Hikari	1	slabs	stainless	1,200 x 150	107,000	Concast 1960	vertical
Muroran	1/2	slabs	carbon	160x1,000,300x2,100	840,000	Hitachi 1965	curved
Yawata No. 1	6	billets	carbon	80,100,115, 145 sq.		Mitsubishi/ Olsson 1967	ordinary bending
Hikari	1	blooms	stainless	180-210 sq,250x210	37,000	Concast 1968	vertical
Yawata No. 2	6	billets + blooms	carbon	100,140,160,175 sq. 115,165 dia.		Mitsubishi/ Olsson 1968	ordinary bending
Kamaishi	4	blooms	carbon	150x300,350x500	300,000	Hitachi 1969	
Nagoya	2	slabs	carbon, general structural heat-treatable	1,000/1,600x200/ /250;1,500/1,900x160, 1,500/2,100x175/300	900,000	Demag 1970	bow-type
Tobata	2	slabs	carbon	max. 300 x 1,800	600,000	USSR/Kobe 1970	vertical
Hirohata	2	slabs	general struct. heat-treatable	950/1,600x165, 1,600/2,000x250	600,000	Demag 1970	bow-type
Kimitsu	2	slabs	general struct.	1,000/1,500x180, 1,250/2,050x210, 1,300/2,200x300	900,000	Demag 1970	bow-type
Oita	3 x 2	slabs	carbon	1,400/2,200x250/300	3,600,000	Demag 1972	bow-type
Oita	2 x 2	slabs	carbon	1,400/2,200x250	2,400,000	Demag 1975	bow-type
Nippon Yakin Kogyo Co.Ltd, Kawasaki	1	slabs	stainless	1,050/1,300/ 1,600 x 145		Concast 1970	vertical
Kawasaki	1	slabs	stainless	1,300/1,050x140		Concast 1965	vertical
Nishi Steel Mfg. Co. Ltd., Tokyo	4	billets	carbon	120 sq.		Mitsubishi/ Olsson 1971	low-head

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Nisshin Steel Co.Ltd., Kure	1	slabs	carbon, al.killed high-carbon	150-250 x 840-1,340	254,000	USSR/Kobe 1967	vertica
Shunan	1	slabs	transformer and dynamo stainless	960/1,280 x 130 960/1,280x155	145,000	Demag 1971	bow-typ
North Japan Special Steel Co., Hachinohe	1	slabs	general struct. stainless	750 x 150	40,000	Demag 1964	vertica
	2	billets	struct.(standard comm.grade), spring, stainless, tool, cold-heading	115,165, 175 sq. 115 sq.	40,000	Demag 1964	vertica
Oji Steel Corp., Gumma No. 1	4	billets	carbon	97,115,130, 145 sq.		Mitsubishi/ Olsson 1970	low-hea
Gumma No. 2	4	blooms + billets	carbon	115,145 sq., 140 x 180		Mitsubishi/ Olsson 1973	low-hea
Osaka Iron+Steel Co.Ltd., Osaka	4	blooms + billets	struct.(standard comm.grade)	135,230 sq.	150,000	Demag 1972	bow-type
Ohtani Jukogyo, Haneda	4	billets	Struct.(standard comm.grade)	120 sq.	200,000	Demag 1972	bow-type
Otani Seitetsu Co.,Toyama	2	billets	carbon	120 sq.		Mitsubishi/ Olsson 1973	low-head
Otani Heavy Industries, Amagasaki	3	billets	carbon	120 sq.		Mitsubishi/ Olsson 1974	low-head low-head
Amagasaki	2	blooms		200 sq. 200 x 250		Mitsubishi/ Olsson1974	low-head
Rinko Seitetsu Co., Osaka	4	blooms + billets	carbon	100,120,130,140, 150,170,190 sq. 190x230		Mitsubishi/ Olsson 1975	low-head low-head
Sanko Seiko KK, Tokyo	4	billets		100,150 sq.		Danieli 1970	
Seibu Kagaku Co., Saitama	4	billets	carbon	110,150 sq.		Mitsubishi/ Olsson 1975	low-head

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Shimizu Seiko Co., Tomakomai	3	billets	carbon	100 sq.		Mitsubishi/ Olsson 1974	low-head
Showa Denki Seiko, Takasaki	2	billets	carbon	100-150 sq.	50,000	Continua/ Kawasaki 1970	curved mould
Sumitomi Electric Industries Ltd., Itami	2	billets	carbon	115 sq.		Mitsubishi/ Olsson 1967	ordinary bending
Sumitomo Metal Industries Ltd., Kokura	6	billets	carbon, low-alloy	110 sq.		Concast 1967	S-type
Wakayama	1	slabs	stainless	800-1,300x115-180	180,000	Concast 1969	vertical
Wakayama	2	slabs	carbon, low alloy	900-2,100x150-300	840,000	Concast 1971	S-type
Kashima	2	slabs	carbon	900-2,300x190-300		Concast 1972	S-type
Kashima	2 x 2	slabs	carbon	900-2,300x190-300		Concast 1974	S-type
Kokura	4	blooms	carbon, alloy	180 sq.		Concast 1976	vertical with bending
Tobu Seitetsu, Misato-City	3	billets	carbon	120 sq.		Concast 1975	S-type
Tohoku Iron Sand Steel Mfg.Co.Ltd., Hachinohe No. 1	1	billets	carbon	85,125,127 sq.		Mitsubishi/ Olsson 1966	progressive bending
Hachinohe No. 2	1	billets	carbon	85,125,127 sq.		Mitsubishi/ Olsson 1970	progressive bending
Tokai Steel Works Ltd., Kitakyushu	4	billets	carbon	100 sq.		Mitsubishi/ Olsson 1971	low-head
Tokyo Kohtetsu Co. Ltd., Oyama	4	blooms + billets	carbon	120,160,200 sq.	500,000	Concast 1973	S-type
Tokyo Seitetsu, Kochi	1	blooms	carbon	170,190 sq., 235x170,250x220, 270x245,300x230, 310x250		Concast 1970	S-type
Kyushu	2 x 3	blooms	carbon	120,170 sq.		Concast 1971	S-type
Okayama	4	blooms	carbon	170 sq,235x170, 220/310/355 x 250,300x230		Concast 1973	S-type
Tokyo Tekko, Hachinoe	5	billets		100-150 sq.		Continua/ Kawasaki	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
JAPAN, cont.							
Oyama	5	billets		95-150 sq.		Continua/ Kawasaki 1972	
Topy Industries Ltd., Toyohashi	3	blooms	carbon	160-280,200 x 360,210 x 400		Mitsubishi/ Olsson 1970	low-head
Tosa Electric Steel Co., Takamatsu	2 x 3	blooms	carbon	120,170 sq.	420,000	Concast 1971	S-type
Toshin Steel Co., Tokyo No. 1	4	blooms + billets	carbon	115,140 sq. 150 x 180		Mitsubishi/ Olsson 1967	progressive bending
Tokyo No. 2	4	billets	carbon	115,140 sq.		Mitsubishi/ Olsson 1969	low-head
Himeji	2	blooms	carbon, alloy	135 sq, 250x200 220 x 180	300,000	Concast 1969	vertical
Himeji	4	billets	carbon	100,115,135 sq.	300,000	Concast 1971	S-type
Himeji	4	billets	carbon, alloy	110,115,135 sq.		Concast 1973	S-type
Himeji	8	billets	carbon	135,150 sq.		Concast 1975	S-type
Toyo Seiko, Kawasaki	3	billets		92,120 sq.		Continua/ Kawasaki 1972	
Tokyo	4	billets	struct. (stand. comm. grade)	120 sq.	200,000	Demag 1974	bow-type
Toyohira Seiko, Sapporo City, Hokk.	4	billets	carbon	100,120 sq.		Concast 1976	S-type
Ube Industries Ltd., Ube	4	billets	carbon	110,150 sq.		Mitsubishi/ Olsson 1975	low-head
Yamaguchi Kyoei Kogyo, Onada City	3	billets	carbon	130 sq.		Concast 1974	S-type
Yamato Kogyo Co. Ltd., Himeji	2	blooms	carbon	160x215; 170x265/ 310/350		Mitsubishi/ Olsson	low-type
Yamato Steel Works Ltd., Osaka	1	slabs	carbon	800-1,550x150-250		Concast 1967	S-type
Yodogawa Steel Works Ltd., Osaka	2	billets		135 sq.		Voest-Alpine/ IHI	in-line reduction stands
JORDAN							
Jordan Iron + Steel Industry Co. Ltd., Zarka-Awajan	1	billets		80,140 sq.		Danieli	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
SOUTH KOREA							
Dongkuk Steel Mill Co.Ltd, Pusan	4	billets	carbon	80,100,120 sq.	300,000	Concast 1973	S-type
Pusan	1	blooms	carbon	max.400 x 100		Concast 1974	S-type
Inchon Iron + Steel Co., Inchon	4	billets	carbon	75,115,145 sq.		Mitsubishi/ Olsson 1973	low-head
Kang Won Ind.Co.Ltd., Pohang	4	billets	carbon	110 sq.		Concast 1974	S-type
Pohang Iron + Steel Co.Ltd, Pohang		slabs		930-1,880x170-250		Voest-Alpine 1976	
Pohang	3	blooms		200,220,230 sq.		Voest-Alpine 1976	
LUXEMBOURG							
Rodange-Athus, Rodange	4	billets	carbon	80,130 sq.		Concast 1976	S-type
MALAYSIA							
Malayawata Steel, Prai	2	billets	carbon	100 sq.	73,000	Mitsubishi/ Olsson 1972	low-head
MEXICO							
Ahmsa, Monclova	2	slabs	carbon, general structural	838/1,067x178	750,000	Demag 1976	bow-type
Laminadora Atzcapotzalco, Mexico City	1	billets	carbon	80 sq.		Mitsubishi/ Olsson 1973	low-head
Aceros de Chihuahua, Chihuahua	2 x 1	billets	carbon	50,65 sq.	70,000	Concast 1961	vertical with bending; tilting ladle
Aceros Corsa SA, Mexico City	1	billets		80,140 sq.		Danieli	
Aceros Ecatapec, Tulpetlac	2 x 1	billets	carbon, alloy	75 sq., 140 x 100	70,000	Concast 1964	vertical with bending; tilting ladle
Tulpetlac	2	billets	carbon	80,100 sq.	70,000	Concast 1971	S-type
Cia.Siderúrgica de Guadelajara, Guadelajara	2	billets	struct.(standard comm.grade)	115,136 sq.	48,000	Demag 1969	bow-type
Hylsa de Mexico, Xoxtla	2 x 4	billets	carbon	100 sq.	600,000	Concast 1969	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
MEXICO, cont.							
Aceros Nacionales, Tlalnepantla	4	billets	struct.(standard comm. grade)	76,108 sq.	160,000	Demag 1973	bow-type
Aceros San Luis, San Luis Potosi	2	billets		90-130 sq.		Continua	
Sicartsa, Las Truchas	3 x 6	billets	carbon, low-alloy	75-130 sq.	1,400,000	Concast 1975	S-type
NEW ZEALAND							
New Zealand Steel Ltd., Glenbrook	4	billets	carbon	80,115 sq.		Mitsubishi/ Olsson 1969	ordinary bending
NORWAY							
Elkem Spigerverket, Nydalen	4	billets	struct.(standard comm. grade)	135 sq.	225,000	Demag 1972	bow-type
Stavanger Staal, Jorpeland	1	billets	alloy, stainless	165 sq.	12,000	Concast/Nyby 1959	vertical
PERU							
Siderperú, Chimbote Chimbote	4	billets slabs	carbon	80-150 sq.	90,000 180,000	Concast 1966 Fives Lille-Cail	vertical with bending
PHILIPPINES							
Philippine Blooming Mills Inc., Manila	4	billets	carbon	75,80,115 sq.	-	Mitsubishi/ Olsson 1974	low-head
Steel Casters of the Philippines Inc., Makai	2	billets	carbon	75,115 sq.		Concast 1975	vertical with bending
POLAND							
Huta Jednosc, Siemianowice	4	blooms	carbon, tube	150 sq.	100,000	USSR/Poland 1962	
Huta Kosciuszko							
Huta Nowotko, Ostrowice	2 x 4	blooms	carbon, low-alloy	220 sq., 320x280		Concast 1976	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
POLAND, cont.							
Huta Pierwszy Maja							
Huta Zawiercie, Zawiercie	2	blooms					
PORTUGAL							
Sid. Nacional, Seixal	4	billets		80,140 sq.	150,000	Danieli 1970	
Oporto	4	billets		115 sq.	200,000	Demag 1975	
PUERTO RICO							
Insid, Bayamón	2	billets					
QATAR							
Qatar Steel Co., Umm Said		billets			400,000	Kobe 1978	
RUMANIA							
Combinat Siderurgic Galati, Galati	2 x 2	slabs	carbon, low-alloy	700-1,900x150-300		Concast 1975	S-type
Otelul Rosu Works	4	blooms + billets	carbon, low-alloy	100,120,140,160 sq. 200 x 180		Concast 1975	S-type
	4	blooms	carbon, low-alloy	160,230 sq., 200 x 180; 260x230		Concast 1975	S-type
EL SALVADOR							
Acero SA, San Salvador	3	billets		90,130 sq.		Danieli	
SINGAPORE							
National Iron + Steel Mills Ltd., Singapore	4 x 2	billets	carbon	120 sq.		Mitsubishi/ Olsson 1974	low-head
SOUTH AFRICA							
Cape Town Iron + Steel, Kuils River	1	billets		80,120 sq.		Danieli 1968	
Dunswart, Benoni	4	billets		80,150 sq.		Danieli 1971	
Highveld Steel + Vanadium Corp., Witbank	4	blooms + billets		140,203 sq.	140,000	Demag 1968	bow-type
Witbank		slabs	general struct.	559x305, 305x254, 406x228		Demag 1968	bow-type
Witbank	4	billets	carbon	100-140 sq.		Concast 1975	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
SOUTH AFRICA cont.							
Iscor, Newcastle	2 x 6	blooms	carbon	315 x 205		Concast 1974	S-type
Newcastle	6	blooms	carbon	315 x 205		Concast 1975	S-type
Vanderbijlpark	2 x 2	slabs	carbon	750–1,900x180/240		Concast 1976	S-type
Newcastle	2	slabs	carbon	800–2,000x190/230	750,000	Concast 1976	S-type
McWillaw Iron + Steel Foundry (pty) Ltd., Isipingo	2	billets	carbon	70 sq.		Concast 1967	S-type
Scaw Metals Ltd., Germiston	2	billets	carbon, low-alloy	80,100,125,140 sq.		Concast 1963	vertical with bending
Germiston	2	billets		4 in, 5.5 in sq.	200,000	Koppers 1968	high-head
Germiston	3	billets		140 sq.	140,000	Koppers	high-head
Usco, Vereeniging	4	billets	carbon, low-alloy	90,100 sq.		Concast 1966	S-type
Vereeniging	4	billets		90,140 sq.		Danieli 1972	
SPAIN							
Acerinox, Algeciras	1	slabs	stainless	900–1,600x130–200	300,000	Demag 1976	bow-type
AHM, Sagunto	4	blooms	carbon	145x170, 280x300 max. 390 sq.		Concast 1976	S-type
Forjas Alavesas, Vitória	4	blooms + billets	struct. (standard comm. grade) cold-heading	100,200 sq. 200 sq.	180,000	Demag 1973	bow-type
J.M.Aristrain SA, Madrid	1	blooms	carbon	250–450x130	50,000	Concast 1966	S-type
Olaberria	4	blooms	struct. (standard comm. grade), cold-heading	145 sq, 160x180; 170 x 200	200,000	Demag 1974	bow-type
Arregui SA, Vitória	4	billets + blooms		90,160 sq.; 200 x 140		Danieli 1970	
Acerias y Forjas de Azcoitia, Azcoitia	3	billets	struct. (standard comm. grade) spring	80,120 sq.	36,000 (initial)	Demag 1972	bow-type
Azma SA, Madrid	3	billets		90,140 sq.		Danieli 1967	
Madrid	3	blooms + billets	struct. (standard comm. grade) cold-heading	100,160 sq.	120,000	Demag 1974	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
SPAIN, cont.							
Indústrias del Besós, Barcelona	1	billets	carbon	80 sq, 200x80	34,300	Concast 1960	vertical with bending; tilting ladle
Barcelona	2	billets	carbon	80,100,120 sq.	73,800	Concast 1966	S-type
Aceros Bueno de la Cruz, Sevilla	3	billets		80,140 sq.		Danieli 1973	
SA Echevarria, Bilbao	3	billets		100 sq.	200,000	Koppers 1970	high-head
Ensidesa, La Felguera	1	billets	carbon	100 sq.		Concast 1965	S-type
Avilés	3 x 6	billets		100,180 sq.	1,000,000	Koppers 1969	high-head
Gijón	1	slabs	carbon	1,350-2,100 x 140-250		Concast 1972	S-type
Gijón	1	slabs	carbon	1,000-1,600 x 140-200		Concast 1976	S-type
Fagsa, Badajoz	2	billets		80-140sq.		Continua/Vascas	
Victorio Luzuriaga SA, Pasajes	3	billets	carbon, alloy	100,160 sq.		Concast 1968	S-type
Hierros Madrid SA, Madrid	2	billets	carbon	90,120 sq.		Concast 1966	S-type
Megasa, Jubia-El-Ferrol	2	billets	carbon	100,120 sq.		Concast 1971	S-type
Nervacero SA, Portugalete	4	billets		90,140 sq.		Danieli 1971	
Portugalete	4	billets	carbon	80-140 sq.		Concast 1975	S-type
Estéban Orbegozo, Zumarraga	4	billets	carbon	80-160 sq.		Concast 1975	S-type
Rico y Echeverría, Zaragoza	3	billets	carbon	80,100,120 sq.	90,000	Concast 1966	S-type
Siderúrgica Sevillana, Sevilla	4	billets		100,140 sq.		Danieli 1973	
Torras, Herreria y Construcciones, Barcelona	3	billets	carbon	80,100,120 sq.	110,000	Concast 1967	S-type
Aceros Eléctricos del Turia, Valencia	2	billets	carbon	100 sq.	50,000	Concast 1968/74	S-type
Marcial Ucín, Azpeitia	2	billets		90,120 sq.		Danieli 1966	
Azpeitia	3	billets	carbon	120 sq.		Concast 1970	S-type
Unión Cerrajera, Vergara						Olsson	
Vergara	3	billets	struct. (standard comm. grade)	80,120 sq.	100,000	Demag 1972	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
SWEDEN							
Fagersta Bruk, Fagersta	1	slabs	special	400 - 840 x 110 - 150	80,000	Voest-Alpine 1973	equipped with temperature equalizing zone
Gränges Steel, Oxelösund	2	slabs	carbon	900-1,650x140-250	450,000	Concast 1967	S-type
Halmstads Järnverk, Halmstad	3	billets			225,000	Olsson	
Kockums Jernverk, Kallinge	4	blooms	carbon, alloy (low)	80-175 sq.		Concast 1975	S-type
Lesjöfors AB, Lesjöfors	1	billets		90x270/300	35,000	Danieli	
AB Motala Verkstad, Motala						Olsson	
Norrbottens Järnverk, Lulea	4	blooms	carbon	200-430x150-225	360,000	Concast 1973	S-type
Lulea	6	blooms	carbon	100-200 sq.		Concast 1975	S-type
Lulea	4	blooms	carbon	200-450x150-225		Concast 1975	S-type
Stora Kopparberg, Domnarvet	1	slabs	mild carbon, gen.struct.	1,000/1,600x 150/250	500,000	Demag 1974	
Domnarvet	1	slabs	carbon, stainless	1,300x180; 1,600x150/225; 1,700x300	300,000	Concast 1966	S-type
SWITZERLAND							
Ferrowohlen, Wohlen	2 x 2	billets		80,120 sq.		Danieli 1966	
Acc.Lam.Monteforno, Bodio	5	billets		80,140 sq.		Danieli 1971	
AG der von Moos'schen Eisenwerke, Lucerne	1	billets	carbon	85,115 sq.		Concast 1959	vertical with bending; tilting ladle
Lucerne	4	billets	carbon	85,115 sq.		Concast 1970	S-type
Von Roll AG, Gerlafingen	1	billets + blooms	struct. (standard comm. grade)	90,200 sq.	15,000	Demag 1965	bow-type
Gerlafingen	2 x 3	billets	carbon	90 sq.		Concast 1976	S-type
SYRIA							
Unicem, Hama	2 x 2	billets	carbon	80-130 sq.		Concast 1977	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
TAIWAN							
China Steel Corp.	4 x 2	blooms	carbon	220 x 260		Mitsubishi/ Olsson	low-head
	2	slabs	mild carbon, gen.struct.	1,140/1,400x155, 1,400/1,680x210, 1,680/1,950x270	1,000,000	Demag 1976	bow-type
Tong Shen Steel + Iron Co.Ltd.	2	billets	carbon	90,120 sq.		Mitsubishi/ Olsson 1973	low-head
THAILAND							
Bangkok Iron + Steel Works Co., Samutprakarn	3	billets	carbon	75,110 sq.		Concast 1976	S-type
Bangkok Steel Industry Co.Ltd., Samutprakarn	2	billets	carbon	75-130 sq.		Concast 1976	S-type
Sisco, Tha Luang	3	billets	carbon	100 sq.		Concast 1969	S-type
TUNISIA							
Elfouladh, Tunis	2	billets	carbon	100,110 sq.		Concast 1974	S-type
Tunis	2 x 2	billets	carbon	95,110 sq.		Concast 1965	S-type
TURKEY							
Colakoglu Metalurji, Istanbul	3	billets	carbon	75-130 sq.		Concast 1975	S-type
Elektrofer Celik Sanayii, Sirkeci	3	billets	carbon	75-130 sq.		Concast 1976	S-type
Elmet, Istanbul	1	billets	struct.(standard comm. grade) spring, stainless tool	80,100,120 sq. 100 sq.	30,000	Demag 1975	bow-type
Eregli Iron + Steel Works, Eregli	1	slabs	carbon	850-1,295x200		Concast 1976	S-type
Metas-Izmir Metalurji Fabrikasi, Izmir	2	billets	carbon, low-alloy	100 sq.	50,000	Concast 1964	S-type
Izmir	1 x 3	blooms +	struct.(standard comm. grade), spring, cold-heading	100 sq., 195 octagons 195 octagons	200,000	Demag 1974/75	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
UK							
Brit.Reinforced Concrete Engineering Co., Stafford	4	billets	carbon	90,140 sq.		Danieli 1975	
BSC General Steels Div., Appleby-Froding	4	blooms	carbon	230 sq.		Concast 1962	vertical, tilting ladle
Barrow	2	blooms + billets	carbon, low-alloy stainless	50-100 sq, 105/150x x50, 180x75		Concast 1952/58	vertical, tilting ladle
Barrow	2	slabs + blooms	carbon, low-alloy, stainless	225 sq, 915 x 140		Concast 1959	vertical with bend. tilting ladle
Barrow	2 x 2	billets	carbon, low-alloy	50-100 sq., 105x50, 150x50		Concast 1961	vertical with bend. tilting ladle
Shelton	2 x 3	blooms	carbon, low-alloy	140,180 sq. 415x230, 355x200, 305x125		Concast 1964	vertical with bending
Shelton	3	blooms	carbon, low-alloy	180 sq., 700 x 355, 415x230, 305x125		Concast 1964	vertical
Shelton	2	slabs	carbon, low-alloy	1,060x200, 620x430, 455x355		Concast 1965	vertical
South Teeside (Lackenby)	8	blooms	carbon	255 sq, 330x255, 405x280, 480x305	800,000	Concast 1972	S-type
Appleby-Frodingham (Anchor Project)	2 x 2	slabs	mild carbon, gen.struct., heat-treatable	1,270/1,525x178, 1,270/1,830x228, 1,270/1,525x254, 1,525x304	2,150,000	Demag 1972	bow-type
South Teeside (Lackenby)	2	slabs	carbon	max.2,060x255	1,000,000	Concast 1973	S-type
South Teeside (Lackenby)	2	slabs	carbon	1,250-2,030x150-250		Concast 1977	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
UK, cont.							
BSC Strip Mills Div.							
Ravenscraig	1	slabs	carbon	760-1,575 x 150-225		Concast 1974	S-type
Ravenscraig	1	slabs	carbon	760-1,575 x 150-225		Concast 1975	S-type
BSC Special Steels Div.							
Panteg	1	slabs	stainless	840-1,320 x 127-165		Concast 1962	vertical
Tinsley Park	1	slabs	stainless	800-1,600 x 140-200		Concast 1977	S-type
GKN Tremorfa Steel Works, Cardiff	2 x 6	billets	carbon	75-130 sq.		Concast 1976	S-type
Lloyd-Cooper Ltd.							
Dudley	3	billets	carbon	80,140 sq. 152x76	80,000	Danieli 1974	
Manchester Steel Ltd., Manchester	4	billets	struct.(stand. comm.grade)	100 sq.	180,000	Demag 1975	bow-type
Round Oak Steel Works Ltd. Brierley Hill	4	blooms	struct.(stand. comm. grade)	355x317	400,000	Demag 1975	bow-type
Sheerness Steel Co. Ltd. Sheerness	4	billets	carbon	100-150 sq.		Concast 1972	S-type
Sheerness	4	billets	carbon	127 sq.		Concast 1974	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
USA							
Ameron-Steel Producing Div., Etiwanda, Calif.	5	billets	carbon	100,115,170 sq.		Concast 1975	S-type
Armco Steel Corp. Sand Springs, Okla.	6	billets	struct. (standard comm. grade)	75,108 sq.	150,000	Demag 1965	bow-type
Butler, Pa.	1	slabs	mild carbon, gen.struct. transformer and dynamo, stainless	1,275 x 152 877 x 152	63,000	Demag 1966	bow-type
Butler, Pa.	2	slabs	mild carbon, gen.struct., transformer and dynamo, stainless	877x152, 965x152, 1,275 x 152, 600x127/203, 1,372x127/203	540,000	Demag 1970	bow-type
Middletown, Ohio	2	slabs	mild carbon, gen.struct.	635/2,080x178/305	720,000	Demag 1971	bow-type
Kansas City	6	blooms + billets	struct. (standard comm. grade), cold-heading, tool	100-200 dia.	500,000	Demag 1976	bow-type
Atlantio Steel Co., Atlantic, Ga.	4	billets	carbon, low-alloy	102 sq.		Concast 1975	S-type
Auburn Steel Co. Inc, Auburn, N.Y.	3	billets	carbon	90-155 sq.	150,000	Concast 1975	S-type
Bethlehem Steel Corp, Bethlehem, Pa. Burns Habour, Ind.	2	slabs	mild carbon, gen.struct.	810/1,930 x 150/303	900,000	Olsson Demag 1973	bow-type
Border Steel Mills Inc, El Paso, Texas	3	billets	carbon	100 sq.; 175 x 125	140,000 (short)	Concast 1970	S-type
BW Steel Inc., Calumet Steel Div. Chicago Heights	2 x 2	billets		4 in., 6 in. sq.	250,000 (short)	Koppers 1967	high-head
Cascade Steel Rolling Mills Ltd., McMinnville, Ore.	2	billets		3 in. sq.	150,000	Wean United	
The Ceco Corp., Southern Electric Steel Co, Birmingham, Ala.	3	billets		4 in.	150,000 (short)	Koppers	low-head
Birmingham, Ala.		billets				Rust Engineering 1975	

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
USA, cont.							
CF + I Steel Corp., Pueblo, Col.	6	billets		4 in., 5,5 in.sq.	400,000 (short)	Koppers	low-head
Chaparral Steel Co., Midlothian, Tex.	4	billets	carbon	133 sq.	200,000	Concast 1975	S-type
Copperweld Corp., Warren, Ohio	4	blooms + billets	struct. (standard comm. grade),	115,138,162,180 sq.	60,000	Demag 1965	bow-type
			cold-heading	138,162 sq.			
			ball-bearing, spring	162 sq.			
Crucible Inc., Midland, Pa.	1	slabs	gen.struct. transformer and dynamo, stainless	620x203, 840x197, 990 x 186, 1,065 x 155, 1,170x143, 1,280x130	300,000	Demag 1972	bow-type
Eastern Stainless Steel Co., Baltimore, Md.	1	slabs	stainless	965/1,270x127	85,000	Concast 1974	S-type
Florida Steel Corp., Tampa, Fla.	2 x 2	billets	carbon	115 sq.		Concast 1965	S-type
Indiantown, Fla.	3	billets	carbon	115 sq.		Concast 1971	S-type
Charlotte, NC	2	billets	carbon	100,115 sq.		Concast 1975	S-type
Georgetown Steel Corp., Georgetwon, NC	4	billets	carbon	100 sq., 135 x 100		Concast 1969	S-type
Georgetown Texas Steel Corp., Beaumont, Tex.	2 x 4	billets	carbon	120-140 sq.		Concast 1976	S-type
Inland Steel Co., East Chicago, Ill.	4	billets	carbon, alloy	145,180 sq.	500,000 (short)	Concast 1970	S-type
East Chicago, Ill.	2	slabs	mild carbon	760/1,670x200/250	1,300,000	Demag 1972	bow-type
International Harvester Co., Wisconsin Steel Div., South Chicago	8	billets		5 in., 6 in.sq.	400,000 (short)	Koppers 1966	high-head, stick
Iowa Steel Mill Inc., Wilton, Iowa	3	billets		5.5 in.sq.	150,000 (short)	Koppers	low-head
Jones + Laughlin Steel Corp., Aliquippa, Pa.	6	billets	..	4 in.-7 in.sq.	500,000 (short)	Koppers 1969	high-head
Judson Steel Corp., Emeryville, Calif.	3	billets	carbon	75-152 sq.		Concast 1975	S-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
USA, cont.							
Kentucky Electric Steel Co., Coalton, Ky.	2	billets	carbon	115 sq., 150x100, 165x115, 175x125	140,000	Concast 1970	S-type
Keystone Steel + Wire, Peoria, Ill.	6	billets		3 in., 4 in.sq. 7 in.x 14 in.	309,000 (short)	Koppers 1968	high-head
Knoxville Iron Div., Steel Service Co.Inc., Knoxville, Tenn.	2	billets		80,140 sq.		Danieli 1969	
Knoxville, Tenn.	3	billets	carbon	90-155 sq.		Concast 1975	S-type
Laclede Steel Co., Alton, Ill.	6	billets + blooms		4 in., 7 in.sq.;	800,000 (short)	Koppers 1967	high-head
Lone Star Steel Co., Lone Star, Texas	2	blooms	carbon	146-185, 230-305 sq.		Concast 1976	S-type
Lukens Steel Co., Coatesville, Pa.	1	slabs	carbon, alloy	1,650 x 180, 2,160x230/305	234,000	Concast 1971	S-type
McLouth Steel Corp., Trenton, Mich.	4	slabs	mild carbon, heat-trea[illegible], stainless	304x915/1,120/1,320/1,525	1,800,000	Demag 1968	bow-type
Detroit, Mich.	4 x 1	slabs	carbon	1,520/1,320/1,120/915 x 305		Concast 1968	S-type
Michigan Seamless Tube Co., Jackson, Mich.	2	tube-rounds			100,000		
National Steel Corp., Weirton, W.Va.	4	slabs	carbon	1,015/965/915/815 x 230		Concast 1968	S-type
Ecorse, Mich.	4	blooms	carbon, alloy	180 sq, 184x152		Concast 1969	S-type
Ecorse, Mich.	1	slabs	carbon	2,640 x 240		Concast 1976	S-type
New Jersey Steel Co., Sayreville, NJ	5	billets		90,140 sq.	300,000 (short)	Danieli 1973	S-type
North Star Steel Co., St. Paul, Minn.	3	blooms + billets	carbon, alloy	100,125,180 sq.		Concast 1970	S-type
Nucor Steel, Dovesville, SC	2	billets	carbon	100 sq.		Concast 1969	S-type
Dovesville, SC	2	billets	carbon	75-150 sq.		Concast 1970	S-type
Jewett, Tex.	2	billets		5 in.sq.	300,000 (short)	Koppers	low-head

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
USA, cont.							
Phoenix Steel Corp., Claymont, Delaware	2	slabs	carbon, alloy	2,030 x 305, 1,520 x 250/150	500,000	Concast 1968	S-type
Pollak Steel Co., Marion, Ohio	3	billets		2,75 in., 4 in.sq.	180,000 (short)	Olsson	
H.K. Porter Co.Inc., Huntington, W.Va,	3	billets	carbon	152 sq.		Concast 1975	S-type
Roanoke Electric Steel Corp., Roanoke, Va.	3	billets		80,140 sq.		Danieli 1970	
Roanoke, Va.	2	billets		4,5 in.	75,000	B + W	
Soulé Steel Co, San Francisco, Cal.	2	billets	carbon	125 sq.		Concast 1965	S-type
Tennessee Forging Steel Corp., Calvert, Ky.	2 x 3	billets		3.5 in., 4.5 in.sq.	300,000 (short)	Koppers	low-head
Harriman, Tenn.	3	billets		3.5 in., 4.5 in.sq.	150,000 (short)	Koppers	low-head
The Tinken Co., Canton, Ohio	4	blooms	carbon, alloy	305 x 240	200,000	Concast 1968	S-type
US Steel Corp., Gary Works	1	slabs		236 x 1,650	2,100,000 (short)	USS 1961	in-line rolling
Torrance, Calif.	4	billets + blooms		2.25 in.sq.-4.5 x 13 in.	200,000 (short)	Koppers 1968	high-head
South Works	4	blooms		190 sq.	1,285,000 (short)	USS 1970	in-line rolling
Texas Works	1*	slabs		180 x 1,830	600,000 (short)	USS 1970	
Fairless Works	2	blooms		250 x 600	600,000	USS 1972	
VENEZUELA							
Sivensa, Caracas	2 x 2	billets	carbon	80 sq.	150,000	Concast 1965	S-type
YUGOSLAVIA							
Metalurski Kombinat Zeljezara Sisak, Sisak	2 x 3	blooms	struct. (standard comm. grade)	430x190/300, 350x 190/174-294 octagons	250,000	Demag 1973	bow-type

Table 2 : continued

Country and Company	No. of strands	Product	Steel type	Casting dimensions (mm)	Capacity (tpy)	Maker and date	Other details
YUGOSLAVIA, cont.							
Rudnici i Zelezara Smederevo, Smederevo	—	—	—	—	—	—	
Smelt, Ljubljana	1	billets		80,120 sq.		Danieli	
Jadranska Zeljezara Split, Split	2	billets	carbon	100 sq.	90,000	Concast 1971	S-type
Zelezarna Store, Store pri Celju	4	billets	carbon, alloy	80-140 sq.	200,000	Concast 1973	S-type
ZAMBIA							
Tika Ltd., Lusaka	4	billets	struct. (standard comm. grade)	100 sq.	200,000	Demag 1976	bow-type

*Additional strands being added

Source : Metal Bulletin Monthly, July, August and September, 1975

Table 2 : continued

Continuous Casting Production Plants in Operation or Under Construction for Steel in the U.S.S.R.

Principal Data : As known 1st January, 1964

Plant (Name in Brief)	Date Started	Ladle Capacity tons	No. of Strands	Machine Design	Section Sizes Cast ins.	Production Rate (As quoted) tons/annum	Steel Qualities Cast
Inclined Conveyor Type Mould Machines							
Beshitsa	1958 (1950 Kamenskij; 1961 Serp-i-Molot)	50 Billets: 20-45 tons	1	Goldobin.	4¾, 5½ sq., 12 x 6½	About 24,000	Carbon steels.
[illegible]	Under Construction		2 machines, 1 strand each	TsNIIChermet/ VNIIMetMash.	5½ sq.		Carbon steels.
Vertical Semi-Continuous Casting Machines							
Krasny Oktyabr A	1951	18½ or 28½ (20 ton poured)	2	TsNIIChermet	23⅝ x 6⅞, 31½ x 7⅞ (twin-stranded)	Aim 36,000	Stainless steels, including titanium stabilised; also other alloy steels.
Krasny Oktyabr B	1960		4		11⅞ x 6⅞, 19⅝ x 5⅞ (four-stranded)		
Kirovsk A	1953 (Now believed semi-production)	5	1	TsNIIChermet	22 x 5⅞ mainly. Also 7⅞ dia., 7⅞ sq. 13⅞ sq.	Semi-production.	Killed carbon steels. Also stainless steel (slabs).
Kirovsk B			1				
Dnepropetstal'	Under Construction				(Square and possibly round billets)		Special steels and other high alloys. (Consumable electrodes)
Vertical Continuous Casting Machines							
Novo Tula I	1959	5 or 10	1 (slabs) 2 (blooms)	TsNIIChermet/ Stal'proekt/ Dnepropetrovsk.	7⅞, 8⅞ sq., 19⅝ x 5⅞, 24⅝ x 5⅞, 24⅝ x 5⅞, 25½ x 7⅞	About 15,000	Killed and rimming carbon steels; also low alloy, including silico-manganese and silicon transformer steels. Also tool steels attempted.
Novo Tula II	Under Construction			Gipromez		Initial aim 3.0 mill. Ultimately 4.0 mill.	
Krasnoye Sormovo A	1955	50	2	TsNIIChermet/ Stal'proekt.	14⅝ x 6⅞, 21⅝ x 5⅞	Aim up to 200,000	Killed and rimming carbon steels.
Krasnoye Sormovo B	1960		2				
Kalinin	1956	1½	1	TsNIIChermet/ TsKBMetMash/ TsNIITMash.	1⅜, 2⅜ dia. (Design: 3⅞ max.)	Spasmodic use.	Medium carbon steels.
Novo Lipetsk I A	1959	90 - 95	2	TsNIIChermet/ Stal'proekt/ Gipromez.	24⅝ x 5⅞, 30⅝ x 5⅞, 40⅝ x 6⅞, 41 x 6⅞	About 250,000	Silicon transformer steels; also killed and rimming carbon steels.
Novo Lipetsk I B	1960		2				
Novo Lipetsk II A	Under Construction	160	6 machines, 2 strands each	Gipromez/ Stal'proekt.	(Slabs)	Aim 2.2 mill.	
Novo Lipetsk II B	Projected	250	8 machines, 2 strands each		(Slabs) Ultimately: 74⅝ x 11⅞	Aim 3.8 mill.	
Donetsk (Stalino)	1960	140	4	TsNIIChermet/ Giprostal'/ Dneprostal.	23⅝ x 5⅞, 27½ x 6⅞, 31½ x 7⅞, 39⅝ x 7⅞. Later: 47⅝ x 7⅞, 23⅝ x 4⅞	Aim 350,000	Killed and rimming carbon steels and low alloy steels.

Table 2 : continued

Plant (Name in Brief)	Date Started	Ladle Capacity tons	No. of Strands	Machine Design	Section Sizes Cast ins.	Production Rate (As quoted) tons/annum	Steel Qualities Cast
Vertical Continuous Casting Machines (Cont'd.)							
[illegible]	1960			[illegible]	9 x [illegible]		Rimming steel.
[illegible]	1962	[illegible] and 15	2	Stal'proekt.	15[illegible] x 5[illegible], 21[illegible] x 7[illegible] Also 3-hole moulds: 8[illegible] sq.	Abt 130,000	Carbon tool steels and titanium stabilised stainless steels.
[illegible]	1962	65	4	Stal'proekt.	7[illegible] sq.	Abt up to 200,000	Carbon steels, mainly rimming qualities.
Zaporozhstal'	Under Construction						
[illegible]	Under Construction				([illegible])		Transformer steel.
[illegible]	Under Construction						High alloy steels.
Azovstal'	Projected plant possibly in abeyance						
[illegible]	Under Construction			[illegible]	(Small billets)		
Krivoi Rog	Under Construction		10 machines	[illegible]		Abt possibly 4.6 mill.	
Nizhne-Tagil'	Under Construction						

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Date Started	Machine Design (in Brief)	No. of Strands and Configuration	Main Plant Dimensions: Casting Platform Height ft.	Pit Depth ft.	Main Machine Plan Area ft. x ft.
[illegible]							
[illegible]		1958 (1958 [illegible]; 1961 [illegible])	[illegible]	1	20	6	193 x 13
[illegible]		Under Construction (See text)	[illegible]/ [illegible]	2 machines, 1 strand each			
Vertical Semi-Continuous Casting Machines							
[illegible]	A	1951	[illegible]	2	[illegible]	[illegible]	
	B	1960		4			
[illegible]	A	1953 (Now believed semi-production)		1	[illegible]	[illegible]	
	B			1			
Vertical Continuous Casting Machines							
Novo Tula		1955	[illegible]/ Stalproekt/ [illegible]	1 (slabs) 2 (blooms)	[illegible]	[illegible]	[illegible] x [illegible] Overall pit: 70 x 70
Krasnoye Sormovo	A	1955	[illegible]/ Stalproekt.	2	[illegible]	[illegible]	33 x [illegible] Strand centrelines at [illegible] ft.
	B	1960		2	[illegible]	[illegible] Total: [illegible]	
[illegible]		1956	[illegible]/ [illegible]/ [illegible]	1	[illegible]	[illegible]	17 x 10
Novo Lipetsk	A	1959	[illegible]/ Stalproekt/ [illegible]	2	[illegible]	[illegible]	47 x 47 Common structure and pit.
	B	1959		2			
[illegible] (Stalino)		1960	[illegible]/ Giprostal/ [illegible]	4 Square plan	[illegible]	[illegible]	82 dia. Strand centrelines at [illegible] ft.
[illegible]		1960	[illegible]				
[illegible]		1962	Stalproekt.	2	[illegible]	[illegible]	
[illegible]		1962	Stalproekt.	4 In-line plan	[illegible]	[illegible]	

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Steelmaking Units: No.	Steelmaking Units: Capacity, tons	Steelmaking Units: Type	Ladle: Capacity tons	Ladle: Type	Ladle: Location During Teeming	Special Features
Inclined Conveyor Type Mould Machines								
Bezhitsa		5	50	Open hearth furnaces	50 Killed: 30-45 tons	Bottom-pour, single stoppered.	Suspended on crane	Bifurcated launder used in tapping.
[illegible]				Open hearth furnaces				
Vertical Semi-Continuous Casting Machines								
Krasny Oktyabr	A, B	1 1	10 80	Arc furnace Arc furnace	12½ or 18½ (10 ton poured)	Bottom-pour, single stoppered.	Suspended on crane	Single ladle frequently used to supply both machines in turn.
Elrovsk	A, B	1	5	Arc furnace, acid-lined	5	Initially bottom-pour, single stoppered. Later lip-pour.	Suspended on crane	
Vertical Continuous Casting Machines								
Novo Tula		1 1 1	10 11 5	Open hearth furnace Oxygen/converter Arc furnace	5 or 10	Bottom-pour, single stoppered.	Suspended on crane	Preheat 400 - 500°C.
Krasnoye Sormovo	A, B	4	50 - 55	Open hearth furnaces	50	Bottom-pour, twin stoppered.	Suspended on crane	Preheated to about 900°C. by oil. Both machines supplied simultaneously.
Kalinin		1	1½ 3	Arc furnace Arc furnace	1½	Lip-pour, with lid.	Tilted in crane	Preheated 1000-1300°C. by oil
Novo Lipetsk	A, B	2	90-95, Planned 80	Arc furnaces (basic roofs and linings)	90 - 95	Bottom-pour.	Suspended on crane	Preheat 900 - 1000°C. max. for killed steel. Vacuum degassed when full.
Donetsk (Stalino)		5	140	Open hearth furnaces	140	Bottom-pour, twin stoppered.		
[illegible]								
[illegible]			50 15	Open hearth furnaces Arc furnaces	50 and 15			
[illegible]		3	90	Open hearth furnaces	65	Bottom-pour, twin stoppered.		

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)	Capacity, tons	No. per Cast	Tundish Features: Mounting	Design	Type of Discharge	Other Features
Inclined Conveyor Type Mould Machines						
[illegible]	1	1	Inclined auxiliary chain conveyor or rail support with looped chain, aligned at 9½° with mould cavity.	Rectangular box fitted with discharge tube at one end.	Refractory lined tube, about 6½ ft. long, extends into mould cavity.	Preheat 400-600°C.
[illegible]						
Vertical Semi-Continuous Casting Machines						
[illegible] A, B		1	Lifting/rotatable table.	Triangular plan-form box with lid.	2 or 4 stoppered nozzles frequently with attached runner brick.	([illegible] pouring [illegible] discarded.) Preheat 1100-1200°C.
[illegible] A, B	[illegible]	1	Carriage with adjustable centering table.	Rectangular box, narrower at pouring end.	Stoppered nozzle.	Preheat 800°C. Metal depth during cast not more than 10-12 ins.
Vertical Continuous Casting Machines						
Novo Tula	[illegible]-2½ Normally 1½	1	Rotatable pedestal. Can be raised or lowered about 8 in.	Oval plan-form box with lid.	1 or 2 stoppered nozzles; for twin-stranding squares always 2 nozzles.	(Various designs tried initially.) Preheated 800-1100°C. by blast furnace gas. Fireclay/graphite nozzle heated electrically.
Krasnoye Sormovo A, B	3½-5	2	Rotatable table, 90° turn.	Triangular plan-form box, 32 in. deep, with baffled nozzle-chambers and lid.	2 stoppered nozzles, each.	Preheated 850-950°C. by oil. Fireclay/graphite nozzles heated electrically.
[illegible]		1	Fixed pivot and support plate, allowing manual readjustment of position.	Launder, 2 ft. long with monolity lining and buried carborundum rods.	Single discharge slot at one end of launder.	Electrically heated (80V. 60A) to 900°C. and thereafter by oxy-acetylene torch.
Novo Lipetsk A, B	5-7	2		Elongated oval form with lid. Strand centrelines at 6½ ft.	2 stoppered nozzles, each.	Preheat 1100-1300°C. Stopper rods air cooled and/or water cooled. Nozzle pouring preferred at 10-12 in. from narrow end of mould.
Donetsk (Stalino)	12½-15 (Normal contents 12)	2	Hydraulically rotatable pedestal support, 180° turn.	Strand/nozzle centrelines on 9⅝ ft. square.	2 stoppered nozzles, each.	Preheated 1150-1250°C. by coke oven gas. [illegible] tundishes to allow 2 casts to be poured consecutively. Stopper rods, water-cooled, allow 90-105 min. casting; air cooled rods also used.
[illegible]						
[illegible]	4½-7	1	Locating table.		2 stoppered nozzles.	Butane or propane gas protection of metal.
[illegible]	4	2	Lifting/rotatable table.	Strand/nozzle centrelines on 9⅝ ft. square.	2 stoppered nozzles, each.	Air-cooled stopper rods.

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Ladle Refractories: Lining	Ladle Refractories: Stopper	Ladle Refractories: Nozzle	Tundish Refractories: Lining	Tundish Refractories: Stopper	Tundish Refractories: Nozzle
Inclined Conveyor Type Mould Machines							
Beshitsi		Fireclay			Fireclay	None used.	Extension tube of special fireclay, with fitted magnesite orifice.
[illegible]							
Vertical Semi-Continuous Casting Machines							
Krasny Oktyabr	A, B			Fireclay			Fireclay.
[illegible]	A, B						Bore: 1¾ in. for 22 x 5¾ in. and for 13¾ in.sq.
Vertical Continuous Casting Machines							
Novo Tula		2½ in. insulation 3½ in. fireclay 30% alumina	Fireclay	Fireclay 1¾ in. bore	⅜ in. asbestos 3¾in. insulation 3¼in. fireclay		Fireclay/graphite, 1 - 1½ in. bore.
Krasnoye Sormovo	A, B	(Dolomite mixture put on metal to insulate.)	Fireclay or high alumina sleeves; thickened over bottom 2 - 3 ft. Normal fireclay heads.	1¾ in.bore	Fireclay	Normal fireclay head.	One-piece fireclay/graphite nozzles, 1½ in.bore. Inserts preferred of high alumina, magnesite, zirconia or fireclay/graphite in fireclay bodies.
Kalinin					Various launder linings tried, mainly based on fireclay.	None used.	Discharge slot (rounded rectangular), 1½ x ¾ in. aperture.
Novo Lipetsk	A, B	Fireclay.	Extra thick fireclay sleeves. Basic sleeves for rimming steels.	Fireclay with magnesite sleeve insert, 1½ - 1¾ in. bore.			Wholly fireclay, or specially shaped, with high alumina or magnesite sleeve inserts, 2¾ in.bore.
Donetsk (Stalino)							One-piece zirconia and/or high alumina nozzles, ¾ - 1½ in.bore. One-piece zircon nozzles also tried.
[illegible]							
[illegible]							
[illegible]							One-piece fireclay, zircon or zirconia nozzles.

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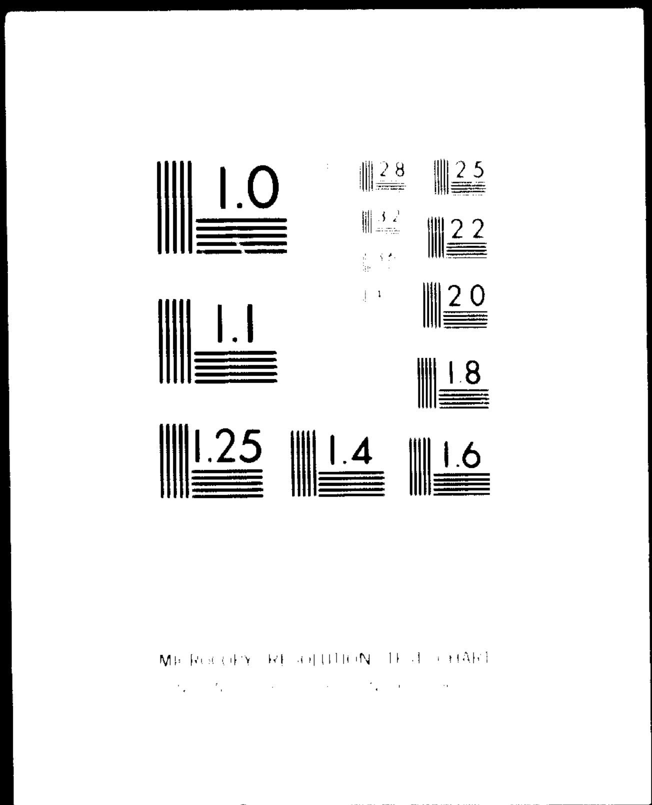

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Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Section Sizes Cast: Dimensions in.	Section Sizes Cast: Max. Length Cast	Section Sizes Cast: Typical Lengths Produced ft.	Production Rate (as quoted) tons/annum	Steel Qualities Cast
Inclined Conveyor Type Mould Machines						
Bezhitsii		$4\frac{7}{8}$, $5\frac{1}{8}$ sq., 12 x $6\frac{1}{8}$	Ladle contents		About 24,000	Carbon steels.
Omutninsk		$5\frac{1}{8}$ sq.				Carbon steels.
Vertical Semi-Continuous Casting Machines						
Krasny Oktyabr	A	$23\frac{5}{8}$ x $6\frac{7}{8}$, $31\frac{1}{2}$ x $7\frac{7}{8}$ (twin-stranded)	$24\frac{5}{8}$ ft.	$14\frac{3}{4}$ - $24\frac{5}{8}$ as cast	Aim 36,000	Stainless steels, including titanium stabilised; also other alloy steels.
	B	$11\frac{7}{8}$ x $6\frac{7}{8}$, $19\frac{5}{8}$ x $5\frac{7}{8}$ (four-stranded)				
Kirovsk	A	22 x $5\frac{7}{8}$ mainly; Also $7\frac{7}{8}$ dia., $7\frac{7}{8}$ sq.	$11\frac{1}{8}$ ft.	Up to $11\frac{1}{8}$ as cast; $9\frac{7}{8}$ - $10\frac{5}{8}$ as cast	Semi-production	Killed carbon steels. Also stainless steel (slabs).
	B	$13\frac{3}{4}$ sq.				
Vertical Continuous Casting Machines						
Novo Tula		$7\frac{7}{8}$, $8\frac{1}{2}$ sq., $19\frac{5}{8}$ x $5\frac{7}{8}$, $24\frac{5}{8}$ x $5\frac{1}{8}$, $24\frac{5}{8}$ x $5\frac{7}{8}$, $25\frac{1}{2}$ x $7\frac{7}{8}$	Ladle contents	$5\frac{7}{8}$ - $10\frac{5}{8}$ as cut	About 15,000	Killed and rimming carbon steels; also low alloy, including silico-manganese and silicon transformer steels.
Krasnoye Sormovo	A, B	$16\frac{1}{2}$ x $6\frac{7}{8}$, $21\frac{5}{8}$ x $5\frac{7}{8}$	Ladle contents (up to 183 ft.)	$6\frac{1}{2}$ as cut; $6\frac{1}{2}$ - $9\frac{3}{4}$ as cut	Aim up to 200,000	Killed and rimming carbon steels.
Kalinin		$1\frac{5}{8}$, $2\frac{3}{8}$ dia. (Design: $3\frac{1}{2}$ max.)	Ladle contents	4 as cut	Spasmodic use.	Medium carbon steels.
Novo Lipetsk	A, B	$24\frac{5}{8}$ x $5\frac{7}{8}$, $30\frac{3}{8}$ x 5; $40\frac{1}{2}$ x $6\frac{5}{8}$, 42 x $6\frac{5}{8}$	Ladle contents	$19\frac{5}{8}$ - $26\frac{1}{4}$; $29\frac{1}{2}$ max., as cut	About 250,000	Silicon transformer steels; also killed and rimming carbon steels.
Donetsk (Stalino)		$23\frac{5}{8}$ x $5\frac{7}{8}$, $27\frac{1}{2}$ x $6\frac{7}{8}$, $31\frac{1}{2}$ x $7\frac{7}{8}$, $39\frac{3}{8}$ x $7\frac{7}{8}$; Later: $47\frac{1}{4}$ x $7\frac{7}{8}$, $23\frac{5}{8}$ x $4\frac{5}{8}$	Contents of 2 ladles.	$13\frac{1}{2}$ - 17 as cut	Aim 350,000	Killed and rimming carbon steels and low alloy steels.
Revda		9 x $5\frac{1}{8}$				Rimming steel.
Gorkii		$15\frac{3}{4}$ x $5\frac{7}{8}$, $21\frac{5}{8}$ x $7\frac{1}{8}$; Also 3-hole moulds: $8\frac{5}{8}$ sq.			Aim 130,000	Carbon tool steels and titanium stabilised stainless steels.
Uzbesii		$7\frac{7}{8}$ sq.		$13\frac{1}{2}$ - $19\frac{5}{8}$ as cut	Aim up to 200,000	Carbon steels, mainly rimming qualities.

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Mould Features: Type	Length	Mounting	Stroke Length in.	Other Features	Typical Water Flow gal./min./strand	Water Velocity ft./sec.
Inclined Conveyor Type Mould Machines								
Beshitsii		Half-mould steel pallets.	About 19 ft. ex. 28 ft. total.	Upper and lower conveyor tracks, with 82 pallets each, moving down 9½° incline.	(Moves steadily forward)	Mould pallets 12 in. long. No mould lubricant used; lower pallets reeked by burning oil.	Small fraction of total usage.	
Omutninsk								
Vertical Semi-Continuous Casting Machines								
Krasny Oktyabr	A, B	4-plate tapered	59 in.	Initially fixed on removable carriage; from 1956 reciprocated, on trolley with 4 self-aligning rollers and guides. Total weight reduced from 3½ to 1½ tons.		Metal fall height: 2½ ins. Lubricant: mineral oil and silvery graphite powder; also paraffin wax. Section wall: 1 in. thick leaving mould at 40 in./min. (approx.) Frequent sticking in stationary mould at 39 in./min.	460 - 530 (At 4 atm. pressure)	20
Kirovsk	A, B	4-plate	59 in.	Initially fixed on removable carriage; later reciprocated, on carriage with guide brackets, by lever arms and cam, making two full cycles per revolution.	For 13¾ in.sq.: 1	Lubricant: axle grease and silvery graphite before casting, liquid or solid paraffin wax manually fed during casting. For 13¾ in.sq.: Wall 5/16 in. thick, chrome-plated; total weight 1½ tons. Reciprocation ratio about 2 : 1.	For 13¾ in.sq.: 396 - 528 (Temp. rise 7.5 - 8.1°C.)	For 13¾ in.sq.: 17 (At 3½ atm. pressure)
Vertical Continuous Casting Machines								
Novo Tula		4-plate tapered on narrow faces.	39½ in., initially 59 in.	Reciprocated on guided frame by lever arms and driven cams. For 7⅞ in.sq., 2-channel mould in one housing used.	¾ (Max: 1⅛)	Descent at same speed as section; rise 6-8 times faster. Lubricant: melted paraffin wax at 0.4 lb./ton average. (Max: 0.75 lb./ton.) Metal fall height: 8-12 ins. Mould wall initially ⅜ in. thick, later machined down to ¼ in.	585 - 795 (At 5-6 atm. pressure)	20 - 33
Krasnoye Sormovo	A	4-plate tapered on narrow faces.	59 in.	Fixed but supported on laterally removable carriage.		Wall: ½ in. thick copper but for re-use may be machined 3-6 times down to ¼ in. Lubricant: melted paraffin wax pump fed automatically at 0.1/0.3 lb./ton average. (Max: 1½ gal./min./in. perimeter.)	330 - 480 and 550	17 - 20
	B		48 in.	Reciprocated.				
Kalinin		Tubular	23½ in.	Reciprocated with compressive release.	1	Reciprocation ratio about 2 : 1. Mould given about ⅛ in. compressive release in lower 25% of stroke. Lubricant: used transformer oil.		39 (At 6 atm. pressure)
Novo Lipetsk	A, B	4-plate	59 in. Also about 51 in.	Reciprocated on lateral rollers inside guide rails.	13/16	Weight: 3 tons overall. Chromium bronze mould plates used. Reciprocation ratio 1 : 1. Typical frequency of mould reciprocation 25 - 30 per min. ⅝ in. thick copper plates welded. Lubricant: liquid paraffin.	550 - 916	
Donetsk (Stalino)		4-plate	59 in.	Reciprocated in frame.	13/16	Lubricant: mineral oil or liquid paraffin mixed 1 : 1 with cotton seed oil. Wall: 1⅛ - 1⅜ in. thick copper. 1-piece and 2-piece moulds being tested to improve life.	730 - 1285 (At 5 atm. pressure)	20 - 23
Revda								
Gorkii		4-plate	59 in.	Reciprocated.		Automatic lubrication.		
Ubonii		4-plate and tubular	59 in.	Reciprocated.				

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)	Specific Water Consumption gal./ton	Cooling Zone Features: Typical Water Flow gal./min./strand	Height ft.	Type	Other Features
Inclined Conveyor Type Mould Machines					
Beshitsii	Total water: 110		7 and 7	Steel box coolers in sliding contact followed by impinging sprays.	Some atomised sprays also applied to billet leaving the mould. At maximum speed 216 in./min. crater length for 5½ in.sq. about 60 ft.
Omutninsk					
Vertical Semi-Continuous Casting Machines					
Krasny Oktyabr A, B	Sprays only: 1000-1200			Roller apron with spray nozzles only in upper half of apron.	Water jets used, not sprays.
Kirovsk A, B	10⅝ cu.ft./sq.ft.hr.	59½ - 72½	11⅝	Roller apron with spray nozzles on 4 sides of 13⅞in.sq; 4in.dia.rolls 17-high at 7⅞in. centres. (Unsupported 5⅝in.gap between 4in. wide rolls on sides normal to lowering beam)	Original worm-type spray nozzles discarded. Dwell time of 13⅞in.sq. cast at 20-24 in./min. in sprays to complete solidification 25 min. (21-22 min.by thermocouple).
Vertical Continuous Casting Machines					
Novo Tula	Sprays only: 55-1100, all cases. 105-180, transformer steel	145 - 440. For 7⅞in.sq.can be nil up to 36 in./min.(only 12 guide rolls needed)	About 10⅞ ex.14¼	Sprayed roller apron above upper withdrawal roll group; 4¾in.dia.apron rolls at 5⅞in. centres, with 5 or 6 nozzles on broad and 1 nozzle on narrow faces; 18 pairs of rollers.	(Various cooling methods tried initially.) For 19⅝ x 5⅞in.,crater depth 13⅞ft.at 1100 gal./ton, also 15¾ and 20ft.at 28 and 36in./min; for 7⅞in.sq. 31¼ft.at 39 in./min.
Krasnoye Sormovo A	Total: 1100-2640. Make-up: 330 - 660	150 - 240 depending on speed (At 4-4½ atm.pressure)	5⅛	Sprayed roller apron; 4⅜in.dia.rolls at 5⅞ in.centres.	Water-air mixtures used to give greater cooling control; water flow controlled automatically in relation to casting speed.
Krasnoye Sormovo B			19⅝	Sprayed roller apron; 4⅜ in.dia.rolls, 38 pairs.	
Kalinin	Mould: 4400. Sprays: 440	(At 5-6 atm.pressure)	2⅝	Water sprays only.	
Novo Lipetsk A, B		160-212 on 30⅞ x 5⅞ in. 180-290 on 41 x 6⅞ in. 110-275 range.	21½ ex.23	Sprayed roller apron; 4¾ in.dia.rolls at 9 in.centres.	Roller apron hinged to columns to facilitate size changes. 250 nozzles on articulated frame divided vertically into 3 - 6 sections with independent water supplies.
Donetsk (Stalino)	Sprays only: 345 on 39⅜ x 7⅞ in. 210-350 on 31½ x 7⅞ in.	132 - 176 (At 4-5 atm.pressure)	36	2 sprayed sections of roller apron, each on individual carriage with motorised screw adjustments for size; 4⅜in.dia.rolls at 9½ in.centres. Roller apron 34½ ft. long.	Traversing jet tried but discarded; 86 fixed nozzles preferred; wide faces have one central column of nozzles spaced 9½ ins; distribution on wide and narrow faces 5 : 1.
Revda.					
Gorkii		55 -240 (carbon steels) 460-860 (stainless steels)	30⅞	4 sections of water-cooled roller apron with or without spray nozzles.	Distance between apron rolls variable about vertical centreline. Roller cooling only for carbon steels, roller cooling plus spray cooling for stainless.
Rubeosii			32⅝ ex.36	4 sections with roller aprons.	Use of traversing jets (45° each side) planned.

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)	Metal Temperatures: Furnace at Tap °C.	Metal Temperatures: Ladle at Start of Cast °C.	Metal Temperatures: Tundish, typical °C.	Casting Speeds: Machine Range in./min.	Casting Speeds: Typical Speeds of Operation in./min	Output per Strand ton/hr.	Duration of Cast (typical) min.	General Features
Inclined Conveyor Type Mould Machines								
Beshitsii	1580-1630	1585 preferred	1540-1590	216 max.	120-156, average on $5\frac{3}{4}$ in.sq. May be 96 or less if steel temperature too high.	25 - 36	52 for 25 ton.	
Omutninsk								
Vertical Semi-Continuous Casting Machines								
Krasny Oktyabr A, B		1590 at least	1530-1540 (for stainless steel)	0-60	16-48 general range 29-36 for carbon steels 44-48 on $11\frac{7}{8}$ x $6\frac{7}{8}$in.stainless steel 52 max.to-date			Metal temp. in $11\frac{7}{8}$ x $6\frac{7}{8}$ in.mould: 1480-1490°C.
Kirovsk A					20 on 22 x $5\frac{7}{8}$in.	16		For $13\frac{3}{4}$in.sq: Linear shrinkage 3-4%. Surface depressions upto 3/16in. at 11-14in./min; at 20-23in./min.bulges upto 3/16in. in roller apron, upto 5/16in. over $5\frac{7}{8}$in.gaps.
Kirovsk B			1540 at least		20-24 on $13\frac{3}{4}$ in.sq.	28		
Vertical Continuous Casting Machines								
Novo Tula	1650	1600 (Typical for 0.10% C. steel) 1580 (Preferred for transformer steel)	1550 1525-1550	$9\frac{1}{2}$-80	48 max.for killed steels 28-36 for rimming steel 28-40 on $19\frac{3}{4}$ x $5\frac{7}{8}$in, 24-44 on $7\frac{7}{8}$in.sq. 32 on $24\frac{3}{8}$ x $6\frac{1}{8}$in.transformer steel	Upto 35	13 for 5 ton 20-25 for 10 ton	Estimated time to complete solidification of $7\frac{7}{8}$in.sq: $9\frac{1}{2}$ mins; crater depth estimated therefrom according to speed.
Krasnoye Sormovo A, B		1560-1600	1540-1580 (1530 normal minimum)	42 max. 60 max.	3-36 general range 32-36 on $16\frac{1}{2}$ x $6\frac{7}{8}$in. About 36 average	24 - 28	55-60	Machine reset time: about 60 min, or 40 min. if preheated tundish available.
Kalinin	1560-1600			220 max.	Up to 156 max.		30-35 for $1\frac{1}{2}$ ton	
Novo Lipetsk A, B	Rimming steels:- 1610-1650 Killed steels :- 1620-1650	 1590-1620 1600-1630	 1520-1550 1545-1575	(48 max.)	20-24 on 41 x $6\frac{3}{4}$in.rimming steel 32-36 on $30\frac{3}{4}$ x $5\frac{7}{8}$in.rimming steel 20-24 on 41 x $6\frac{3}{4}$in.killed steel 34-36 on $24\frac{3}{8}$ x $5\frac{7}{8}$in.killed steel	 42 - 51 33 - 37	65-75 for 90 tons rim steel	Killed steel: Limits of 0.020%S.and 0.020% S. for 0.14%C. and 0.17%C.steels, resp. Rim steel: Aim 15-23% FeO in slag; mould metal level 6-8 in.from mould top.
Donetsk (Stalino)	1620-1650		1520-1570	16-60 (Reverse 120)	48 max. on $24\frac{3}{8}$ x $5\frac{7}{8}$in. 20-40 on $47\frac{1}{4}$ x $7\frac{7}{8}$in. 16-28 usual range.	36 - 43 Typical	45-50 (4 strands) 95-100 (2 strands)	Carbon steels, mainly up to 0.18% C: Sulphur limited to 0.013% to minimise cracks. Machine reset time: about 60 min.
Revda								
Gorkii				16-80	28-52 typical			
Ushenii				48 max.	About 32 typical		70	

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Hours of Operation	Direct Plant Manning: Operators Per Shift	Operators Days Only	Maintenance Per Shift	Maintenance Days Only	Staff	Total	Yield: Cast Product ex.Hot Metal %	Comparable Static Ingot Material %	Specific Metallic Charge: Tons Charged per Cast Product Ton tons/ton	Comparable Static Ingot Material tons/ton
Inclined Converter Type Mould Machines												
Beshitsii		2 shifts per day	$5\frac{1}{2}$		$\frac{1}{2}$			12	92 - 98 (ex ladle contents)			
Omutninsk												
Vertical Semi-Continuous Casting Machines												
Krasny Oktyabr	A, B	Continuous rota										
Kirovsk	A, B	Intermittent operation.							(Pipe depth about 44 ins.)			
Vertical Continuous Casting Machines												
Novo Tula		Continuous rota	5	2	2	5		35	92 (slabs)	Gains 8-10 (slabs)		
Krasnoye Sormovo	A, B	Continuous 4-shift rota	1 + 13	-	3	2	2	72	96(slabs) 78(strip ex slab)	90(slabs) 73(strip ex slab)	1.399 (liquid metal to $\frac{1}{2}$ - $\frac{5}{8}$ in. thick plate)	1.513 (liquid metal to $\frac{1}{2}$ - $\frac{5}{8}$ in. thick plate)
Kalinin		2 shifts per day	3	1				7				
Novo Lipetsk	A, B	Continuous rota							96 (killed steel)	Gains 8-12 (killed steels)	1.135 (finished slab)	1.262 (slabs at Zaporozhe)
Donetsk (Stalino)		Continuous rota							93 (killed carbon steel)	Gains 10 (on 3/16 - $\frac{5}{8}$ in. rolled plate)		
Revda												
Gorkii		Continuous rota										
Ushenii		Continuous rota										

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)	Dummy Starting Bar: Total Length ft.	Dummy Starting Bar: No. of Parts per strand	Dummy Starting Bar: Connection	Dummy Starting Bar: Type of Head	Withdrawal Units: No. of Groups per Strand	Withdrawal Units: Brief Description	Withdrawal Units: Position Below Top Platform ft.
Inclined Conveyor Type Mould Machines							
[illegible]	About 5	1	None (single piece of wood)			Forward moving mould pallets provide intrinsic discharge; single pair of pinch rolls installed to extract last part of cast.	
Omutninsk							
Vertical Semi-Continuous Casting Machines							
Krasny Oktyabr A		1	Auto-disconnect coupling.	Luted with oil-bound clay into mould at 24 ins. from bottom; dovetail.	1 for 2 strand	Cross-beam with detachable dummy bars sliding on water-cooled columns and raised and lowered by looped cables at each end.	Travels vertically.
Krasny Oktyabr B		1			1 for 4 strand		
Kirovsk A					1	Cross-beam with detachable dummy bar raised and lowered on pinion driven screw columns at each end.	Travels vertically.
Kirovsk B					1		
Vertical Continuous Casting Machines							
Novo Tula	17⅝	2	Auto-connect/disconnect coupling of first length.	Dovetail, set 28 ins. up into mould, ⅛ in. gap luted with clay.	2 7⅞ in.sq. twin-stranded with rolls common.	Withdrawal roll groups, each with 2 pairs of spring-loaded rolls, 11⅝ in. dia., set 9⅞ and 26¼ ft. below ground level and joined by link shaft (16 and 32¾ ft. below meniscus). Upper rolls open for 7⅞ in.sq.	19⅝ and 36
Krasnoye Sormovo A	13½	2	Auto-connect/disconnect coupling.	Dovetail, with 5⅛ in.sq. steel cover-plates; 3/16 in. gap luted in mould with china clay.	1	Double pair spring-loaded withdrawal rolls, 11⅞ in. dia., set 2½ ft. below ground level.	14¾
Krasnoye Sormovo B	27½	1	One-piece.		1	Similar set about 18½ ft. below ground level. Length integrator initiates cut-off operations.	About 32
Kalinin					1	Double pair of withdrawal rolls with single chain drive to one side only; loaded pneumatically. Roll faces V-shaped.	
Novo Lipetsk A, B	29½			Dovetail	1	Cluster group of 4 withdrawal rolls, 11⅞ in. dia., set 2 ft. below ground level.	31½
Donetsk (Stalino)	4⅝	3	Auto-connect/disconnect coupling at about 57 ft. below ground level by bogie supported clamp.	Dovetail	1	Double pair of withdrawal rolls, 13¾ in. dia., held in clasp support and hydraulically loaded.	
Revda							
Gorkii						Cluster group of 4 withdrawal rolls, 11⅞ in. dia., hydraulically loaded and self-centring; section gripping device operates if hydraulics fail.	
[illegible]		1		Sealed in mould with refractory ramming.	1	Cluster group of 4 withdrawal rolls, 9⅞ in. dia., spring-loaded and self-centring.	

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Type of Variable Speed Drive	Rating of Main Drive Motors KW.	Total Power Requirements KW.	Special Control Arrangements
Inclined Conveyor Type Mould Machines					
Bochitsdi		Single d.c. motor to main sprocket wheel on lower conveyor track only.	Conveyor drive: 20 (In operation: 10)		Metal level between pallets observed and manually controlled by pallet conveyor speed. Gamma-ray metal level detection and sub.control recently fitted. Ladle stopper control to be fitted later.
Onstuinsk					
Vertical Semi-Continuous Casting Machines					
Krasny Oktyabr	A, B	Each machine: Single d.c. motor with m.g. set.	Each machine: 9		
Kirovsk	A, B	Each machine: Single d.c. motor driving pinions for cross beam and for mould reciprocation.			
Vertical Continuous Casting Machines					
Novo Tula		Electrically synchronised d.c. motors for mould reciprocation and each withdrawal stand.	Reciprocation: 8.5 Withdrawal: 8.5 (each stand)	Connected: 176	Gamma-ray metal level control at mould still being developed. Also ladle stopper opening controlled electrically by weight of tundish.
Krasnoye Sormovo	A	Each strand: Electrically synchronised d.c. motors with m.g. sets.	Withdrawal: 9.0	Operating: 168 Connected: 480	Manual tundish stopper control. Gamma-ray metal level detection at mould and tundish. Closed circuit television of mould and of 4 points of cut-off operation at casting platform.
	B		Withdrawal: 15	Connected: 993 including reserves: 225	
Kalinin					Multi-level gamma-ray metal level detection using 10 sources at mould linked to withdrawal speed; metal level 6-8 in.below top of mould.
Novo Lipetsk	A, B		Withdrawal: 16		Automatic metal level control to ±$\frac{3}{8}$ in. range in regular use, based on use of radioactive isotopes with device to compensate metal flow variations due to nozzle erosion when teeming.
Donetsk (Stalino)		Hydraulic, but rotated electrically.	Reciprocation: 12 Withdrawal: 22		Improvements being made in metal level detection at tundish and mould and in control of ladle and tundish stoppers using tensometers at tundish and gamma-rays at mould.
Revda					
Gorkii					
Nabosdi					

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Position Below Top Platform ft.	Cut-Off Equipment: Manual, Mechanised, or Automatic	Cutting Equipment on Each Strand	Mounting
Inclined Conveyor Type Mould Machines					
Bochitsii		Approx. at ground level.	Manual	Oxy-kerosene manual cutting torch; 40 secs./cut for $5\frac{1}{2}$ in.sq.	Cut manually on horizontal travel.
Omutninsk					
Vertical Semi-Continuous Casting Machines					
Krasny Oktyabr	A, B			None on machine.	
Kirovsk	A, B			None on machine.	
Vertical Continuous Casting Machines					
Novo Tula		$40\frac{1}{2}$	Mechanised with remote controls.	Oxy-acetylene torches traversed at up to 16 in./min; 2 torches used for $7\frac{7}{8}$in.sq. Detail design by VNIIavtogen.	Frame, clamped pneumatically to descending section, at approx. 50 ft. below meniscus; down travel $10\frac{5}{6}$ ft. Twin-stranded $7\frac{7}{8}$in.sq. cut simultaneously.
Krasnoye Sormovo	A	37		Single oxy-natural gas torch and second unit in reserve; 55-60 secs./cut for $16\frac{1}{2}$ x $6\frac{7}{8}$ in. Detail design by VNIIavtogen.	Water-cooled frame, clamped pneumatically to descending section; down travel 5ft; cut lengths delivered $37\frac{3}{4}$ft. below ground level. Water-cooled frame, clamped hydraulically. Closed circuit television to observe cutting operation.
	B	$51\frac{5}{6}$	Mechanised with remote controls.		
Kalinin			Manual	Oxy-gas torch manually traversed on descending section; 5 secs./cut for $1\frac{5}{8}$in.dia.	Position of manual cut-off about 6 ft. below mould.
Novo Lipetsk	A, B	$59\frac{1}{2}$		Twin oxy-acetylene torches.	Frame, clamped to section; down travel $9\frac{5}{6}$ ft.
Donetsk (Stalino)			Automated from section length measuring device.	Twin oxy-blast furnace torches.	Operators cabin and torches on each strand clamped by pneumatically loaded eccentrics to section and moved on carriage vertically by hydraulic cylinders and tension chains.
Revda					
Gorkii				Oxy-gas torches with powder feed for stainless steels.	
Ubocsii				Oxy-gas torches.	Down travel $9\frac{1}{2}$ ft.

Table 2 : continued

Details of Soviet Casting Machines in Operation

Plant (Name in Brief)		Discharge Equipment: Mechanised, or Automatic	Discharge Equipment: Mode of Discharge	Additional Operations (in brief)
Inclined Conveyor Type Mould Machines				
Brzhitsii			After 9½° bend, and cutting to length on horizontal travel, cut lengths delivered horizontally and collected on 40 ft. wide skid bank.	Twin opposed scrapers positioned before bend to horizontal to remove unwanted fins solidified on side faces of section.
Omutninsk				
Vertical Semi-Continuous Casting Machines				
Krasny Oktyabr	A, B		Cast section raised by cross-beam when tundish and mould moved aside.	No cut made on machine. Cast length later subdivided, when cold, by iron powder or aluminium/magnesium powder torch. Top discard 10 in.
Kirovsk	A, B		Cast section lifted out when tundish and mould moved aside.	No cut made on machine.
Vertical Continuous Casting Machines				
Novo Tula		Automated (45 sec. cycle time)	Single cradle receives cut lengths on synchronised downward travel, lowers to tilt under counterpoised chain suspension to horizontal roller track, from which lengths raised by vertical elevator to ground level.	Moulds removed to insert dummy bar from above. Special winch used to lower the last length cast.
Krasnoye Sormovo	A	Mechanised	On each strand, counterbalanced cast steel cradle, with movable bottom plate to receive cut lengths, tilts to inclined conveyor track which raises lengths to ground level.	Moulds removed to insert dummy bars from above.
	B		On each strand similar cradle tilts to discharge horizontally; thereafter cut lengths removed by various conveyors for despatch.	Dummy bar inserted from below. Last length cast lowered by cut-off carriage, using hydraulic clamps.
Kalinin		Mechanised (Overbalancing design)	Single cradle tilts with cut length to horizontal roller track from which continuously rising dogged conveyor lifts each length at right angles.	
Novo Lipetsk	A, B		On each strand, cut-lengths received in cradle at 35 ft. below ground level, lowered, tilted and raised in cradle to ground level, where cradle tilts to discharge horizontally under action of auxiliary pinch rolls.	Dummy bar used to help remove last length cast. At ground level delivered lengths subdivided to 6½ - 7¾ ft., collected on stacking frame and charged to reheat furnaces.
Donetsk (Stalino)		Automated	On each strand, hydraulically operated cross-support lowers cut-lengths into receiving cradle which tilts to discharge along horizontal roller track; thereafter vertical lift, 15 ton capacity, raises cut lengths to ground level.	Trap mechanism included for removing crop ends. Discharged slabs finally cut to 3½ - 5 ft. lengths for rolling to sheet.
Revda				
Gorkii		Automated	On each strand, receiving cradle lowered with cut-lengths into frame which is hydraulically tilted to inclined rails to allow cradle to rise on a winch and deliver cut lengths to ground level.	
Uzbecii			Discharge group of 4 driven rolls, on cantilever supports, hydraulically opened and/or closed to grip section, or dummy bar, and deliver into cradle which tilts to horizontal. Cut-lengths raised therefrom by vertical lift to ground level.	Dummy bar used to lower last length cast. Similar group of rolls used to hold dummy bar in ambush below tilting-cradle mechanism.

For the production of seamless pipes, world's largest centrifugal continuous caster, has been installed at the Keihin works of NKK in Japan. Billets of 120 to 240 mm diameter are produced in a four strand caster and the monthly production capacity is 27,000 tons. Other relevant particulars of the continuous caster, are as follows:

Caster height	—	Overall height 34.8 m
Tundish	—	Capacity 12 tons
Mould	—	Cu - Cy alloy mould;
		455 mm long;
		Cooling 110 t/hr/strand;
		Lubrication, rape seed oil;
		Rotation, 120 rpm max;
		Oscillation, 140 cpm max;
		Stroke, 26 mm max;
Withdrawal	—	3.5 m per minute, max;
Metallurgical height	—	16.5 m.

The yield of sound billets is 89 per cent and the length of billet is kept within ± 0.5 per cent.

5.3 Choice of Process:

There are a number of technical and economic factors which influence the decision to choose one of the three processes of casting, namely,

(i) Conventional small ingot casting practice

(ii) Conventional large ingot casting practice

(iii) Continuous casting.

The parameters influencing the choice of the process are:

(a) production scale

(b) type and quality of product

(c) materials yield and balance

(d) investment and energy requirements

(e) operating costs

(f) manning

(g) technical requirements in supporting sectors

(h) management and control requirements

The conventional ingot casting/primary mill route involves considerable cost sources. With continuous casting the two independent functions, namely, casting and primary rolling, are combined into one simple process. The operation involved in the two processes, are represented in Table 3.

Table 3: Steps in two processes

Ingot Casting/Primary Mill	Continuous Casting
1. Furnace tapping	1. Furnace tapping
2. Laddle transfer to casting pit	2. Laddle transfer to casting platform
3. Casting into moulds	3. Continuous casting
4. Transfer of the ingot moulds to the stripper yard	4. Subdividing of the cast strands
5. Stripper	5. Transfer of the cast material to the rolling mill
6. Transfer of the ingots to the pit or pusher furnaces	
7. Ingots placed into pit or pusher furnace	
8. Heating the ingots	
9. Transfer of the ingots to the primary mill	
10. Primary rolling	
11. Grinding of the rolled products	
12. Transfer to the rolling mill	

The applicability of the three processes to different types of steel products, is shown in Table 4.

Table 4: Applicability of the three processes to different types of steel product

	Small Ingot direct rolling	Large Ingot blooming	Continuous Casting and breakdown
Reinforcing bar	yes (1)	yes (1)	yes (1)
General Structural bar and section	yes (1)	yes (1)	yes (1)
Low-carbon wire rod	yes (2)	yes (1)	yes (1)
High-carbon wire rod	yes (2)	yes (1)	yes (1)
Cold-drawing quality	Doubtful	yes (3)	yes (4)
Cold-heading quality	Impossible	yes (5)	yes (4,5)
Mechanical Structural carbon steel	Difficult	yes (5)	yes (4,5)
Low-alloy steel	Impossible	yes (5)	Doubtful
High-alloy and Stainless steel	Impossible	yes (3)	Doubtful

Source: S.Kojima – 3rd Interregional Symposium on I. and S. Industry, Brazil

Notes:
(1) Easily applicable
(2) Only applicable for low quality level
(3) Surface conditioning required
(4) Over 150 mm square bloom recommended; surface conditioning required
(5) Surface conditioning and guaranteed internal quality required.

The energy requirements for blooming mill and continuous casting are 35–55 Kwh/ton and 10–30 Kwh/ton, respectively. Water requirement is more for continuous casting installation, namely 12-18 m^3 per ton per hour as against 4-7 m^3 per ton per hour for blooming mill.

However, continuous casting can not be applied universally for the entire range of a flat-product mix. For all outputs, there are often local factors to be examined in making the choice. The most critical considerations are those of scale and volume, yield and capital cost and, the steel quality. Continuous casting does not produce a satisfactory rimmed steel slab or bloom.

5.4 Cost Data

Investment costs depend very largely on geographical conditions, layout of the plant, product range, tariffs, economic policies of the country, local market costs, freight, labour costs, etc. These factors vary greatly from country to country.

The small ingot process is labour-intensive, requiring more employees per ton of production and increasing markedly as the output rises. The large ingot blooming process is a large-scale one, and so an increase in capacity utilization can effectively increase the productivity per employee. The continuous casting of square section products has a production limit per machine of 500 - 600,000 tons.

(i) A comparative idea of operating costs for the three processes is given in table 5. However, it may be mentioned that the figures should be taken as indicative only. The current actual cost per ton would be more due to escalation and inflation. Since there will be variations in the local prices for copper moulds for continuous casting and for blooming mill rolls, comparison of operating costs, becomes only an approximation.

Table 5: Relative operating costs for the three process.

Process	Items	Consumption	Cost, US$ per ton
Small Ingot	Bricks and refractories	7.0 - 10.1 Kg/t	
	Moulds and plates	8.9 - 15.3 Kg/t	
			4.2 - 5.8
Large Ingot Blooming	Bricks and refractories	7.2 - 15.0 Kg/t	
	Moulds and plates	8.4 - 16.6 Kg/t	
	Heavy fuel oil	20 - 40 l/t	
	Rolls	0.4 - 0.7 Kg/t	
	Electric power	35 - 55 kwh/t	
			6.6 - 10.4
Continuous Casting	Bricks and refractories	5.0 - 18.0 Kg/t	
	Moulds	70 - 500 heats/moulds	
			3.0 - 4.8

Source: S. Kojima - 3rd Inter-regional Symposium on I and S Industry, Brazil.

The above figures show that the operating costs of continuous casting, are the lowest, the small ingot process comes next, and the large ingot blooming process is comparatively, most expensive.

(ii) Arthur D. Little Inc. have estimated capital investment for continuous casting plant to be about US$800,000 for a 300 tons per day plant and about US$4,000,000 for a 4000 tons per day continuous caster.

(iii) H. Fastert and R. Gautschi (3rd Interregional Symposium on Iron and Steel Industry, Brazil, 1973) estimate investment cost per ton of installed capacity for a slab casting machine of 6000 casts per annum, to be 30 per cent lower than for the conventional process.

(iv) R. Missbach and J. th. Wasmuht (ID/WG.146/68) in a study have worked out comparative capital cost figures for continuous casting projects and the conventional process for different capacities. The information is summarized in Table 6.

Table 6: Comparative Capital Costs

Plant capacity, cost and yield factor	Conventional pouring route	Continuous casting route
0.8 million tons per year		
Capital cost, per cent	100	45 -55
Yield factor, per cent	83 approx.	97 approx.
1.2 million tons per year		
Capital cost, per cent	100	65 - 75
Yield ratio, per cent	87 approx.	96 approx.
1.5 million tons per year		
Capital cost, per cent	100	80 -90
Yield ratio, per cent	85 approx (killed steel)	95 approx.

(v) In a survey made by the Organisation for Economic Co-operation and Development on Continuous Casting of Steel in the USSR, it has been stated that the cost of converting liquid steel into cast slabs, is about 25 per cent less than converting it into rolled slabs and the casting process costs could be reduced further if the productivity of the machine could be increased by introducing new steelmaking equipment. At present for the plant at NOVO Lipetsk, two electric furnaces with 25 MVA transformers produce steel which is continuously cast in two twin-strand machines. The steels generally cast are transformer and dynamo steels, rimming carbon steels, killed carbon and semi - killed carbon steels in various slab sizes which overall range from 24 3/8 x 5 7/8 to 40 1/8 x 6 3/4 inches in section. Typical casting speeds quoted are in the range 32 - 36 in/min for the large slabs.

The two machines, when operating with 90 - 95 ton capacity laddles, have produced up to 800 tons in 8 - 9 casts/day.

The consumption of liquid metal/ton of slabs of transformer steel has been found to be respectively 26.3 and 24.3 per cent lower than at Kuznetsk and at Dneprospetsstal and Zaporozhstal taken together. The process costs in the arc furnace shops, on the roughing mills, and the expenditure on deoxidizers and addition materials at kuznetsk amount to 21.0, 5.9 and 2.2 roubles/ton in total. At Dneprospetsstal and Zaporozhstal, these amount to 24.4, 6.8, 2.8, giving a total of 34.0 roubles/ton. Hence, the saving for continuously casting the slabs is estimated at 7.7 and 8.3 roubles/ton respectively. The difference in costs for continuously casting the metal, plus scarfing the cast slabs as against casting ingot and rolling on a slabbing mill is given at an average of 0.8 roubles/ton of cast slabs so that the real saving in these comparisons is placed at 8.5 and 9.1 roubles/ton. This saving in cost is expected, however, to increase still further with increase in the production of cast slabs.

The economic advantage of changing over to continuous casting, whilst largely due to the increased yield of sound metal or reduction in metal waste, also includes a reduction in the extra capacity of steelmaking units and roughing mills which would otherwise be required to meet the planned rates of expansion. There would, therefore, be corresponding savings on these operations as well as reduced consumptions of de-oxidisers and flux materials on the liquid metal that is saved.

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