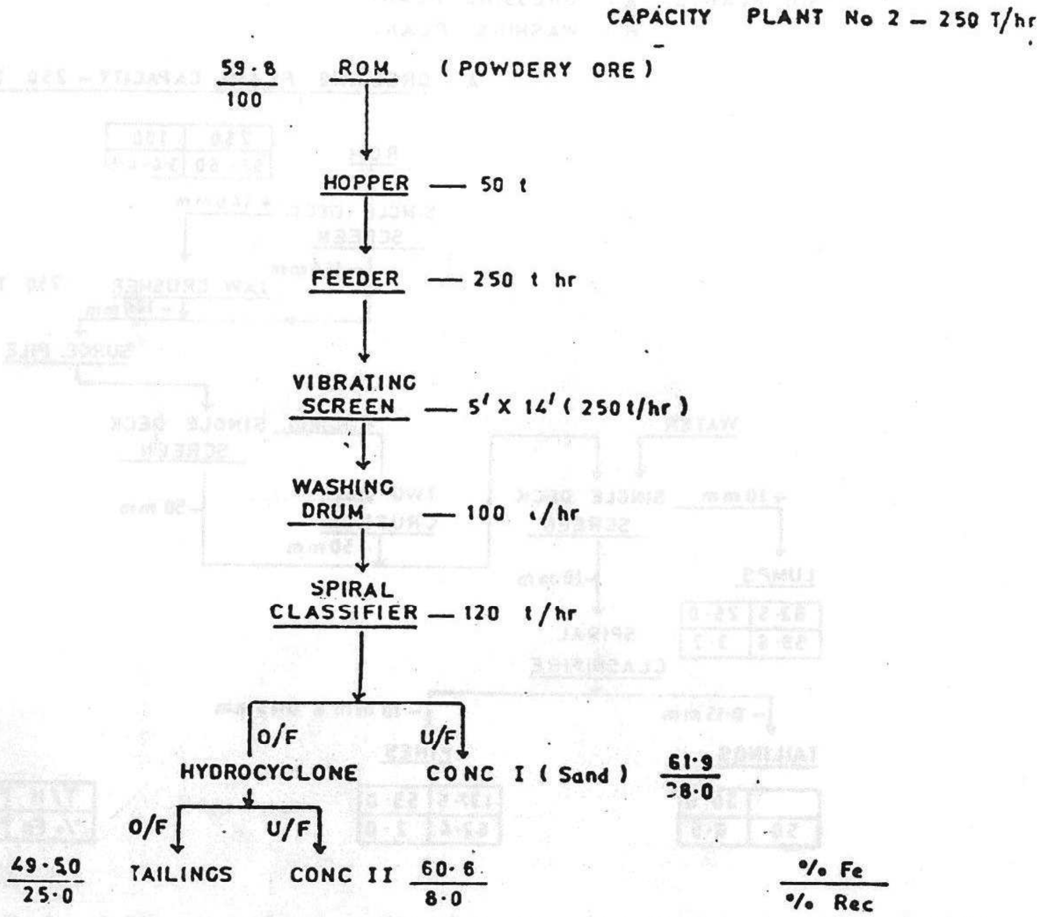
Fig, 10.8 : Flowsheet of Amona Iron Ore Beneficiation Plant No. 1 & 2 of M/s Sesa Goa Ltd. Goa.



1 LOCATION — The plant is located about 10 kms from Goval Shanshi mine, Sanqueiim, Goa

2 CHEMICAL ANALYSIS —

PRODUCTS	% Fe	% Dist.	% Al_2O_3	% SiO_2
Feed	59·80	100·00	7·63	3·90
Classifier V F	61·90	38·00	3·70	2·60
Cyclone V F	60·60	8·00	3·50	3·50
Tails	49–50	25·00	7–8	11–12

LUMPS — 29 % Feed to Plant no.1 for crushing.

3 PROCESS — Screening, Washing, :sification and Hydrocycloning.

TABLE 10.6 : BENEFICIATION EQUIPMENT IN MAJOR IRON ORE PROCESSING PLANTS

Sr. No.	Plant Location	Screen size (width x length) in mm	Scrubber size (dia x length in mm)	Classifier width/dia x length (mm)	Concentrating Equipments (size in mm)
1	Barsua	1524x3658 (Dry) 1830x4280 (Wet)	2400x4500	Spiral (1500x8460)	Jigs (1500X4800)
2	Bolani	1830x6100 (Dry)	--	--	--
3	Bailadila-5	2400x6000 (Wet)	--	Rake (4800x11580)	--
4	Bailadila-14	2130x6100 (Wet)	--	Spiral (1830x9800) Cyclone (610)	--
5	Daitari	1600x6700 (Wet)	--	Spiral (1250x7500)	--
6	Dalli	1750x3500 (Dry) 1750x3500 (Wet)	2480x6100	Spiral Duplex (2400x9200)	--
7	Donimalai	1830x4880 (Wet)	--	Spiral (1830x11000) Cyclone (600)	--
8	Gua	1830x3658 (Dry)	--	--	--
9	Kiruburu	2100x6000 (Wet)	2400x7000	Rake (3658) Spiral (1500x10000)	--
10	Kudremukh	1524x3658 (Wet)		Cyclones (900)	Spirals (445:Pitch) Magnetic Separator (1220:Dia)
11	Meghataburu	1830x4877 (Dry) 1830x4877 (Wet)	--	Rake (3657x10972) Cyclone (610)	--

TABLE 10.7 : LOSS OF IRON VALUES IN TAILINGS/SLIMES FROM IRON ORE PROCESSING PLANTS

Sr. No.	Location of Processing plants	Rated Capacity (million tonnes per year of r.o.m.)	Average Feed grade (% Fe)	Tailing and slimes			
				Average grade (% Fe)	Wt.%	Tonnage (million tonnes per year)	Tonnage of iron values (million tonnes per year)
1	Barsua	2.5	58.0	49.0	22.8	0.57	0.28
2	Bailadila-5	6.0	68.0	68.0	12.0	0.72	0.49
3	Bailadila-14	6.0	66.5	58.0	16.0	0.96	0.55
4	Bolani	2.5	61.0	49.0	30.0	0.75	0.37
5	Daitari	2.5	62.0	56.0	10.0	0.25	0.14
6	Dalli	2.5	62.0	47.0	6.0	0.15	0.07
7	Donimalai	4.0	64.0	60.0	14.0	0.56	0.34
8	Kiruburu	5.0	63.6	64.0	15.0	0.75	0.48
9	Meghataburu	5.0	62.5	55.0	14.0	0.70	0.38
10	Noamundi	3.5	64.0	58.0	14.0	0.49	0.28
11	Amona	3.0	60.0	49.0	30.0	0.90	0.44
12	Bicholim	3.0	58.0	53.0	14.0	0.42	0.22
13	Codli	1.5	60.2	48.0	16.0	0.24	0.12
14	Costi	3.6	60.3	48.0	13.0	0.47	0.23
15	Cudgel	1.5	59.6	51.0	21.0	0.32	0.16
16	Kirpale	1.2	60.5	51.0	17.0	0.21	0.11
17	Maina	4.5	62.0	49.0	16.0	0.72	0.35
18	Navelim	1.5	44.4	21.0	25.0	0.38	0.08
19	Pale	3.0	58-61	51.0	20.0	0.60	0.31
20	Kudremukh	22.5	39.0	24.41	63-64	15.00	3.66
	Total	84.8	--	--		24.16	9.06

10.2.3 Processing Problems

The problems associated with beneficiation of Indian iron ores are manyfold.

a) Indian hematites, being very soft in nature, generate substantial proportion of r.o.m. (35-60%) as fines during mining, preparation and beneficiation. Tailing and slimes generated during processing of hematite ores amount to about 5-30% of r.o.m. and are discarded as waste. The information about nature and quantum of slimes/tailing generated by various processing plants is given in Table 10.7.

It is observed that about 5.4 million tonnes of iron values are lost per year during processing of hematitic iron ores in the country. The iron content in the tailings/slimes ranges from 21 to 68%. The Indian mineral processing industry is currently beset with the problems of economic utilization/disposal of the tailings and the pollution/environmental problems caused by the effluent discharge or embankment failure.

b) High alumina content in the ore and intimate association of alumina minerals (clay, felspar, mica, chlorite, etc.) with iron oxide minerals (hematite, goethite and limonite) pose processing and smelting problems. If the ore is high in alumina, the fluidity of slag is affected. The alumina/SiO_2 ratio for better performance of the blast furnace should be less than 1.5 and preferably below 1.0. Even benefication at fine size does not bring about desired reduction in the ratio.

c) The processing of magnetic iron ore at Kudremukh generates about 13-15 million tonnes of tailings assaying 24 to 25% Fe[2] amounting to 40% of total iron values lost in tailings and slimes generated by Indian plants. This is due to (a) intimate association of quartz, the main gangue, with iron oxide minerals, mainly non-magnetic iron oxide minerals and (b) magnetic and gravity separation at coarse size (-28 mesh).

10.2.4 Research and Development Efforts

The Indian Bureau of Mines, and other premier R&D organisations concerned with mineral beneficiation in the country address themselves to the problems confronting Indian iron ore processing plants and have made concerted efforts to recover iron values from the ore fines, tailings and slimes.

The Indian Bureau of Mines has established Modern Mineral Processing Pilot Plant and Laboratory with the assistance from United Nations Development Programme. The Pilot Plant is well equiped with all necessary modern equipment to test different types of ores including iron ores. The pilot plant has crushing and grinding capacity of 5 tonnes/hour and about 2 tonnes/hour capacity for down stream separation. A wide range of beneficiation units for iron ore beneficiation provided in the plant are:

1. Heavy Media Separation Units.
2. Jigs:
   - a) Harz
   - b) Denver
3. Spiral Concentrators - Humphrey
4. Concentrating Tables:
   - a) Wilfley, Holman (suitable for fine size)
   - b) GEC Duplex Concentrator and Buckman Tilting Table (capable of recovering values in ultrafine size)
   - c) Multi Gravity Separator (fine and ultrafine)
5. Tray Test Assembly
6. Magnetic Separators - Wet & Dry
7. Attrition Scrubbers - Twin attrition scrubbing in continuation with spiral classifiers, Stokes Sizer and Rotary screens
8. Cyclones of various sizes.

Detailed R&D studies are conducted in the country to maximise the recovery of saleable iron ore concentrate. The salient data of some important bench/pilot - scale beneficiation studies conducted by IBM and other institutions for recovery of sinter and pellet grade concentrate from ore fines, tailings and slimes are given in Table 10.8 and 10.9, respectively.

A close look at the tables will reveal that (i) sinter grade iron ore concentrate can be recovered by jigging employing batac jigs and mineral jigs with substantial iron recovery, (ii) hydrocycloning of tailings helps in recovery of pellet grade concentrate, (iii) recovery of very fine concentrate from slimes can be effected by wet high intensity magnetic separators and centrifugal gravity separators (MGS : Multigravity separator). Commercial application of MGS is yet to be established. (iv) Cyclosizing tests on Goan iron ore slimes have indicated the possibility of recovering pellet grade concentrate with higher iron recovery by adopting appropriate technology to recover +10 micron particles. Selective flocculation, desliming and reverse flotation may emerge as appropriate technology. (v)Gravity separation on Kudremukh non-magnetic product at slightly finer size (28 to 35 mesh) may increase the iron recovery by 10-15%. Regrinding of other gravity tailings to 100 to 150 mesh size followed by WHIMS or froth flotation may help in minimising the tailing losses and maximising iron recovery.

Table 10.8: SALIENT DATA PERTAINING TO IMPORTANT BENEFICIATION STUDIES CONDUCTED ON IRON ORE SAMPLES BY INDIAN BUREAU OF MINES

S.No.	Deposit (Source)	Feed grade (Assay %)	Minerals present	Concentrate			Process adopted
				Grade (Assay %)	Wt% yield	% Fe recovery	
1	Bonai (Orissa)	Fe : 59.16 Al_2O_3 : 3.22 SiO_2 : 2.43 LOI : 7.08	Goethite, limonite, hematite, quartz, clay & mica.	Fe : 63.0	81.15	86.86	Trommel washing
2	Kudremukh (Karnataka)	Fe : 39.46 Al_2O_3 : 2.44 SiO_2 : 43.82 LOI : 2.09	Magnetite, goethite, hematite, quartz, amphibole.	i) Fe : 67.82 ii) Fe : 70.89	40.81 37.24	70.85 66.38	Low intensity wet magnetic seperation at 96% -28 mesh size. Low intensity wet magnetic separation at 93% -48 mesh size.
3	Goa (M/s Salgaonkar)	Fe : 59.18 Al_2O_3 : 6.55 SiO_2 : 1.50 LOI : 6.35	Hematite, magnetite, gibbsite, quartz, felspar.	Fe : 65.45 Al_2O_3 : 2.41	64.83	70.44	Low intensity wet magnetic separation followed by gravity separation at -48 mesh size.
4	Goa (M/.s EMCO Pvt. Ltd.)	Fe : 48.90 Al_2O_3 : 1.23 SiO_2 : 28.80 LOI : 0.74	Hematite, magnetite, quartz, chlorite, clay.	Fe : 66.49 Al_2O_3 : 0.59 SiO_2 : 4.67	53.50	72.65	Hydroclassification at -100 mesh size followed by magnetic separation of fine fraction.
5	Eleyttimala (Kerala)	Fe : 42.72 Al_2O_3 : 1.09 SiO_2 : 35.50 LOI : 3.21	Magnetite, goethite, quartz.	Fe : 65.09 SiO_2 : 3.65	61.53	90.12	Low intensity wet magnetic separation at -100 mesh size followed by gravity separation on nonmagnetics after regrinding to -48 mesh size.
6	Sindhudurg (Maharashtra)	Fe : 55.03 Al_2O_3 : 4.52 SiO_2 : 8.83	Magnetite, goethite, quartz, gibbsite, and clay.	Fe : 61.04 Al_2O_3 : 2.80 SiO_2 : 3.26	68.64	76.14	Scrubbing, hydroclassification and spiralling
7	Tailing of Jadugūda Plant (Bihar)	Fe : 59.74 Al_2O_3 : 2.27 SiO_2 : 11.67	Magnetite, quartz, chlorite	Fe : 70.65 SiO_2 : 2.16	80.5	96.40	Low intensity wet magnetic separation.

Contd..

Table 10.8 Concld...

8	Iron ore fines from Dalli Mines (MP)	Fe : 62.21 Al_2O_3 : 4.28 SiO_2 : 2.87 LOI : 2.89		Fe : 64.62	81.7	84.3	Jigging
9	Iron ore fines from Codli Mines Goa.	Fe : 56.97 Al_2O_3 : 7.49 SiO_2 : 2.36 LOI : 7.32		Fe : 60.49	62.3	66.1	Jigging
10	Iron ore fines from Mayurpani (MP)	Fe : 58.45 Al_2O_3 : 5.91 SiO_2 : 6.75 LOI : 3.7	Hematite, quartz, mica, clay and amphibole	Fe : 62.90 Al_2O_3 : 4.05 SiO_2 : 3.40	74.1	79.7	Jigging
11	Blue dust (NMDC Hyderabad)	Fe : 67.78 SiO_2 : 2.86		Fe : 69.94 SiO_2 : 0.26	63.67	65.69	Electrostatic separation.
12	Iron ore slimes (M/s Sociadode De Fomento Goa)	Fe : 57.50 Al_2O_3 : 5.66 SiO_2 : 6.84 LOI : 4.66	Hematite, martite. goethite, clay, mica, quartz, gibbsite.	Fe : 64.74 Al_2O_3 : 2.54 SiO_2 : 2.20 LOI : 2.40	69.2 (+9 micron product)	77.60	Cyclosizing
13	Iron ore slimes (M/s Sociadode De Fomento Goa)	Fe : 56.35 Al_2O_3 : 5.40 SiO_2 : 7.36 LOI : 5.99	Goethite, limonite, hematite, martite, clay, mica, quartz	Fe : 64.54 Al_2O_3 : 2.30 SiO_2 : 2.16 LOI : 2.88	56.60	64.40	Wet high intensity magnetic separation.
14	Iron ore fines from Dalli Mines (MP)	Fe : 59.70 Al_2O_3 : 5.23 SiO_2 : 7.52	Hematite, goethite, martite, quartz, and clay	Fe : 63.75 Al_2O_3 : 2.10 SiO_2 : 2.65	66.7	73.2	Hydroclassification, jigging and spiralling.

10.2.5 Research and Development Needs

It may not be out of contest to mention that some of the problems confronting iron & steel industry, despite our best efforts to resolve them, have not been tackled so far. In order to resolve these problems, it is imperative to conduct intensive R&D studies in premier mineral processing laboratories of India. The following measures may prove fruitful:

a) Characterization of iron ore deposits : Detailed chemical analysis and mineralogical studies need to be conducted on iron ore samples from various deposits in the country. Mineralogical studies should be oriented towards (i) identification of valuable and gangue minerals, (ii) determination of their mode of association and liberation size, and (iii) size and nature of association of iron and gangue minerals in the tailings/slimes. These studies may help in process development studies and may lead to maximisation of iron recovery or modification in the present process flowsheet.

Detailed chemical analysis of feed samples, tailings and slimes samples may indicate (a) the nature and amount of other valuable/ deleterious metals present and (b) need to remove/recover them economically. Tailings from Kudremukh deposit are reported to contain recoverable amount of gold. Iron ore samples from some Goan deposits were also investigated for determination of their gold content. Therefore, it is essential to analyse iron ore samples from all deposits for estimation of the contents of important elements like gold, silver, chromium, nickel, tin, cobalt, etc.

b) Based upon characterisation of iron ores in the country, detailed process development studies need to be conducted to evolve commercially viable flowsheet to maximise iron recovery, recover byproducts and bring down the content of deleterious impurities to the acceptable level.

c) R&D studies are also required to be conducted to ascertain ways and means to utilize tailings for construction and other purpose, to dewater tailings profitably to facilitate their disposal without causing any environmental hazards.

10.2.6 Production of Ferrite Grade Concentrate

Ferrites are defined as magnetic oxides formulated by ceramic processing of ferric oxide with other divalent oxide like MnO,MgO, etc. Ferrites are used in manufacture of

TABLE 10.9: SALIENT DATA PERTAINING TO SOME IMPORTANT INVESTIGATIONS CARRIED OUT BY OTHER R&D INSTITUTIONS FOR RECOVERY OF SINTER AND PELLET GRADE CONCENTRATE FROM SLIMES

S.No.	Source	Feed grade (Assay %)	Concentrate			Process adopted	Investigating Agency
			Grade	Wt. % yield	% Fe recovery		
1	Joda and Noamundi (Bihar) (Classifier fines)	3.14 to 4% Al_2O_3	1.5 to 2% Al_2O_3	72-83%	--	Jigging (batac jig)	TISCO
2	Naomundi (Iron ore slimes)	5.88% Al_2O_3	1.24% Al_2O_3	47.3%	--	Multigravity separator	TISCO
3	Barsua	Fe : 49.0 Al_2O_3 : 8.9 SiO_2 : 11.40	Fe : 60.8	49.7	61.1	Hydrocycloning	RRL Bhubaneshwar
4	Kiriburu	Fe : 60.4 Al_2O_3 : 4.96 SiO_2 : 2.96	Fe : 64.8	69.7	74.8	Hydrocycloning	RRL Bhubaneshwar
5	Daitari	Fe : 59.82 Al_2O_3 : 4.52 SiO_2 : 2.30	Fe : 63.02	74.1	78.1	Hydrocycloning and Tabling	RRL Bhubaneshwar
6	Bailadila	Fe : 62.8 Al_2O_3 : 4.26 SiO_2 : 3.68	Fe : 68.20	79.5	86.3	Hydrocycloning	RRL Bhubaneshwar
7	Bailadila	Fe : 63.3 Al_2O_3 : 4.4 SiO_2 : 2.76	Fe : 66.55	70.8	74.1	Flotation	NMDC
8	Bailadila	Fe : 60.64 Al_2O_3 : 3.1 SiO_2 : 7.76	Fe : 65.17	75.4	81.2	WHIMS	NMDC
9	Donimalai	Fe : 54.3 Al_2O_3 : 7.78 SiO_2 : 8.86	Fe : 63.40	40.9	47.1	FLOTATION	NMDC
10	Meghataburu	Fe : 57.65 Al_2O_3 : 5.95 SiO_2 : 4.38	Fe : 63.52	54.9	60.3	Hydrocycloning	NML
11	Bolani	Fe : 49.8 Al_2O_3 : 8.1 SiO_2 : 6.6	Fe : 58.0	49.7	57.9	Hydrocycloning	NML
12	Gandhamardan	Fe : 54.8 Al_2O_3 : 6.1 SiO_2 : 7.9	Fe : 60.5	64.5	74.6	Hydrocycloning	NML
13	Bellary-Hospet	Fe : 57.6 Al_2O_3 : 5.9 SiO_2 : 8.0	Fe : 66.9	60.0	81.8	Hydrocycloning	NML

ferromagnetic ceramics, magnetic media (tapes, floppy, disks,, toners, etc.). Ferrites are generally of two types, e.g. hard ferrites and soft ferrites.

a) Hard ferrites : Ferric oxides are combined with barium and or strontium to produce hard ferrite materials which are used in small motor magnets, loudspeakers and business equipment, permanent magnets, etc.

b) Soft ferrite are iron oxide combined with among others, Mn, Zn, Ni - Zn compounds and are used as cores for transformers and to suppress electrical noises. Other applications include use in electronic recording heads, electromagnetic interference (EMI) filters, microwave devices, etc.

Specifications[18] : Presently, most of the ferric oxide requirement for ferrite manufacture is met by regenerated iron oxide obtained from pickling liquor. The specifications of iron ore concentrates required for various types of ferrites are given in Table 10.10.

Production : National Mineral Development Corporation Limited (NMDC) is operating a 1200 tpy demonstration plant at Hyderabad for

TABLE 10.10: SPECIFICATIONS OF FERRITE GRADE CONCENTRATE[18]

Constituents	Specifications (% by weight)		
	Hard ferrites	Soft ferrites	Ultra-pure ferrites
Fe_2O_3 min	98.50	99.40	99.40
SiO_2 max	0.60	0.30	0.005
CaO max	0.05	0.05	0.015
MgO max	0.05	0.05	0.010
MnO max	0.30	0.01	0.02
Al_2O_3 max	0.20	0.07	0.07
S	Traces	Traces	--
Cl	Traces	Traces	--
Average particle size (micron: Fisher)	3	3	3

TABLE 10.11: INDIAN SINTERING PLANTS

S.N.	Belong to steel plant	Rated sintering capacity (million tonne/year)	Sintering area (m^2) x No of strand	Suction (mm) water gauge	Bed (mm) height	Sinter productivity	
						$t/m^2/hr$	% sinter in the burden
1	Bokaro	6.94	252/312x3	13.50	--	1.20	70
2	Bhilai	5.18	75x4	1100	300	1.28	60
3	Rourkela	1.20	125x2	900	527	1.00	45
4	Durgapur	1.50	143x2 180x1	945	400	0.80	35
5	TISCO	2.54	--	1400	590	--	65
6	Visakhapatnam	5.25	312	--	--	--	--

production of hard and soft grade ferrites by beneficiating blue dust from its Bailadila mines. The process employed comprises gravity separation and magnetic separation. Electrostatic separation tests conducted by IBM on NMDC samples have also established that it is possible to obtain ferrite grade concentrate.

NMDC is also setting up a commercial plant at Vishkhapatnam (A.P.) to produce ultra-pure ferric oxide (6,000 tpy) from blue dusts by hydrometallurgical process. A pilot plant is also being set up at Hyderabad for optimisation of various parameters (mixing, spray drying, etc.) for producing soft grade ferrite powders using indigenous raw materials.

10.2.7 Agglomeration (Sintering and Pelletisation) Plants

As already discussed, mining and processing of Indian hematite deposits generate substantial amount of fines (35-60% of r.o.m.) which as such cannot form a feed to blast furnace. Beneficiation of iron ores from magnetitic deposits produces concentrates in fine form. Besides, India possesses large deposits (about 500 - 600 million tonnes) of blue dusts which are high grade- fine grained hematite fines occurring naturally in Bihar, Goa and Madhya Pradesh[(14)]. All these fine material need to be agglomerated for their utilization in iron and steel marketing. Generally, -10 mm +100 mesh material is agglomerated by sintering and -100 mesh material by pelletisation.

Sinter constitutes a major part of iron-bearing burden in the blast furnace. Significant decrease in coke rate and increase in productivity are achieved by replacing lumpy ore by fluxed or super-fluxed sinter. In India, sinter production on a commercial scale started at TISCO in 1959 with two machines of 75m^2 area. Since then, there has been a steady increase in sintering capacity. All the steel plants except IISCO have sinter plants to provide sinter charge to the extent of 30-70% in the blast furnace burden. The detailed information about Indian sintering plants is given in the Table 10.11.

The largest machines of 312 m^2 area have been installed at Bokaro and Visakhapatanam steel plants(22). There are also two-batch Pan-type machines at VISL (Karnataka) and KIWC (Bihar).

Bedding and blending of raw material is necessary to produce sinter with consistent sinter chemistry. TISCO and Vishakhapatnam steel plants have already bedding and blending facilities(22). Tests conducted by NMDC have established that use of -100 mesh material to the extent up to 30-35% in the sinter mix is beneficial. TISCO is using 60% blue dust fines in the mix, the bed permeability problem due to use of fine material is taken care of by using 20 kg/t of lime. While using higher proportion of fines/ultra-fines in the sinter mix, more moisture has to be added for micropelletisation. During sintering, the excess moisture recondenses in the lower portion affecting bed permeability and sintering speed. The preheating of sinter mix to 60-70°C is being practiced to overcome these problems. This technology is much relevant to India, as in coming years, Indian sinter plants will have to incorporate larger quantity of ore fines, beneficiated sinters and fine beneficiated concentrate in the sinter mix. Bhilai Steel Plant has successfully adopted this preheating technology. In general, with increase in bed height, the productivity of sinter improves and energy consumption is reduced. Deep bed sintering practice (590 mm) at TISCO's sinter plant has helped in achieving promising results on all fronts (strength, productivity, sinter size, return fines, FeO in sinter, etc.). Unlike dolomite, dunite (olivine rock) does not require any calcination. When dunite was used in place of dolomite at TISCO's sintering plant, a saving of 8 kg/t of coke breeze was achieved and the high temperature properties of resultant sinter (softening and melting characteristics, reducibility, etc.) were also found to be better.

It is a well known fact that iron ore material finer than -100 mesh size are generally agglomerated by pelletisation. Fine beneficiated concentrate from Indian iron ore magnetitic deposits, beneficiated slimes and finer protion of blue fust form feed to Indian pelletisation plants. The information about the pelletisation plants is given in Table 10.12.

TABLE 10.12: CAPACITY OF INDIAN PELLETIZATION PLANTS

Sl.No.	Name of the plant	Rated capacity (million tonnes/ year)	Specification of the fines used
1.	Kudremukh Iron Ore Company Ltd. Karnataka	3.0	Fe : 67-68% SiO_2 : 3-3.85% Al_2O_3 : 0.40%max Size : 60% -325 mesh
2.	Chowgule & Co. Ltd.,Pale, Goa.	0.55	--
3.	Mandovi Pellets Ltd., Mandovi, Goa.	1.8	--
4.	Noamundi, TISCO (Bihar)	0.8	--

Kudremukh and Mandovi are supplying direct reduction grade pellets to domestic as well as foreign sponge iron plants. Pellets from both the plants have an iron content more than 67% and gangue less than 3.5%. A recent change of binding material and new quality control programme has improved pellet quality which eventually could make the pellets a primary feed material (more than 50% in the feed) for sponge iron production. Although sulphur content in Mandovi pellet is slightly high, it has good chemical and physical properties. All the plants produce DR- grade pellets. Essar steel is planning to install a pellet plant at Vishakhapatnam and M/s Jindal Ispat is contemplating to set up a 3 million tonnes per year pellet plant in Karnataka. Due to rapid rise in the demand of pellets, KIOCL is also thinking to raise the capacity of its pelletisation plant. A 400-tpd cold bonded pelletisation plant is to be set up at Gua (Bihar) by M/s SAIL to utilize high grade super-fine iron ores based on a new indigenously developed technology.

10.2.8 Direct Reduction Plants

Sponge iron is produced by direct reduction of high grade iron ore or pellets to metallic iron in solid state employing solid (coal) or gaseous (natural gas) reductant(26). Due to shortage of melting scrap and its non-availability at competitive price, much importance is now being given to sponge iron production in India. As far as the demand for sponge iron in the country is concerned, the expected production of steel from the secondary sector (DR-EAF steel-making route) is projected to be 7.8 and 11.5 million tonnes in 1995-96 and 2000-2001, respectively, taking into account the conservative annual growth rate of 8% for Indian steel makers.

Direct reduction and Electric Arc Furnace (DR-EAF) route is the economical alternative route for steel making. This is largely due to the fact that India is bestowed with one of the world richest iron ore reserves, abundant resources of non-coking coal, and has financial constraints. This route of iron-making is less capital intensive. Studies conducted for Sponge Iron Manufacturers Association by AF Ferguson & Co. (India) have indicated that a 150,000 tpa coal- based sponge iron plant with total infrastructural facility will cost Rs. 200 crores. The cost for gas-based plant is also same. The limited availability of gas in India makes it difficult to set up more gas-based plants. Thus, the main growth in DRI production will be from coal-based plants due to availability of coal in various regions of the country[(23),(24)].

High grade iron ore reserves suitable for DRI plants (Fe > 65%) is available in certain regions only (Bailadila, Banaspani, Bellary, Hospet and Sesagoa). Only Bailadila and Bellary-Hospet ores have been used by Midrex plants. All of these ores are high in iron content (Fe : 67.5 - 69%, gangue : 2-5%) and have excellent reduction characteristics. Bailadila ore is very reducible with only moderate fine generation and is regarded by several plants as the best lump ore available.

Ore from Banaspani and Sesagoa mines are among the best tested by Midrex at its technical center and could potentially be used as 100% feed mix but accessibility is a problem. Although Bellary-Hospet is high in iron, it tends to produce substantial amount of fines (oxide and metallic), but it has been used with good results up to 20% in the feed mix.

India's major natural gas deposits are in Bombay High and Gujarat fields in west, Assam and Tripura fields in the north-east and

TABLE 10.13: DIRECT REDUCTION PLANTS IN INDIA

Sr.No.	Technology	Producer	Installed capacity (million tonnes per year)
A	Coal-Based		
1.	SAIL	a) Sponge Iron India Ltd., Paloncha. b) Tamil Nadu Sponge Iron Ltd., Salem c) Bellary Steel, Karnataka. d) Kumar Metallurgical Co. Ltd., Hyderabad. e) HEG Ltd. f) Raipur Alloys (MP)	0.16 0.03 0.03 0.03 0.06 0.03
2.	SL/RN-TDR	IPITATA Sponge India Ltd. Joda	0.24
3.	SL/RN-Lurgi	Bihar Sponge Iron Ltd., Chandil Prakash Industries Ltd., Champa (M.R.) Nova Steel (A.P.)	0.30 0.15 0.15
4.	ACCAR	Orissa Sponge Iron Ltd., Keonjhar	0.12
5.	CODIR	a) Sunflag Iron & Steel Ltd., Bhandara b) Goldstar Steel & Alloys Ltd., Vizianagar	0.15 0.22
6.	Jindal	Jindal, Raigarh	0.20
		Total	1.87
B	Gas-Based		
1.	Midrex	a) Essar Gujarat Ltd., Hazira (3 units of 0.44) b) Nippon Denro Ispat Ltd., Raigad.	1.32 1.00
2.	HYL III	Grasim, Raigad	0.75
		Total	3.07
		Grand Total (A + B)	4.94

Godavari in south. Nippon Denro Ispat Ltd (NDIL) at Raigad is the single largest direct reduction plant in the world with 1.0 million tonnes capacity. The first coal-based direct reduction plant based on SL/RN process was set up by Sponge Iron India Ltd (SIIL) at Paloncha (Andhra Pradesh). Thereafter, many coal-based direct reduction plants employing different processes have come up/are comming up/are planned to be installed. The list of such plants is given in Table 10.13.

It may be observed that coal-based plants account for nearly 40% of the total installed capacity of sponge iron plants. There will be still shortfall of 3.8 million tonnes and 9.3 million tonnes of sponge iron as feed stock for mini-steel plants in the country for 1995-96 and 2000 -2001, respectively. It is, therefore, essential that an additional capacity of 10 million tonnes of sponge iron is created between 1996 and 2000 to meet the projected demand of secondary steel sector. This can be only met by setting up new coal-based direct reduction (sponge iron) plants in the country.

10.3 ALTERNATIVE ROUTES OF IRON MAKING

It is a well-known fact that conventional blast furnace and basic oxygen process route for iron and steel making are highly capital intensive. An additional handicap is the limited resources of good coking coal in India. The DR-EAF route, though less capital intensive, needs substantial amount of electric power of which there is major shortage in India. Many new routes of iron and steel-making are claimed to be answer to these problems. Smelt Reduction Process, Kawasaki Process, Plasma Smelting Process, Mini-blast Furnace processes, etc. are of worth consideration in Indian context.

10.3.1 Smelt-reduction Process

Development of smelt reduction processes as an alternative to blast furnace route has gained significant momentum in recent years. Based on the number of stages, the process can be classified into three categories.

10.3.1.1 Single Stage Process

The entire reaction involved in iron making is carried out in a single reactor where coal, iron ore and oxygen are fed. The gases evolved from the molten bath are post-combusted to very high degree and major portion of the heat of post-combustion is transfered back to the molten bath. The FLPR process developed in Russia is a single-stage process. This process accepts iron ore and coal without, or with marginal, pretreatment (agglomeration) and is less capital intensive but coal and oxygen requirements are high. It has not yet found commercial application.

10.3.1.2 Two-Stage Process

Hot pre-reduced ore having low degree of reduction (FeO) is charged into smelting reactor along with coal and oxygen/preheated air. The gas evolving from the molten bath is post-combusted by oxygen/preheated air to a moderate degree (50%) inside the smelter. The post-combusted gas cooled to 900°C is used for preheating and pre-reduction of iron oxide to FeO either in a shaft or fluidized bed reactor. Hi-smelt process developed by Klockner (Germany) and GRA (Australia) is based on this process. This process is generally complicated and involves high pressure operation.

10.3.1.3 Three-Stage Process

This process includes an additional step of gas reforming between smelting and pre-reduction reactors. The conditioning of the hot gas evolving from molten bath and gasification of coal are simultaneously carried out in upper part of the smelting reactor. The conditioned gas is used to reduce iron oxide in a shaft reactor. The Corex process developed by Voest Alpine of Austria represents the three-stage process. The process uses cheaper non-coking coal and generates less fines and effluents than conventional BF route because coke oven and sintering causing environmental problems are not needed in this process. A commercial plant of 300,000 tpy capacity is already in operation in Pretoria, South Africa based on this process. M/s Jindal Vijaynagar Steel Ltd. (JVSL) is setting up a 1.25 million tonnes/year steel plant based on this process. Iron ore from Bellary-Hospet will be used in this plant.

10.3.2 Mini -Blast Furnace (MBF)

China is able to produce iron and steel at less cost by employing mini-blast furnaces with lower energy consumption, cheaper labour and higher per head output. China is employing mini blast furnaces ranging in volume from 150-700 m^3 for a 0.5 million tonnes/year plant. These furnaces are operating with high rate of coke injection (70-200 kg/t of hot metal) which brings down coking coal requirement to 700 kg/t of hot metal. M/s Malvika Steel Ltd. (MSL) is setting up a 1.4 million tonnes/year steel plant at Jagdishpur in Uttar Pradesh. The Company will have 2 mini-blast furnaces of 350 m^3 capacity and each furnace will be supported by two sintering plants and two L.D. converters of matching capacity. Sri Vasavi Steel Ltd. is also adopting Chinese technology, i.e. Mini-Blast Furnace - BOF - CC route for its 0.2 million tonnes/year plant at Vishakhapatnam.

TISCO, in collaboration with M/s Korf-Stahl AG, Germany had developed mini-blast furnaces for producing steel at cheaper cost. Tata Korf MBF technology is low cost operative and less capital intensive. M/s Sesagoa produce pig iron adopting this technology. Four MBF of Tata Korf origin are in operation in India.

10.3.3 Iron Making Without Agglomeration

Plasma reduction and smelting process and Kawasaki process accept feed as ore fines and reductant as low grade coal[26]. The application of thermal plasma for production of iron and steel as an alternative process is based on (a) its independence of oxygen potential, (b) its flexibility in using even low grade coal, (c) high energy density with smelter reaction vessel and (d) excellent pollution control. Because of points c and d, there is greater scope for decreasing capital cost as compared to BF/BOF technology. The major limitation in adoption of this technology is high energy cost.

Kawasaki Steel Corporation through pilot scale test work has made a breakthrough in production of iron by smelting/reduction of iron ore fines. The process uses a furnace which is of blast type and has two portions. The upper half is a pre-reduction zone and the lower half a smelting zone. Fine ore is fed into the reduction zone where CO at high temperature emitting from the smelting zone pre-reduces the ore up to 60 to 70%. The main smelting furnace in which coke is charged from the top has dual tuyers located near the bottom of the furnace. The lower tuyer is used for injection of hot blast of air/oxygen and pre-reduced ore is injected through the upper tuyer into the high temperature zone (1450 - 1500°C). Today's blast furnace burden employing 80% sinter adoption of Kawasaki process will save millions of rupees as it bypasses costly sintering/pelletisation process. Research studies are continuing to optimise operating parameters for commercializing the process.

10.4 TYPICAL FLOWSHEETS

10.4.1 Iron Ore Concentrator at Savage River Mines, Tasmania, Australia

The r.o.m. is crushed to -200 mm size employing 1350x1850 mm gyratory crusher (400 hp). The crushed product is sent to 88,000-100,000 tonne stockpile through conveyor and stacker system. Ores reclaimed from the crusher stockpile are weighed on loaded cells and pass over a magnetic iron sensor and thereafter fed 9.5 m dia x 3.6 m long autogenous grinding mill (2 x 3,000 hp) having 9 mm grate openings. The mill discharge passes over 122.4 x 6.0 m rubber-decked vibrating screen having 25 x 3 mm slotted openings. Oversize is recirculated over a magnetic belt pulley and the magnetic fraction being returned to the autogenous mill, and the non-magnetic fraction containing about 2% magnetic iron is rejected. The screen undersize is subjected to low intensity wet magnetic separation employing five 0.9 m dia x 2.4 m wide double-drum magnetic separators. The non-magnetic fraction amounting to 45% by weight and containing about 1% magnetic iron is rejected. The rougher magnetic concentrate assaying 60% iron is screened over eight 0.75 m x 1.2 m inclined stationary screens having wedge bar media and 8 mesh wide openings. Screen oversize returns to the autogenous mill and

TABLE 10.14: SAVAGE RIVER PLANT

Product	Wt.%	Assay%			
		Mag.Fe	Total Fe	SiO_2	Dist.% Mag.Fe
Concentrate	48.4	66.7	68.9	1.0	97.2
Tailings	51.6	1.8	--	--	2.8
Feed	100.0	33.0	--	--	100.0

Size of the concentrate : 100% - 200 mesh/87% -325 mesh,
Blain No. (cm^2/g) - 1600-1800.

Plant capacity : (Million tonnes/year)
r.o.m. : 4.8
Concentrate : 2.5

undersize goes on to the fine grinding circuit. The above circuit has two mill lines. The undersize from fine screens, per mill line is fed to thirty-two 300 mm dia cyclones operating in closed circuit with a 3.84 m dia x 8.7 m long 300 hp rubber-lined ball mill using 40 mm balls and operating at 76% critical speed with 300% circulating load. The cyclone overflow (11% solids pulp density) passes on to a 15 m dia x 4 m high hydroseparator and overflow from hydroseparator passes to tailing thicker. The underflow at 45% solids is pumped via pulp distributor to eight 0.75 m dia x 2.4 m wide to triple-drum magnetic separator. The non-magnetic tailings also join tailings thickener and amount to 2-4% by weight. The cleaned magnetic concentrate passes over eight 0.75 m x 1.2 m flat/inclined fine screens equipped with rapping devices and having 0.015 mm openings. Stainless steel fine screen media is of wedge bar type. Screen oversize returns back to the cyclone. The undersize product (43-48% by weight) is essentially all -200 mesh assays 68-69% Fe and accounts for 97% of the magnetic iron in the r.o.m. This product is thickened in a 18 m dia thickener. The underflow is stored in two agitated slurry tanks (12 m x 13.5 m). Slurry from the tank passes on to 7.5 m x 7.8 agitated slurry tank where solids are adjusted to 60% by weight and from where the slurry is pumped in a 85-km long slurry pipeline to the pelletising facility. Four 600 hp tirplex main plunger pumps located at the feed end are used for slurry pumping. Line pressures range between 1600 and 1800 psi and pulp velocities are 4-6 fps. The tailings from the magnetic separator are cycloned in four 0.81 m dia cyclones for removal of coarse material. The cyclone overflow, the cleaner non-magnetic tailings and hydro-separator overflow are all fed to 60 m x 5.7 m tailing thicknener. The cyclone underflow and the thickener underflow are pumped to tailing pond by four 300 mm x 250 mm centrifugal pumps. The metallurgical results are given in Table 10.14.

Ore mineralogy: **Medium-grained magnetite associated with quartz** **Instrumentation:** The crusher and concentrator operations are controlled from a central control room. The plant data, such as weight of discharge from crusher, content of magnetic iron in the feed, mill feed rate, regrind power draw, cyclone feed density, hydroseparator interface levels, etc. are regularly logged. Similarly, pulp density of thickened concentrate prior to pumping to the slurry line is also recorded.

10.4.2 Iron Ore Concentrator At Empire Mine, Michigan, (USA)

The r.o.m. is processed in 24 lines. The capacity of the plant is 18 million tonnes of r.o.m. per year with a production capacity of 5.94 million tonnes of concentrate having 10.5% moisture. The concentrate is pelletised in a grate kiln pelletising plant. The ore is a fine-grained magnetic cherty iron formation with magnetite as the primary ore mineral. The other associated minerals are hematite, goethite, siderite, iron silicates, chert and quartz.

The process consists of crushing, two-stage autogenous grinding, magnetic separation hydraulic separation, flotation and dewatering. The grinding system is reported to represent the first application of a two-stage fully autogenous grinding circuit for fine grinding of iron ores.

Crushing : The r.o.m. is dumped by trucks from two sides directly into a 1.5 m x 2.23 m gyratory crusher driven by 5,000 hp motor (capacity : 4,000 tph). The crushed ore (-225 mm) is conveyed to a conical surgepile (270,000 tonne capacity).

Grinding: The crushed ore is fed by apronfeeders to 21 primary autogenous mills (7.2 m x 2.4 m) with grate discharge system. The mills discharge to double-deck screens having screen openings 15 mm at feed end, 25 mm at discharge end for upper deck, and 2 mm for bottom deck. The -2 mm product is pumped to 21 DSM screens (1 mm openings) of 1 m^2 screen area. The screen under size (-20 mesh product) is pumped to cobbers. The cobber concentrate and pebble mill discharge are classified by sixteen 250 mm cyclones and five 375 mm cyclones operating at 30 psi. The cyclone overflow contains 90% material finer than 500 mesh. The cyclone underflow passes on to pebble mills (sixteen mills of 3.75 x 7.2 m size and five mills of 4.65 x 7.2 m size).

Concentration: The DSM screen underflow is subjected to magnetite separation employing five 400 mm x 2,400 mm three drum magnetic separators in each line (925 - 890 gauss : permanent magnets). The cyclone overflow from the pebble mills are fed through magnetizing coils to 11.4 m dia siphonizer. The sized concentrate from siphonizer is cleaned by two-drum magnetic separators (777 gauss : 900 x 1,800 mm and 900 x 2,400 mm size). The cleaner magnetic concentrate are further cleaned by flotation employing 60 cubic feet cells and 500 cubic feet flotation cells. Flotation is carried out at 35% solids pulp density employing 0.025 lb/t primary acetate salt of primary aliphatic ether amine for silicate flotation and 0.04 lb/t of hydrogenated alcohol as frother. No reagent conditioning is required and flotation is carried out at natural pH (8- 8.5). The final concentrate analyses 66.6% Fe and 6.5% SiO_2. The flotation concentrates are thickened to 70% solids and pumped to slurry tanks for blending and storage prior to filtration.

Filtration : Eight disc filters (7.8 m dia) are employed for filtration of concentrate to obtain product containing 10.5% moisture. Two-stage wet vacuum pumps are used to provide 25 to 26" Hg vacuum. The filtered concentrate is conveyed to pellet plant or for storage. The plant metallurgical results are given in the Table 10.15

Controls : Conveyors are interlocked and provided with speed switches and emergency pullcords. Bins are equipped with high and low level indicators and conveyor transfers use high level probes. Pebble mills are operated to a pre-set power drawn by controlling the rate of pebble addition. Gamma rays are used to determine pulp density of pebble mills and filter feed. Samples are taken hourly. Chemical and moisture analysies of concentrates are done by XRF and wet analytical method. Automatic samplers are employed for taking samples.

10.4.3 New Iron Ore Concentrator at Kiruna, Sweden

The ore from the mine contains apatite as one of the main contaminants. The r.o.m. on an average assays 58% Fe and 1% phosphorus.

TABLE 10.15: METALLURGICAL RESULTS

Product	Wt.%	Assay%		Recovery %	
		Total Fe	Mag.Fe.	Total Fe	Mag.Fe
Dobber conc.	48.77	50.2	44.1	71.8	95.6
Siphoniser conc.	36.9	61.9	58.8	67.0	96.4
Cleaner Mag.Conc.	35.1	64.1	61.8	66.0	96.4
Flotation Conc.	32.2	66.5	63.9	62.8	91.4
Plant feed	100.0	34.1	22.5	100.0	100.0

Magnetite is the main iron-bearing mineral. In the concentrator, there are two parallel process lines, each of 350-400 tph capacity. The -100 mm crushed product from the mine site is transported by conveyor to two surge bins (3500-tonne capacity for each bin). The raw material drawn out of bins alternately in order to reduce segregation is conveyed to concentration section for primary grinding. The primary grinding is carried out in two 6.5 m diameter x 5.4 m long autogenous grinding mills (4500 kW) at 85% critical speed. The mill discharge passes into a trommel which removes 10-35 mm fraction for use as pebbles in the second grinding stage and the -10 mm fraction is pumped to a spiral classifier and from the classifier, coarse material is recycled to the autogenous mill while the fine product passes to primary magnetic separator. The rougher concentrate from the primary separator is fed to pebble mills (two 6.5 m x 8.5 m, 4500 kW mills). The excess of 10-35 mm material is crushed in two 1-m cone crushers and recycled to the autogenous mill. The discharge from the pebble mills passes onto a trommel screen, any +4 mm material recycled to the autogenous mill while -4mm material is pumped to hydrocyclones. The cyclone underflow is fed back to pebble mill. The cyclone overflow passes to two pre-separation stages, each in four group of magnetic separators (1.2 mD x 3.0 mL drums) before passing to flotation section where apatite is floated out. The apatite float passes through magnetic separator to recover entrapped magnetite before sending to tailing thickener, and entrapped magnetite is fed back to the flotation cells. The flotation tailings (magnetite portion) passes on to a two-stage magnetic separation before storage and blending ahead of pellet plant. The final concentrate analyses 68% Fe and 0.025% phosphorus.

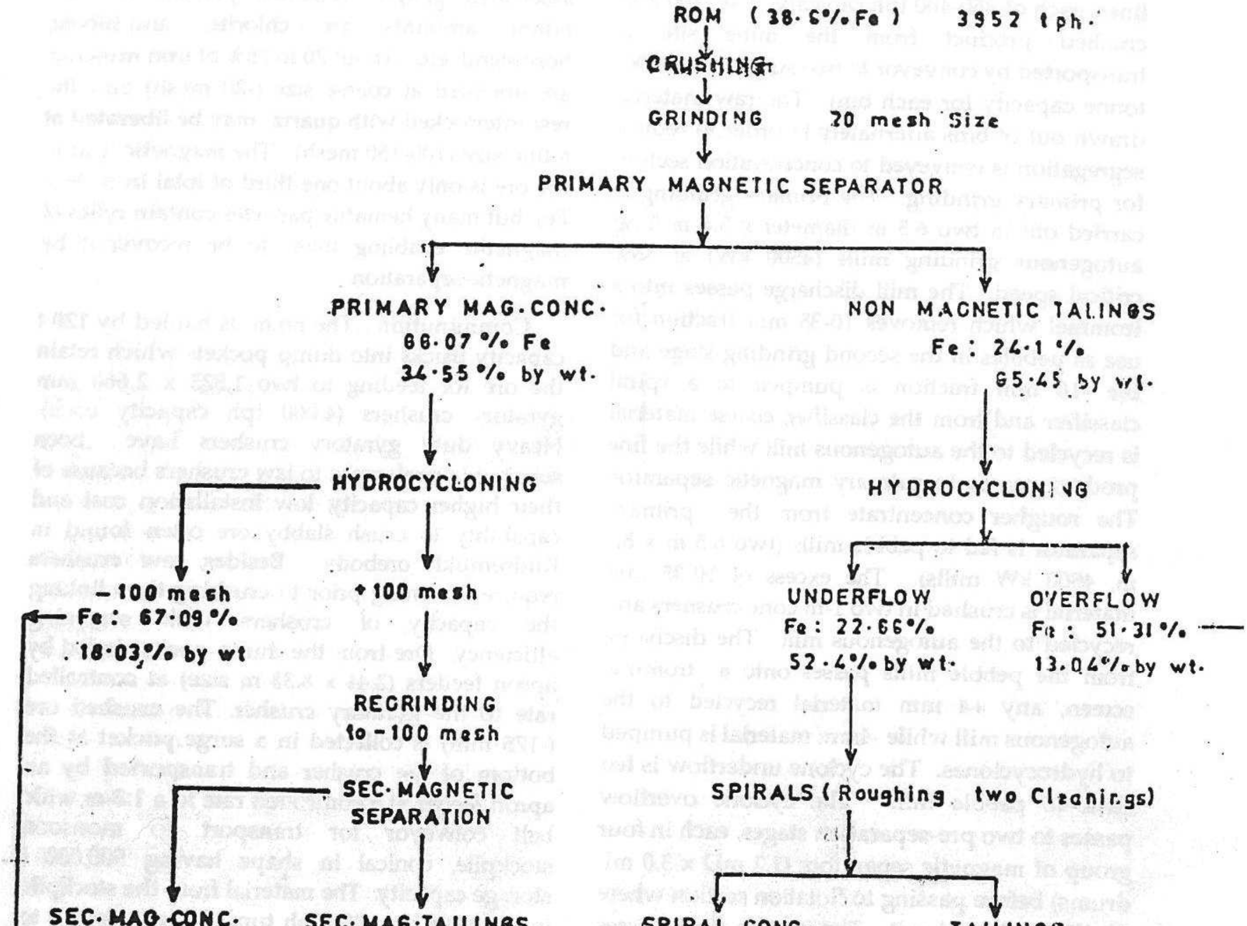
10.4.4 Iron Ore Concentrator at Kudremukh (KIOCL), India

The plant has the rated capacity for production of 7.5 million tonnes per year of high grade iron ore concentrate from 22.5 million tonnes of ore. The ore contains magnetite, hematite, goethite and limonite associated with quartz, the main gangue mineral. The other associated gangue minerals present in very minor amounts are chlorite, amphibole, hornblend, etc. About 70 to 75% of iron minerals are liberated at coarse size (-20 mesh) and the rest interlocked with quartz may be liberated at a fine size (100-150 mesh). The magnetic iron in the ore is only about one-third of total iron (39% Fe), but many hematite particles contain relics of magnetite enabling them to be recovered by magnetic separation.

Comminution : The r.o.m. is hauled by 120 t capacity trucks into dump pockets which retain the ore for feeding to two 1,525 x 2,660 mm gyratory crushers (4,000 tph capacity each). Heavy duty gyratory crushers have been selected in preference to jaw crushers because of their higher capacity, low installation cost and capability to crush slabby ore often found in Kudremukh orebody. Besides, jaw crushers require screening prior to crushing thus linking the capacity of crushers with screening efficiency. Ore from the dump pocket is fed by apron feeders (2.44 x 8.33 m size) at controlled rate, to the gyratory crusher. The crushed ore (-175 mm) is collected in a surge pocket at the bottom of the crusher and transported by an apron feeder at a controlled rate to a 1.8-m wide belt conveyor for transport to monsoon stockpile, conical in shape having 500,000 t storage capacity. The material from the stockpile is removed by 6,000 tph tunnel apron feeder to 1.8 m wide conveyor belts. Ores from these belts are screened at 100 mm size.

Coarse and fine fractions are separately collected by 1.8 m wide conveyor belts and both of which convey the ore to a tripper conveyor system feeding 8 silos. Ore from the storage silos is fed by a separate conveyor to four 9.6 m dia x 4.8 m length autogenous mills, using about 5% of grinding balls. The discharge from each mill is fed by chutes to 8 scalping screens to separate +4 mesh particles which are fed back to the mill and screen undersize is pumped to 96 sizing screens and oversize goes to the mill and screen undersize (-20 mesh mostly) is pumped to twenty-four triple-drum (1.2 m dia x 3.05 m

Fig. 10.9 : Flowsheet of Iron Ore Concentrator at Kudremukh, Karnataka.



length) primary permanent magnetic separators (950 gauss measured 50 mm from the drum surface) operating in counter current mode. The primary magnetic concentrate is subjected to classification by four 650 mm krebs hydrocylones to make separation at 100 mesh size. The coarser fraction (classifier underflow) is stored in a agitated slurry tank for regrinding to -100 mesh size (60% -325 mesh) in five 4.25 m dia x 10.5 m length ball mills and then fed to fifteen secondary magnetic separators of same size as for primary separators. The tailings from primary magnetic separators are fed by gravity to thirty-two 900 mm desiliming cyclones for dewatering and removal of fine material prior to treatment in spirals. The cyclone underflow goes to 728 double start (3.0 tph) rougher spirals (5 turns with 445 mm pitch), 336 and 336 double start cleaner and recleaner spirals. The final tailings from spiral are dewatered by twenty 650 mm cyclones. The cyclones overflow are fed to two 110 m dia tailing thickeners which also collect tailing from secondary magnetic separator. The underflows from thickener and cyclone are pumped to the tailing pond. The final (recleaner) spiral concentrate is stored in agitated slurry tank from where it goes to four ball mills for regrinding to -100 mesh size. The reground spiral concentrate and secondary magnetic concentrate are cycloned employing 24 (12+12) 650 mm hydrocyclones. The underflow goes to regrinding ball mills and the overflow constitutes the final iron ore concentrate. The concentrate is fed to 264 rapifine double stage DSM screens (610 mm wide screen with 0.1 mm openings) to ensure -100 mesh product for trouble-free transportation through slurry pipe lines. The screen undersize is pumped to two 36 m . dia concentrate thickeners. The screen oversize is sent to regrind ball mills. The thickener overflow is reclaimed for process water through tailing thickener and underflow is stored in slurry tank where it is continuously agitated to keep the particles in suspension. Slurry is drawn from the storage tanks and pumped through eight centrifugal pumps along 66 km pipelines at a pulp density of 60% solids to Mangalore. At Mangalore end, the slurry from the storage tank is fed to 18 vacuum disc filters (each filter contains 10 discs of 2,700 mm dia). The filtered cake containing 8-9% moisture is sent to pelletisation plant at Mangalore. The process flowsheet is shown in Figure 10.9.

The iron recovery is about 60% (wt.% yield 36-37%). The plant management is now planning to clean rougher spirals concentrate by froth flotation replacing spirals in cleaner and recleaner circuits in one of the four lines. Initial experimentation has yielded encouraging results and if commercial trials are found successful, spirals may pave the way for flotation to take over. KIOCL is planning to reduce silica content below 2% in the concentrate.

The fine concentrate with 9% moisture is mixed with hydrated lime and thereafter fed to a 7.5 m dia disc pelletiser. The green pellets are fed through roller feeder to Lurgi Straight grate furnace for induration. The KIOCL concentrate and pellets are exported to over 22 countries(China, Turkey, Japan, Taiwan, Iran, Indonesia, Malaysia, Bahrain, Australia, Hungary etc.) M/s ESSAR, M/s Vikram Ispat are also buying KIOCL pellets. An important development is the greater demand of KIOCL concentrate for use in sintering as it has been established that blending KIOCL concentrate with iron ore fines from other sources improves inter-productivity.

The chemical composition of concentrate and pellets produced by KIOCL at its concentrator at Kudremukh and pelletisation plants in Mangalore is shown in Table 10.16.

TABLE 10.16 CHEMICAL COMPOSITION OF CONCENTRATE AND PELLETS

Constituent	Assay%		
	Concentrate	Pellets	
		B.F. Grade	DRI Grade
Fe	67.0	65.5	66.5
FeO	13.0	0.5	0.5
SiO_2	3.5	3.5	2.75
Al_2O_3	0.5	0.5	0.5
S	0.01	0.02	0.015
P	0.03	0.03	0.03
TiO_2	0.15	0.15	0.15
Combined water	1.0	--	--

Contd..

Table 10.16 (Concld.)

Other metals	0.2	0.2	0.2
Moisture	9.0	2.0 (October to May) 6.0 (June to September)	--
Basicity	--	0.4 - 1.0	--
$SiO_2 + Al_2O_3$	4.0	4.0	3.25

10.4.5 Sintering Plant of M/s Krupp Stahal, Reinhausen, Ag, at Duisburg, Germany

The sinter strand in the plant is one of the largest strands in Germany. The installed capacity of the strand is 16,000 tpd with sinter productivity of 40 $t/m^2/24$ hr.

Proportioning: The sinter feed is hetrogenous in character as ores and fines from different countries constitute the raw material for ore mix. Therefore, thorough mixing before storage is necessary. Iron ores, fine concentrates, pellet-fines, etc. are stockpiled in separate beds (4 beds each with 200,000 t capacity) where they are thoroughly mixed and then transported to ore bunkers (4 in number each with 250 m^3). The proportion of -150 mesh material in the ore mix is about 15-20%. Coke breeze, sinter return fines, lime, limestone, olivine, siliceous iron ores and LD slag are stored in separate bunkers. Weigh table feeders are located under each bunker to control the feed rate to belt conveyors located underneath.

Mixing: The different mix components are mixed and moistened in a mixing and re-rolling (micro-pelletising) trommel (4 m dia x 24 m length) having 1,300 tph capacity. The filling degree and inclination of the trommel are 20% and 40°, respectively. The total mixing (retention time) is about four minutes.

Ignition and Sintering : The sintering strand is Dwight Lloyed type having rotary cooler (length : 100 m, width : 4m, bed height : 600 mm) with 21 double-wind boxes, 157 pallets equipped with grates moving on rails mounted on metal structure and sealed by stationary plates with adjustable springs. The mix to be sintered containing 5.5 to 6% moisture is discharged from trommel into a feed hopper mounted over an electric weighing system and from there it is discharged by a variable speed feed roller on to the strand. Prior to mix charging, a hearth layer (50 mm high) of 12-18 mm sinter lumps is laid on the pallet to prevent the sticking of sinter with the pallet and to protect the pallet from burning. The mix is then ignited as it passes under ignition hood equipped with 12 gas burners, six on each side of the hood (20 m in length). The ignition is done at 1,250°C for about 5.0 minutes. The flame progresses over the entire length of sintering zone by sucking in air through the bed.

Two radial blowers driven by 6.2 MW synchronous motor (990 rpm) create a suction of 1,400 mm water gauge. The height of the chimney is 184 m. The sinters discharged from the strand fall on a spiked crusher for crushing to -200 mm size.

Hot Screening and Cooling: The crushed product is screened over a 4 m x 6.5 m openings in 19% of the screen surface having 1,200 tph screening capacity for hot screening. The height of the hot material over the screen is about 180 mm. The screen undersize is all -5mm and is produced at a 245 tph rate. The screen oversize (+5mm) passes to a 35 m dia rotary cooler (pressure type) having cooling capacity of 960 tph (cooling surface : 380 m^2, cooling : 1 hour, height of material : 1.5 m). The air for cooling is supplied by six blowers, each supplying 5.5m^3 air per minute. The cooler cools down the sinter lumps having 800°C. The discharge from the cooler is crushed in a roll crusher to -50 mm size and screened to reject -5 mm material (sinter return fines) and obtain hearth layer material (12-18 mm). The finished sinter goes to blast furnace for iron making.

Dust Collection : Waste gases are processed in a high efficiency electrostatic precipitator and thereafter discharged into atmosphere (150 mg dust/Nm^3 in the dedusted gas). The cooling air is dedusted in cyclones. A collection duct system takes care of dusts from sinter returns, hearth layers, etc. The dust laden air (20 g/Nm^3 is dedusted in an electrostatic filters to ensure almost a clean (120 mg/Nm^3, i.e. 70 mg/m^3) effluent air.

Process Control: (i) Moisture control in the sinter mix is done with the help of neutron probe. Water is added in the trommel at two points in the form of spray, first near feed end (major portion) and then near discharge end (ii) Burn through point is controlled with continuous measurement of highest waste gas temperature in the wind boxes (iii) Feed rate of different mix constituents is controlled by belt speed of conveyor having weightometer. (iv) Colour T.V. in the control room flashes the photo of sinter discharge with the help of photo-camera fitted in the discharge zone. Light yellow colour, dark yellow colour and deep yellow/red colour indicate proper sintering, incomplete sintering and over sintering, respectively. Operator adjusts the coke/burning fuel rate accordingly. (v) Mixing of different ore ingredient is done by rotating excavators and elevators before transporting to bunker and bins. The size and chemical composition of sinter mix and sinter are shown in Table 10.17. The other important data are given in Table 10.18.

TABLE 10.17: SIZE AND CHEMICAL COMPOSITION OF SINTER MIX (WITHOUT COAL) AND SINTER.

Constituent	Chemical composition Assay %		Size composition of sinter mix	
	Sinter mix	Sinter	Fraction/ mm	Wt.%
Fe	51.4	57.1	+10	0.7
FeO	5.95	9.0	-10 +5	10.8
Mn	0.15	0.17	-5 +2	22.4
O	0.05	0.06	-2 +0.5	23.0
SiO_2	4.76	5.29	-0.5 +0.1	24.9
Al_2O_3	1.14	1.27	-0.1	18.2
Total				100.0
CaO	8.49	9.63	--	--
MgO	1.69	1.89	--	--
Basicity	--	1.82	--	--

10.4.6 The New Pelletisation Plant at Kiruna, Sweden

The capacity of the new pellet plant is 4 million tonnes of pellets per year. The major advantage of magnetite pelletisation is that its oxidation, being exothermic, supplies 62% of the energy need. The concentrate slurry and other additives are mixed in a tank and then passes on to four Sala pressure filters with the help of 2.4 m wide x 18 m long Roxonbelt feeder. The filter feed is transported to a buffer bin from which it is fed into a mixer together with a binder. After mixing, the concentrate is transported to bins in balling area. The concentrate from the bins is fed into four balling drums (5 mD x 13 mL) reported to be the biggest in use worldwide in which green balls of 10-12 mm size are formed. The drums operate normally at 7° inclination. Green pellets are screened, undersize pellets being returned to the bins. Correctly sized pellets are transported to Allis chalmers grate kiln induration system. A feeder belt which moves from side to side distributes the green balls onto a 4 m wide roller screen from which they are unloaded onto the travelling grate. At this stage, the green pellets contain 8.5 to 9% moisture. The green balls are dried in a controlled manner, otherwise quick escape of moisture may cause cracking. The drying is carried out in two stages, beginning with up draught drying (UDD) in which hot air from the last stage of cooler is used, followed by down draught drying (DDD). Then the pellets reach tempered preheat (TPH) zone where they are exposed to a down draught gas flow. The last stage of grate is the preheat (PH) zone where gases from the kiln heat the balls. The preheated pellets are then fired in 33.5 long kiln lined with refractory brick at a constant temperature in the last 20 m of the kiln. Coal is the main fuel. Oil is used at start-up and as secondary fuel. The annular cooler transports the pellets across three cooling zones. In each cooling zone, sufficient air is supplied for cooling. After cooling, the pellets are discharged into a product kiln.

TABLE 10.18: OTHER IMPORTANT DATA

(a) Fuel consumption (kg/t sinter)	56.0
(b) Sinter returns (kg/t sinter)	192.0
(c) Sinter Strength i) ISO (+6.3 mm)	85.1%
ii) LTB (-6.3 mm) kg/t Sinter	47.5
iii) -5 mm material in sinter	4.0%
(d) i) Coke (kg/t of hot metal in blast furnace)	468
ii) AiL (kg/t of hot metal) in the blast furnace)	31
Ore mix average size	3.56 mm

REFERENCES

1. Devaney F.D., 'Iron Ore' SME Mineral Processing Handbook, Volume 2 -1985.

2. Amanullah, "Report on Kudremukh Iron Ore Company Limited (India), (Unpublished), June 1978.

3. Wills B.A, 'Mineral Processing Technology', 1979.

4. Carol Iron Ore Project, Canada, Mining Engg., December 1978, p. 1639, Mining Magazine November, 1986, p. 419.

5. Production of Super-Grade Iron Concentrate at Malmberget Operation (Sweden), Mining Engineering, April, 1982, p. 1341.

6. Minerals Year book USA, 1992, p. 752

7. Column Flotation Cells, Mining Magazine, June, 1991, p. 383- 389.

8. Xizhang Zeng "A New Method of Sintering, Step-by-Step Box Sintering Process & its Equipment (China), ISBA, Bhubaneshwar-1992, p. 81-87.

9. Ball DF, Dartnel J, Davison J.G. Weve A & Wild R, "Agglomeration of Iron Ore, 1973".

10. Mishra DD, "Pelletisation of Iron Ores and its Scope in India", IIT, Kharagpur.

11. Davis CG & McFarlin J.F., "Direct Reduction Technology and Economics" Iron - Steel Making, 1982, Vol. 9, No. 3.

12. Kortman A Heinrich & Ritz J. Volker.

"State of Test Methods Based on ISO Standards for Physical Testing Iron Ores for Blast Furnace and D.R. Feed Stocks. ISBA, Bhubaneshwar, 1992".

13. Meyer Kurt, " Pelletisation of Iron Ores " 1980. Verlag Sthleisen MB. H. Dusseldorf (Germany).

14. Amanullah & Satyanarayana K "Beneficiation of Ferrous Ores", National Seminar on Mineral Benficiation at Nagpur, December, 1986.

15. Basu SK & Das SC, MECON, Ranchi, "Processing of Iron Ore in India".

16. Inplant Study Report (unpublished) pertaining to Inplant Studies Conducted by IBM Officers in 1990-91.

17. Investigation Reports (unpublished) Based on beneficiation studies conducted by IBM on many low grade iron ores from Indian deposits.

18. Information received from N.M.D.C., Hyderabad (India)

19. Indian Minerals Year book (IBM's Publication), 1994.

20. Das SR, Agrawal SSC & Goel P.K. "Sintering Plants in India, their Problems, Remedial Measure, ISBA, Bhubaneshwar (India), December, 1986.

21. Iron & Steel Review- Nov/December 1988-89.

22. Roy SC, Dey DN & Ray H.S., Some Aspects of Iron Ore Sintering, Iron & Steel Review - June, 1992.

23. Modi U.K., "Coal-Based DRI Industry in India" Iron & Steel Review, Annual 1992.

24. Ropfle T. John, Battles D Donald "Gas Based Direct Reduction in a Changing Indian Steel Industry"., Iron & Steel Review, Annual 1992.

25. Ray AK, Prasad KK, Choudhary PK & Aeson S.M. "Iron Making by Smelting Reduction for Analysis under Indian Context", Minerals & Metals Review December, 1993.

26. Amanullah, "Report on Advanced Training in the field of Mineral Beneficiation (Non-Coal) and Agglomeration of Ferrous Ore Fines & Beneficiated Products in Germany (Unpublished), 1985.

27. Brewis Tony, "LKAB's Kiruna Developments KUJ 2000 and SAK 2000 " Mining Magazine August, 1994.

28. Minerals & Metals Review, Annual 1992-93.

11.0 Future Outlook

11.1 INTRODUCTION

Like other industries, steel industry also experiences upswing and downturn in a cyclic fashion depending on many unpredictable and variable factors in global and local markets covering econo-political environments. And it is the iron ore which is directly linked with steel industry. So fluctuations in prices and production of steel influence iron ore production and its pricing. Fortunately, it is now the period of upswing which is being experienced since 1992-93 though iron ore prices fell during this period. World leading producers of iron ore are China, CIS (former USSR), Brazil, Australia, India, USA, Canada, South Africa, Sweden and Venezuela. Majority of producers are also big players in export market.

It is very difficult to forecast iron-steel market for a longer period, say 10-20 years as factors controlling the market change unpredictably. So, forecast discussed under this Chapter is only up to AD 2000. However, the same has been made up to 2010-11 for local market (India).

11.2 WORLD SCENARIO

11.2.1 General Information

During 1980-88, the global iron ore market came down heavily on the reason of imbalance in supply and demand for the ore. During the last decade, enough investments were made in iron ore mines which had resulted in supply surpassing the demand. The situation was further aggravated by the expectation that steel production would grow in late 1980s which did not take place. As a result, supply of iron ore in the global market kept on rising in the stagnated steel market which in turn resulted in contraction of iron ore demand. It is this imbalance in demand-supply which led the price-cut by the buyers on the suppliers. It is surprising that accumulated price cuts during 1983-88 reached the level of 32%.[1] But towards the end of 1988, the world economy started recovering with sign of strong growth in the international steel industry. As a result of chain effect, iron ore stock in producing countries depleted, and iron ore trade and steel production reached an all-time high in 1989. Export of iron ore during this buoyant period (1989-91) could secure price increase of about 40%, and shipment volumes also would have remained at the peak when mines were also working at practically full capacity, having slim stockpiles. This happy period did not last long, as from the end of 1991 global steel industry started moving towards decline as the global economy experienced go-slow specially in developed market economy countries.

Again from 1993, world market for iron ore resumed its cyclic growth. This time, the market received stimulation mainly from Asian market, the leader of which was China where steel demand became buoyant. As a result, world iron ore trade enjoyed a happy period during 1994. Major iron ore suppliers reported substantial pressure on world shipping schedules, and reduction in iron ore stocks was reported, particularly during the second half of 1993 though the economic activities in Japan and European countries did not receive acceleration.[2]

11.2.2 Long-Term Outlook[3]

Various prognostications are available from experts, which underline that the long-term outlook for iron ore is bright. A few of them are discussed below :

(i) According to "Drewry Shipping Consultants", cyclic recovery in steel industry has already started and there could be a surge in iron ore trade in 1995-96 which has come true. Consequent to unification of European Countries (EU), steel industry in this region would get further boost. Till 1991, EU, USA and Japan used to import over 250 Mt of iron ore (74% of world trade). But now substantial increase in shipment would be seen in newly industrializing countries of the South-East Asia notably due to demands by this region's expanding steel plants. But Japan's buoyancy could not be seen at this moment. Import of iron ore in this region is expected to touch 25% more than what it was. And by 2000 year, Drewry anticipates that shipments to EU would fall by some 10 Mt from 135 Mt forecast for the year 1995. Japanese imports should range between 105 and 120 Mt while US import may hold steady at 15-16 Mt. For China, South Korea and Taiwan, shipment of iron ore could reach 70 Mt, an increase of 15 Mt compared with 1991 level. Export opportunity to the Eastern Europe for iron ore would not rise as that region is constrained by the limited capacity of steel plant and foreign exchange requirement coupled with some political unrest.

(ii) According to another forecast by the Companhia Valedo Rio Doce (CVRD) of Brazil, world steel production would grow as a result of steel production programmes of South Korea, Turkey, Iran and China, and DRI Steel Mills of Egypt, Saudi Arabia, Indonesia, Libya, Mexico and Algeria. As a result, demand of iron ore is expected to rise by 35 Mt from 1995 level. To cope up with this situation, over 60 Mt production capacity in the form of expansions and new additions of iron ore mines is envisaged in Canada, India, Venezuela, and Spain. All these capacities will be available between 1995 and 2000. The CVRD has further pointed out that during this period, supply and demand are expected to move closer till they meet around 400 Mt iron ore export in AD 2000. Further, Latin American Combine and South Africa will also increase their shares in the world production. Many East European countries are already reporting increase in output of steel.

(iii) In December, 1995, the annual iron ore meeting was hosted by Commodity Division of UNCTAD (United Nations Commerce, Trade and Development) at Geneva. The conclusions of this Meet revealed that iron ore market for 1995 was good and the next year (1996) will remain bright because of the increased economic activity in the developing countries. They showed more demand of iron ore by China and improved performance in the Eastern Europe. Present market scenario would have given price benefit to ore exporters for improved demand over last two years, but such thing did not take place. The UNCTAD reported that world trade in iron ore in 1994 reached 430 Mt which was 7.5 percent more compared with that in 1993 and this trend continued in the first half of 1995, because of higher steel demand in the developed and developing countries. World's consumption and production of iron ores rose by 3.4% each to 954.6 Mt and 970.7 Mt, respectively, in 1994 whereas the value of world trade increased modestly due to price fall. Pushed by lower interest rates and a cyclical resumption of investment, consumer confidence started restoring with a positive effect on aggregated demand and industrial output, favouring iron ore demand. Moreover, the ongoing adjustment of steel capacity in Europe may help to stabilise the level of steel output in the region at 800-805 Mt by 2000 year. The earlier consumption and forecast of iron ore and steel production is detailed in the Table 11.1.

Though world iron ore and steel production is expected to increase at least till 2000, the traditional steel-making regions - Europe, Japan and the USA - will have a lower share of total steel production(4).

11.2.3 Statistical Analysis(5)

Statistical data analysis of the world iron ore production shows that there is a tendency for its

TABLE 11.1 : WORLD PRODUCTION OF IRON ORE AND STEEL AND THEIR PROJECTION

(Million Tonnes)

Item	1991 Actual	1992 Actual	1993 Actual	1994 Actual	1995	2000 Projected
1. IRON ORE	943.9	915.1	938.2	970.7	NA	1005
2. CRUDE STEEL	731.1	723.1	730.1	723.3	NA	805

NA : Not Available

Source : 1. Minerals and Metals Review, 1994
2. Mineral and Export Intelligence, Dec., 1995

growth. It has been observed that the periodicity of iron ore production and demand, according to this variation period, makes 12 years and variation amplitude shows positive tendency of 1.04 Mt per year. It is recommended to take into consideration this regularity while predicting growth of iron ore and steel industry.

11.2.4 Iron Ore Prices[6]

Iron ore market was very weak in 1992 which resulted in a sharp drop in iron ore prices for 1993. The SNIM, Mauritania and Sallac (Uscnor group) settled a price (fob) for Mauritania ore, which was 12 to 15% less than the prevailing one at that time. And this trend was also applied to CVRD's ores which lowered the world's reference price by 11 percent for fines and 10 percent for pellets. This world iron ore pricing started rolling down to the extent that prices of 1993 were back to the level of 1981 which in real terms were the second lowest in the last ten years.

Though in 1994, fundamentals were good for iron ore pricing for sellers - high demands for most products and lower stocks, the price competition among suppliers once again favoured iron ore buyers. Even in this year, price drops of 9.5 percent for fines and 5.9 percent for lumps were experienced. Even in the case of pellets which were in short supply, sellers could not succeed in taking advantage of the tight market condition. In fact, selling competition for getting bigger market share was the main cause of the price fall vis-a-vis the strong position of grouped buyers. During 1995, position changed a little in favour of sellers in terms of stability of iron ore prices. It is expected that the price level may slowly improve by A.D. 2000 as Asian market has entered into boom phase especially due to China which may produce 120 Mt of crude steel by the turn of this Century. Further, higher prices for comparable materials, such as finished steel and scrap, justify higher iron ore prices.[7] But suppliers so far have not taken advantages "of one of the tighest-ever market condition".[7] Perhaps, sellers have accepted lower prices in exchange of market share.

11.3 ASIAN MARKET

Shift in the global pattern of steel production and consumption - towards Asia and away from the Central and Eastern Europe is forecast for the remainder of the 90s.[8] About 47 percent of the world's steel consumption will be seen in Asian countries compared with 34 percent in 1990 as per the study made by MEPS (Europe), Sheffield Steel Consultancy. During this period, production from these countries will rise from 31 percent of the world's total to about 40 percent, but in totality Asian countries will remain as net importers of steel and iron ore. For reasons of buoyant economic growth rates, these countries will remain hot well past this Century. However, Japan's recession may continue or at best will remain steady at the present level, resulting in possible fall of iron ore imports by that country[9]. But silver linings are seen in Japan's market as economic measures implemented in 1994 may encourage the expansion of public investments, expecially in housing which may bring recovery in near future. According to the recent forecast by MITI and Steel Federation of Japan, the production of steel in this country was likely to cross 100 Mt[10] mark during 1995 for the first time since 1991.

Due to expansion of steel industry in China, iron ore demands continue to grow in the condusive environment of infrastructure development, especially port facilities. All these together made China to import 40 Mt in 1994. Apart from this, in all the developing countries in Asia, iron ore demand is likely to remain either steady or grow moderately. Further, good quality ferrous scrap now costs more; this situation may lead to higher demand of iron ore for making primary steel.

Production of steel in Asia is forecast to rise by 50 Mt, or 19 percent, to 316 Mt, between 1994 and 2000. [8] China's production may rise by 22.5 Mt to 113 Mt, but despite this possible growth, China will remain a net importer of steel well into the next century, though it exports some 10 Mt steel to the South-East Asian countries for the benefit of trade. China will remain more reliable destination for the countries exporting iron ores which may increase by as much as 50% by the year 2000 as "China cannot expect to rely on domestic ore for the growth of steel production" and "ore imports could rise from 40 Mt to 60 Mt by the year 2000 with some caveats". [7] China produced 91 Mt of steel in 1994 and 46.4 Mt in the first half of 1995 and it has now three companies, each capable of producing 8 Mt of crude steel.

South Korea's steel production may continue to increase up to 41.5 Mt by 2000. And by this time, many new capacities will be added. So, major producer countries in Asia will increase their production to meet at least part of higher steel demand. Thus, grade of iron ores in Asia will also remain buoyant in the environment of new manufacturing plants for engineering products which will create the steady demand for steel followed by iron ores. Iran and Australia will also have increased share in the world's production of steel and to some extent production of iron ores. But main looser would be CIS in comparison with 1990's level of production, though their re-growth was expected from 1995.

11.4 INDIAN SCENARIO

Like China, India is also expecting boom in steel industry followed by iron ore production and consumption but at a lower pace compared to the former. With increased investment, especially in infrastructure like ports, roads, power and housing, demand of steel is increasing steadily. Against per capita consumption of only 18-20 kg in the country, Japan's consumption is at 160 kg and China's 80 kg. In 60s both China India were producing 3 Mt of steel, and by the turn of this Century, India has targeted only 31 Mt for domestic consumption and 6 Mt for export whereas China has the proposal to cross 100 Mt mark by that time. However, steel production in the country is expected to be doubled in next 5 years (present production : 18 Mt) due to the projected growth in infrastructure in the face of liberalization of economy.

Compared with the present level of production, India may face shortage of 100 Mt of iron ores by the year 2010 and all efforts are needed for three-fold production of iron ore by that time. It is more important in the face of shortage of scrap which may continue. [11]

Except bluedust, all Indian iron ores contain alumina (Al_2O_3) more than 2 percent which is not suitable for making sinter. Whereas "Corex Technology" can accept any type of iron for making steel, this technology gives scope to use iron ores containing high alumina for making iron of varying qualities suitable for steel making. Jindal Vijaynagar Steel would be the first integrated plant in India to use this technology for producing 1.25 Mt of steel. This process uses coal in place of coke; most of Indian coals are not suitable for coke making for which coking coal is imported. Further, Corex process can accept 100 percent sinter, 100 percent lime and iron ore mix, or any combination of either variety. By this process, hot-metal-making cost is likely to be reduced by 15 to 25 percent than what would be by conventional process. The main advantage of this process is generation of off gases which find their usage in the steel plant itself. The various uses of off gases are given below :

(a) Reheating within steel plants to make downstream products.

(b) To feed into a turbine generator and use for power generation.

(c) To heat direct reduction furnace as has been planned for the Posco plant at Pohang, South Korea.

Further, Corex process is a eco-friendly technology which reduces emission levels to one-tenth of industrial standards. All these together would boost steel industry in the country and as a result, iron ore demand in the domestic market would go up. In addition to this technology import, the Steel Ministry is contemplating to import "Plasma Technology" mainly for conservation of energy. So, addition and expansion of steel industry will take place in some cases with new technology which will create demand for iron ores in domestic market rather than their export.

11.4.1 Expansion and Addition of Steel Plants

The next five years, i.e. up to 2000 years, over 9 Mt would be added to the capacity of steel making and by the end of this year itself, some new plants could be ready for production. A profile of these plants is detailed below :

11.4.1.1 Kudremukh Iron Ore Company Limited (KIOCL)

The KIOCL is planning to set up a Rs. 235-crore joint venture to produce pig iron and ductile iron spun pipes. By 1996, the project is expected to be completed. At present, the Company has the largest pelletization plant in the country which may produce 50,000 tonnes more from its present level of 3 Mt. So, KIOCL may enhance production of iron ore (r.o.m.) in near future from its current level of 18 Mt.

11.4.1.2 Jindal Vijaynagar Steel Ltd. (JVSL) - Jindal Group

This group of companies is setteing up a Rs. 33 - billion steel plant of 1.2 Mt capacity near Bellary (Karnataka) including a pelletization plant of 3 Mt capacity per year. So, about 2 Mt of iron ores would be consumed by this plant in near future.

11.4.1.3 Nagarjun Fertilizer Limited

At Mangalore, the Company has 1 Mt steel project which is further planned to produce 2 Mt. The total investment is around Rs. 100 billion (including estimate for 1000 MW captive power plant). The proximity of KIOCL's mine and port facility at Mangalore are the important advantages of the Company. So, the raw material (iron ore) production of KIOCL also may go up for feeding this steel plant in near future.

11.4.1.4 Mesco Group

The Mesco Group, owner of a dozen companies, plans to set up second export-oriented steel plant. The Company is floating Indo-Chinese joint venture in steel and will set up another steel plant. The new plant would cost Rs. 23 billion with capacity of 4.5 Mt hot-rolled and other steel products annually. Production may commence from December- 1996 with initial hot-rolled coils (HRC) of 2.25 Mt. It has been reported that this plant would be the largest integrated steel plant in the country. The Company will be located in Orissa and will be called Mesco-Kalinga Steel Limited. To feed this plant, the Company is floating a new company, Mesco-OMC Mining Corporation for mining iron ores. This Company will have capacity to mine 11 Mt of iron ore a year.

11.4.1.5 Tata Iron and Steel (TISCO)

TISCO signed a Mou with Orissa Government to set up a 10 Mt port-based steel plant at Gopalpur. But this unit will start with an installed capacity of 2.5 Mt in first phase itself (A.D.2000) and thereafter would go on adding modules to take its capacity to 10Mt by AD 2010.

11.4.1.6 Larson and Toubro (L&T)

The L&T has also a proposal to set up a 7 Mt port-based steel plant in Orissa near Gopalpur.

11.4.1.7 Tamil Nadu Industrial Development Corporation (TIDCO)

The Tamil Nadu Government is actively considering establishment of a half-a-Mt integrated steel plant involving a capital outlay of about Rs. 15 billion near the new Ennore port.

Apart from the plants mentioned above, many mini-steel plants are coming up in the country. So, the overall scenario of steel and thus iron ore is bright at least till 2010.

11.4.2 Spong Iron/Pig Iron

For sponge iron manufacturing, 18 coal-based units with capacity of 5.4 million tonnes per annum have already been commissioned. Another 4 units with capacity of 1.3 million

TABLE 11.2: INSTALLED CAPACITY FOR SPONGE IRON MAKING

(lakh tonnes per annum)

Status	Coal-based	gas-based	Total
Existing units	17.10	35.10	52.20
New units	9.20	25.50	34.70
Total	26.30	60.60	86.90

(Source : Performance Budget of Ministry of Steel 1995-96, p.22)

tonnes per annum are under construction.The installed capacity for sponge iron is given below:

Of the installed and under implementation capacity of 8.69 million tonnes for sponge iron making, production of 3.39 million tonnes was reported in 1994-95 and 4.4 million tonnes was estimated for 1995-96.

For pig-iron manufacturing besides integrated steel plants, 1.35 million capacity has been commissioned since liberalization. In addition to already commissioned pig iron manufacturing capacity, another 1.62 million tonnes is reported to be under various stages of implementation.

11.4.3 Future Iron Ore Export and its Domestic Consumption

On one hand, domestic consumption of iron ore is increasing due to coming up of new iron and steel plants and on the other hand, prospect of export to other countries especially to China is very bright. Earlier, Indian iron ore production could not rise beyond a limit as it was basically dependent on export market which is still controlled by major producers like Australia and Brazil. Now the scenario is different; a major portion of iron ore produced in the country will be consumed locally due to expansion of existing steel plants and addition of new steel plants.

Steel production in the country is forecast to grow from 27 Mt in 1996-97 to 67 Mt by 2010-11 with increase in domestic demand for iron ore from 49.6 to 125.2 Mt.[8] According to the Ministry of Commerce, India could potentially export approximately 30-35 Mt of iron ore by that time. The prospect of steel and iron ore is summarized in Table 11.3 (next page).

To achieve the figures as projected in Table 11.3, the major iron producing companies in the country are also expected to produce 106.59 Mt and 121.27 Mt of iron ore and concentrates, respectively, in 2001-02 and 2006-07. Companywise projected production targets are detailed in the Table 11.4.[12] In addition to these projected figures, it is expected that during this period, new mines may come up to cater to the needs of proposed/new steel plants, details of which are already discussed under Para 11.4.1. Expansion of Chiria mines in Bihar and development of Rowghat Iron Ore Mines (5 Mt) meant for SAIL's plants would take place by that time. These will add in the total further capacity of around 18 Mt of iron ore giving around 15 Mt of finished product for feeding various steel plants. So, the country may be able to produce about 140 Mt of iron ore and its concentrates to cater to the requirements of the steel plants and the export of about 35 Mt as well.

To reach this target, the major constraint would be railways which is the major carrier for crude steel and other semi-finished products. In

TABLE 11.4: PROJECTED PRODUCTION BY MAJOR INDIAN COMPANIES

(in Mt)

Name of the Company/Belt	2001-02	2006-07
NMDC	29.20	29.20
SAIL	24.00	33.18
KIOCL	6.80	6.80
TISCO	7.84	7.84
ESSAR, GUJARAT*	3.00	3.00
BIHAR-ORISSA*	6.50	9.00
BELLARY-HOSPET*	7.50	7.50
MAHARASHTRA AND A.P.*	2.00	5.00
GOA*	19.75	19.75
TOTAL	106.59	121.27

* Excluding production targets, if any, of the companies mentioned in this Table.

Note : Projected production includes lumps, fines, concentrates and pellets

Source : Report of Sub-Group-II of Working Group on Iron and Steel for the IXth Five-Year Plan, July, 1996.

TABLE 11.3 PROSPECT OF INDIAN CRUDE STEEL AND IRON ORE PRODUCTION IN INDIA

(In million tonnes)

		PRODUCTION						FORECAST			
	Year	1960s	91-92	93-94	94-95	95-96	96-97	2000-01	2001-2	2006-7	2010-11
STEEL		3	15.33	16.27	17.73	19.3(P)	27.00	36.6	42.0	NA	67
IRON ORE	Consumption	NA	21.52	23.79	NA	NA	49.60	NA	NA	NA	125.00
	Export	NA	32.49	26.86	26.06	23.10*	30.00	31.00	NA	NA	35.00
	Total Production	NA	57.46	58.33	60.00	66.57	79.60	87.00	107.0	140.0	160.00

N. A. : Not Available.
(P) Extrapolation based on figures of April-Sept., 1995.
* Figure pertaining to April-December, 1995.

Source : Indian Bureau of Mines, Nagpur.

its present form, Indian Railways is not in a position to carry more than 16 Mt. [13] So Railways should enhance its capacity for haulage of such huge quantity of steel. Over and above, the Indian Railways should immediately undertake the railway line connection between Banspani and Daitari to streamline the export of iron ore from Barbil-Barajamda-Banspani area to Paradip Port which will also reduce the freight charges in turn. Further, most of the steel plants are located near the raw material base which is on the eastern side of the country whereas major consumers are either in western and southern parts of the country, which has necessitated more transportation capacity. So, steel plants should now come up in western/southern regions. A steel plant named JVSL has come up in Bellary- Hospet area.

Fortunately, port facility may not be required to be developed at the same pace at which iron ore production will grow as major part of the steel to be produced would be consumed in the domestic market. In conclusion, it can be said that future of steel and iron ore in India is very bright as the Government has decided to invest more in the infrastructure like roads, power plants, port facility, railways and it in turn will consume more steel in the country which is endowed with huge quantity of high grade iron ores that can be mined for a few centuries.

India is expected to occupy a position next to China in the decade ahead in terms of steel demand growth[14] in the world and so is the bright future of iron ore.

REFERENCES

1. Journal of Mines, Metals and Fuels, November-December, 1993.

2. Minerals and Metals Review, 1994.

3. Journal of Mines, Metals and Fuels, November-December, 1993.

4. Business Standard, Calcutta.

5. 16th World Mining Congress - World Iron Ore Mining and its Production - Author Byzov V. F. Prof. D. E. Et. Tuhami Fauzi.

6. Minerals and Metals Review, 1994.

7. Mineral and Export Intelligence - December, 1995.

8. Information Bulletin (Tata Steel), January, 1995.

9. Minerals and Metals Review, 1994.

10. Business Standard, Calcutta, dated 4.5.1995.

11. Financial Express, Bombay, dated 22.1.1995.

12. Report of Sub-Group-II of Working Group on Iron & Steel for the IXth Five-Year Plan, July, 1996.

13. Mineral and Export Intelligence - October, 1995.

14. Mineral and Export Intelligence - May, 1995.

ADDENDA

1. Indian Iron Ore Production, 1995-96 and 1996-97 ---- 225

2. World Iron Ore Production, 1991 to 1995 ---- 226

Addendum-1
to Chapter-VI

STATEWISE INDIAN IRON ORE PRODUCTION FOR 1995-96 AND 1996-97

(Quantity in '000 tonnes)

MINERAL/STATE	APRIL, 1996 - MARCH, 1997(P)	APRIL, 1995 - MARCH, 1996
IRON ORE (TOTAL) INDIA	66669	67423
ANDHRA PRADESH	188	187
BIHAR	12451	12625
GOA	14015	15126
HARYANA	6	5
KARNATAKA	12408	12846
MADHYA PRADESH	16808	17337
MAHARASHTRA	91	172
ORISSA	10680	9088
RAJASTHAN	22	37
Iron Ore (Lumps) INDIA	29642	29411
ANDHRA PRADESH	126	122
BIHAR	5477	5227
GOA	2894	2845
HARYANA	6	5
KARNATAKA	4681	4862
MADHYA PRADESH	9064	9610
MAHARASHTRA	76	136
ORISSA	7296	6567
RAJASTHAN	22	37
Iron Ore (Fines) INDIA	31051	31433
ANDHRA PRADESH	62	65
BIHAR	6974	7398
GOA	10705	11762
KARNATAKA	2167	1924
MADHYA PRADESH	7744	7727
MAHARASHTRA	15	36
ORISSA	3384	2521
Iron Ore Concentrates INDIA	5976	6579
GOA	416	519
KARNATAKA	5560	6060

(P): Provisional
SOURCE : Indian Bureau of Mines

Addendum-2
to Chapter-VII

YEARWISE AND COUNTRYWISE WORLD IRON ORE PRODUCTION DURING 1991 TO 1995

(tonnes)

Country	1991	1992	1993	1994	1995
United Kingdom	59 400	30 900	1 068	1 271	1 350
Austria	2 120 000	1 627 000	1 427 000	1 644 000	2 107 000
Finland	32 672	22 836	11 245	---	---
France	7 490 000	5 707 000	3 543 000	2 418 000	1 500 000
Germany, Federal Republic of (f)	118 000	109 000	146 000	*100 000	---
Portugal(f)	16 070	14 545	16 175	14 330	14 535
Spain	3 120 000	2 750 000	*2 475 000	2 086 000	1 982 000
Sweden	19 328 000	19 277 000	18 728 000	19 909 000	21 400 000
Albania (b)	446 000	21 000	---	---	---
Azerbaijan	---	*40 000	*300 000	*100 000	---
Bosnia & Herzegovina	---	*500 000	*250 000	*200 000	---
Bulgaria	300 000	393 000	452 000	466 000	*450 000
Czechoslovakia	1 738 000	1 500 000	---	---	---
Macedonia	---	*20 000	*20 000	*20 000	---
Norway	2 360 540	2 258 409	2 182 184	2 459 955	2 169 011
Romania	1 461 000	1 229 000	903 500	950 800	---
Russia	---	82 100 000	76 100 000	73 300 000	78 300 000
Slovakia	---	---	1 092 000	1 021 000	---
Soviet Union	1 99 300 000	---	---	---	---
Turkey	5 334 502	5 579 000	5 070 000	5 772 046	4 963 935
Ukraine	---	75 689 000	65 335 000	51 147 000	---
Yugoslavia (h)	(d) 2 574 000	551 000	106 000	*32 000	---
Algeria	2 344 000	2 523 000	2 311 000	2 047 000	2 200 000
Egypt (i)	2 131 000	2 287 000	2 229 000	3 869 000	---
Liberia	1 200 000	1 710 000	---	---	---
Mauritania	10 246 000	9 110 000	9 362 000	10 443 000	---
Morocco	98 676	84 679	66 318	65 233	39 689
Nigeria	*350 000	*350 000	*350 000	*350 000	---
South Africa (c)	29 075 422	28 225 859	29 385 168	32 321 215	31 945 511
Tunisia	295 000	291 000	298 800	235 000	153 000
Zimbabwe	1 137 000	1 181 000	374 493	3 500	311 352
Canada (g)	36 383 000	32 697 000	30 505 000	36 566 000	37 961 000
Mexico	7 540 000	7 809 000	8 480 000	8 358 000	8 523 000
USA	56 761 000	55 593 000	55 661 000	58 400 000	62 450 000
Argentina	160 684	5 958	3 267	67 000	1 000
Bolivia	101 642	34 956	32 108	---	---
Brazil (a)	151 764 214	1 46 447 408	150 000 000	1 67 900 000	*175 000 000
Chile	8 414 443	7 224 030	7 379 016	8 340 505	8 431 647
Colombia	607 329	674 219	544 775	609 915	734 000
Peru	3 592 976	2 848 071	5 203 991	6 943 437	*5 800 000

Contd..

(Addendum - 2 Concld.)

Venezuela	20 343 000	18 887 115	16 851 071	18 318 000	19 484 000
China	190 558 000	210 220 000	225 990 700	250 560 000	245 000 000
India	56 915 000	54 870 000	55 818 000	58 000 000	60 700 000
Indonesia	173 242	287 821	341 335	334 895	348 371
Iran (e)	3 888 100	4 193 650	8 652 900	6 244 735	---
Japan	31 444	39 791	10 621	3 058	2 959
Kazakhstan	---	17 671 000	13 128 900	19 700 000	2 300 000
Korea, Dem. P.R. of	*9 500 000	*9 500 000	*9 500 000	*9 000 000	---
Korea, Republic of	221 525	221 592	218 663	191 313	184 443
Malaysia (g)	375 869	319 919	245 849	243 182	202 322
Thailand	240 075	427 242	208 939	142 795	---
Australia	117 673 000	112 115 000	120 534 000	128 493 000	142 936 000
New Zealand	2 264 849	2 934 111	2 388 783	2 080 115	2 300 000
World total	960 000 000	930 000 000	936 000 000	992 000 000	1 004 000 000

Note(s):

(1) In addition to the countries listed, Vietnam is belived to produce iron ore

* estimated

(a) Including beneficiated and direct shipping ore

(b) Nickeliferous iron ore

(c) Including by-product magnetite

(d) Excluding data from August to December for the Republic of Croatia

(e) Years ended 20 March following that stated

(f) Including manganiferous iron ore

(g) Including by-product iron ore

(h) As from 1992 data are for Serbia and Montenegro only

(i) Years ended 30 June of that stated

Source - World Mineral Statistics