BENEFICIATION STUDIES ON IRON ORES OF BIHAR

1. Concentration of Blast Furnace Flue Dust from TISCO

A mixed sample of flue dust mostly of −20 mesh size and weighing 50 kgs, from the blast furnaces of TISCO was received to study whether its impurities can be reduced to a reasonable level by simple ore-dressing methods, so that it can be used in their sinter mix along with the iron ore fines. It assayed as follows :

Constituent	Assay %
Fe	39.47
SiO_2	14.38
Al_2O_3	9.54
CaO	3.30
Mn	0.51
P	0.23
Free C	11.14
LOI	15.31

It consisted of lateritic hematite, magnetite, ochre, quartz, calcite and appreciable quantities of coke dust. Alumina was present mostly as laterite.

Straight magnetic separation of the original sample did not produce a satisfactory grade of concentrate. It could produce a magnetic concentrate assaying 56.43% Fe, 7.9% SiO_2 and 8.95% Al_2O_3 with 46.1% Fe recovery only. Tabling of the sample yielded a table concentrate assaying 60.63% Fe, 5.62% SiO_2, 6.82% Al_2O_3 and 0.2% P with 64.2% Fe recovery. This product was found to be satisfactory to be mixed with the sinter mix or refed to the blast furnace.

2. Beneficiation of Classifier Overflow from the Noamundi Iron ore Washing Plant

A sample of classifier overflow mostly −100 mesh in size, from the Noamundi iron ore washing plant was received from M/s. TISCO Ltd., for beneficiation tests. The sample assayed as follows :

Constituent	Assay %
Fe	51.42
Al_2O_3	12.80
SiO_2	8.51

It was desired to produce a −200 mesh product assaying over 90% Fe_2O_3 for paint manufacture. The sample contained fine hematite and lateritic material with hydrated oxides of iron and alumina with a little silica. Quartz and magnetite were in minor amounts.

Straight tabling of the sample yielded a concentrate assaying 63.84% Fe (91.3% Fe_2O_3), 7.59% Al_2O_3 and 1.98% SiO_2 with a recovery of 38% iron in the product which contained 12.1% by weight of +200 mesh material. This needed grinding to meet the specification.

Tabling of an attrition — ground sample produced a concentrate assaying 64.18% Fe (91.3% Fe_2O_3), 5.98% Al_2O_3 and 1.88% SiO_2 with 34% Fe recovery. But this concentrate also got the same quantity of +200 mesh oversize, which would require further grinding for paint manufacture.

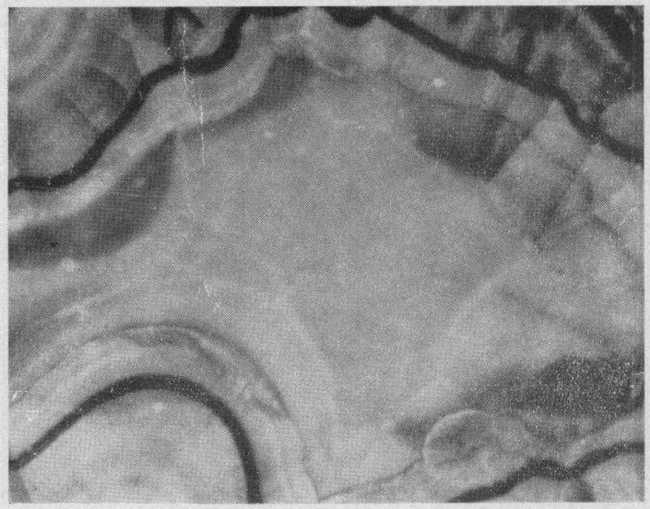
Tabling of the sandy portion after hydraulic classification of the sample, yielded a concentrate assaying 64.01% Fe (91.04% Fe_2O_3), 7.8% Al_2O_3 and 1.93% SiO_2 with only 18% Fe recovery in the product.

Conclusively none of the concentrates obtained by the above methods exactly satisfied the size specification, viz. −200 mesh, as they all contained 11-12% oversize which would require finer grinding in a ball mill.

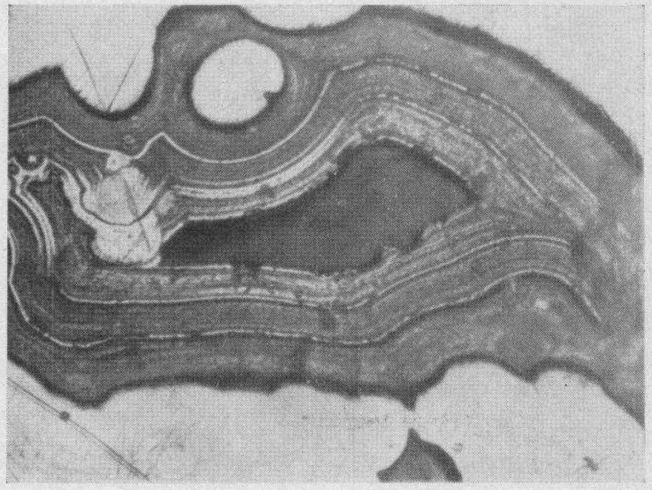
3. Studies on the Beneficiation of Iron Ores from TISCO

Five samples of iron ores which normally form the blast furnace ore burden, from different mines of TISCO were received for beneficiation studies. These studies included (a) detailed petrological studies, chemical analysis, crushing and screening characteristics, (b) washing studies at −50 mm and −25 mm sizes, (c) Heavy media separation of the washed ore lumps and (d) Sintering studies of the natural fines (−10 mm material) obtained from the ore samples crushed to −50 mm as well as on the −10 mm materials obtained after having first washed the ore at −50 mm and 25 mm respectively, eliminating thereby the very fines rich in the delterious insolubles.

(a) The iron ore samples received were from Noamundi I, Noamundi II, Joda, Badampahar and Gorumahisani Mines. Those from Noamundi I, Noamundi II and Joda consisted mostly of hematite with a smaller proportion of hydrated iron oxides, goethite, lepidocrocite and limonite. Kaolin and laterite accounted for the bulk of alumina in these ores. The ores from Badampahar and Gorumahisani contained mostly of



B—Coarsely crystalline lepidocrocite exhibiting colloidal texture. Etched with $SnCl_2$ + HCL for 2 min. crossed nicols X 140. Reflected Illumination (Badampahar Iron ore).

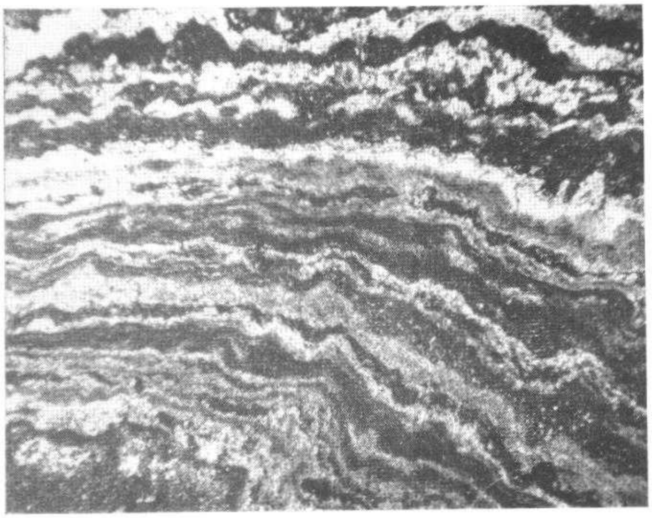


C—Exhibiting rythmic precipitation of lepidocrocite (white) and clayed material (grey) in cavity. Etched with $SnCl_2$ + HCL for 1 mins. Reflected Illumination X 140 (Badampahar Iron ore).

A—Showing oolites of goethite embedded in ochery material (soft spongy variety). Reflected Illumination X 140. Iron ore from Noamundi.

hydrated iron oxides and a little of hematite; yellow and red ochres also formed part of these ores. Silicate gangue was also present in minor quantities as incrustations and chemical analysis of the five ROM ore samples is given in Table 2.1.

In all the five samples, alumina content was higher than silica and the total insolubles varied from 5.3% to 8.65%. Particular attention should be given to the loss of ignition which varied from 3.8% to 10.0% in the different samples which pointed to the predominance of hydrated iron oxides in the soft ores from Badampahar and



D—Microscale folding of hematite laminae (section parallel to the laminae) Reflected Illumination X 6.0 (Joda East, Iron ore Orissa).

TABLE 2.1—CHEMICAL ANALYSIS OF THE ROM ORE SAMPLES

Sample	%						
	Fe	SiO_2	Al_2O_3	P	CaO	MgO	LOI
1. Noamundi II	64.2	1.9	3.7	0.15	Tr.	0.08	3.82
2. Joda	61.6	2.7	4.3	—	0.52	Tr.	5.4
3. Noamundi I	60.5	2.3	5.5	0.18	Tr.	0.50	6.6
4 Gorumahisani	56.3	4.0	4.65	0.12	Tr.	0.11	10.0
5. Badampahar	59.2	2.9	3.4	0.47	0.58	0.50	8.4

Gorumahisani which probably accounted for their high reducibilities and low crushing strengths.

Ore from Joda was the hardest to crush followed in order by Noamundi II, Noamundi I, Gorumahisani and Badampahar. The presence of a large quantity of −50 mm material which varied from 42% to 65%, in the run-of-mine ore samples indicated that pre-screening should be adopted to decrease the load on the crushers. As the ores would get wet and sticky during monsoon, roll-grizzlies are to be preferred to vibrating screens for the purpose. Secreenability tests carried out with different moisture contents in the ores indicated that maximum screening difficulties were likely to be encountered even with as little as 5% moisture in the case of Joda and Noamundi II ores, with 10% moisture in case of Noamundi I and Badampahar ores and with 15% moisture in case of Gorumahisani ore.

Washing

Washing not only facilitates easy handling of the wet and sticky materials but also eliminates the "very fine fractions" which are invariably exceedingly high in insolubles and are on the whole detrimental for smooth running of blast furnace.

In the washing set-up the ore from the ore bin was conveyed through a belt conveyor to a log-washer scrubber to which about 25% water was added. The material from the scrubber was then fed to a double deck vibrating screen where it was washed with water sprays. The screens used were of 25 mm (1″) and 10 mm (3/8″) square apertures in case of −50 mm (−2″) ore and a 10 mm square screen for washing of −25 mm ore. The screen undersize (−10 mm) was passed through a cross flow classifier for dewatering. The classifier overflow containing mostly −200 mesh material was sent to thickener. Thickener underflow (slime) was allowed to settle in settling tanks. Clear water from the settling tanks and thickener overflow was reclaimed and reused in the washing operations. The washing results (condensed) are given in Table 2.2.

As seen from the washing results (Table 2.2), it was observed that there was a decrease of about 1% in the total insoluble content in the final concentrate. The silica rejection varied from 27% to 50%, whereas the total alumina rejected varied from 16.4% to 28.7%. Thus, there was a preferential rejection of silica over alumina in the final product during washing operation.

The weight of slime which would have to be rejected varied from 6.1% to 12.2% in case with −50 mm samples. The iron loss varied from 4.3% to 11.2%. Higher losses in the Noamundi ores were principally due to the presence of very fine "blue dust" of −325 mesh size in the ores. The insolubles in the slimes ranged from 12.2% to 26.3%. Similar trends were observed in case of −25 mm washing tests, with more slime varying from 9.9% to 17.2% and 7.6% to 16.2% iron losses. The slimes could perhaps be utilised for making of bricks, paints etc.

One important result of washing was that the coarse products (+10 mm) obtained were completely clean and free from adhered fines, and had moisture contents of 1.4% to 8.0% which

TABLE 2.2—WASHING RESULTS (CONDENSED)

Sample	Product	Wt. %	Assay %			Recovery %		
			Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Noamundi II Washing at —50 mm	Final Conc.	87.8	64.7	1.35	3.36	88.8	61.5	79.8
	Slime	12.2	59.1	6.1	6.1	11.2	38.5	20.2
		100.0	64.2	1.93	3.7	100.0	100.0	100.0
Washing at —25 mm	Final Conc.	82.8	65.1	1.2	3.16	83.8	50.0	71.9
	Slime	17.2	60.7	5.9	6.10	16.2	50.0	28.1
Joda Washing at —50 mm	Final Conc.	93.9	62.8	1.84	3.73	95.7	69.5	82.0
	Slime	6.1	43.2	13.7	12.6	4.3	30.5	18.0
	ROM (Calc.)	100.0	61.6	2.7	4.3	100.0	100.0	100.0
Washing at —25 mm	Final Conc.	90.1	63.3	1.9	3.45	92.4	62.6	78.7
	Slime	9.9	47.5	10.1	8.5	7.6	37.4	21.3
Noamundi I Washing at —50 mm	Final Conc.	89.7	61.8	1.6	4.8	91.5	60.4	77.3
	Slime	10.3	49.6	8.9	12.8	8.5	39.6	22.7
	ROM (Calc.)	100.0	60.5	3.3	5.5	100.0	100.0	100.0
Washing at — 25 mm	Final Conc.	85.4	61.4	1.3	4.7	87.0	49.4	78.8
	Slime	14.6	53.4	6.1	7.4	13.0	50.6	21.2
Gorumahisani Washing at — 50 mm	Final Conc.	90.3	58.1	3.3	4.2	91.9	72.2	80.6
	Slime	9.7	47.7	11.8	9.4	8.1	27.8	19.4
	ROM (Calc.)	100.0	56.8	4.0	4.65	100.0	100.0	100.0
Washing at — 25 mm	Final Conc.	87.8	58.2	3.1	3.8	89.4	70.6	73.0
	Slime	12.	49.8	9.4	10.1	10.6	29.4	27.0
Badampahar Washing at — 50 mm	Conc.	89.9	60.9	2.0	3.2	91.6	61.0	83.6
	Slime	10.1	49.0	11.4	5.6	8.4	39.0	16.4
	ROM (Calc.)	100.0	59.2	2.95	3.44	100.0	100.0	100.0
Washing at — 25 mm	Conc.	87.8	60.3	1.9	2.96	89.1	62.3	76.4
	Slime	12.2	53.4	8.4	6.6	10.9	37.7	23.6

was only surface moisture. It should be very easy to handle this product both during transport and in the blast furnace.

The −10 mm classifier sand with 8% to 13% moisture content and only 3% to 5% of −200 mesh material was free flowing and should not be very difficult for handling within and outside the plant.

The sieve analyses and the settling rates of iron ore slimes obtained in the washing tests are given in tables 2.3 and 2.4.

The sieve analysis of the slimes (Table 2.3) indicated that the slimes removed at −50 mm were slightly coarser than those of −25 mm and a major portion was in the −200 mesh size. The settling rate values (Table 2.4) should be useful in the design of a thickener of proper size for each of the slimes. Normally the thickener underflow

TABLE 2.3—SIEVE ANALYSES OF SLIMES OBTAINED FROM WASHING TESTS

Mesh	Noamundi II		Joda		Noamundi I		Gorumahisani		Badampahar	
	—50 mm test	—25 mm test	—50 mm test	—25 mm test	—50 mm test	—25 mm test	—50 mm test	—25 mm test	—50 mm test	—25 mm test
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
+150	9.0	0.2	1.4	0.2	6.0	0.6	0.8	0.6	9.6	0.8
—150+200	4.6	0.4	2.6	1.0	6.8	1.7	3.4	1.8	6.4	5.0
—200+270	2.4	0.8	2.0	1.2	5.4	2.5	4.6	1.6	7.4	4.0
—270+325	19.4	5.0	10.6	2.0	20.0	11.2	16.0	7.6	24.8	19.4
—325	64.6	93.6	83.4	95.6	61.8	84.0	75.2	88.4	51.8	70.8
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 2.4—SETTLING RATE OF IRON ORE SLIME AT 3% SOLIDS AND ULTIMATE PULP DENSITY AFTER SETTLING FOR 19 HR.

Sample	Settling rate ft/hr.		Ultimate pulp density % Solids	
	from 50 mm ore	from 25 mm ore	from 50 mm ore	from 25 mm ore
1. Noamundi II	4.8	4.6	72.2	72.2
2. Joda	3.58	4.0	50.7	56.5
3. Noamundi I	4.25	5.3	60.0	59.0
4. Gorumahisani	3.35	2.1	51.0	50.9
5. Badampahar	3.4	3.4	56.5	56.5

may be expected to contain about 25% solids. This together with moisture contents of sized ore and the classifier product, should indicate the amount of 'make-up' water necessary for washing tests.

Heavy Media Separation

One of the most important aspects in the beneficiation of Indian iron ores is their complex nature from the stand point of elimination of alumina. Alumina may be present as fine clayey material adhering to the coarse pieces and as cavity fillings, or as laterftic material. By washing alumina present as clayey material as well as fine silica can be partly removed, whereas laterite does not itself be effected by washing treatment. There is thus preferential removal of silica over alumina, which naturally increases the alumina-silica ratio (Al_2O_3/SiO_2) in the washed product. Higher alumina content in these products is due to the presence of laterite. It was observed experimentally that gravity methods can be successfully employed to decrease this lateritic material of the ores due to the wide difference in specific gravity between the iron ore minerals and the laterite. There is a preferential rejection of alumina over silica when laterite is rejected.

The various methods of gravity separation included heavy media separation, jigging and tabling depending on the size of the ore fractions to be treated.

The heavy media separation tests were conducted using a suspension of finely ground ferro-silicon in water as the medium prepared for specific gravities of 2.9 and 3.0. The +10 mm material obtained during washing of —50 mm and —25 mm material was treated. The sink and float products obtained with each of the five ore samples were washed to become free from adhering medium, dried and chemically, analysed. The results are given in Table 2.5.

As seen from the results of H.M.S. Tests (Table 2.5), the alumina content of the sink products was much lower and the floats had very high alumina content. Although alumina-silica ratio after the heavy media separation was higher than that of the original ore, there was an overall rejection of 33.6% to 61.3% of the total alumina and 39.7% to 70.6% of silica in the ore. The improvement in iron contents of the final concentrate would be 1.4% to 3.3% higher when both washing and heavy media separation are employed. Thus use of beneficiated, sized ore free from fines would increase the production capacity by way of decrease in the thermal and metallurgical load on the blast furnace due to better gas-solid content which has resulted by improved permeability of the furnace charge. The alumina content could well be adjusted by suitable additions of a small proportion of quartzite or BHQ, or use of limestone high in silica. Sufficient slag volume for effecting adequate desulphurisation will have to be ensured in using the high grade ore and its beneficiated counterpart.

TABLE 2.5—HEAVY MEDIA SEPARATION RESULTS

Sample	Product	Wt. %	Assay %			Recovery %		
			Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Noamundi II								
—50 mm washing and HMS	Sink	59.3	68.1	0.6	1.3	63.0	19.3	21.4
	Cl. sand	21.6	62.2	1.6	5.4	20.9	17.8	31.6
	Total conc.	80.9	66.5	0.9	2.42	83.9	37.1	53.0
	Float	6.9	45.8	6.8	14.3	4.9	24.4	26.8
	Slime	12.2	59.1	6.1	6.1	11.2	38.5	20.2
	ROM Head (Calc.)	100.0	64.2	1.93	3.7	100.0	100.0	100.0
—25 mm washing and HMS	Sink	50.8	68.0	0.5	1.6	53.7	13.1	22.2
	Cl. sand	26.7	63.3	1.5	4.5	26.3	19.7	32.8
	Total conc.	77.5	66.4	0.84	2.6	80.0	32.8	55.0
	Float	5.3	46.2	6.3	11.3	3.8	17.2	16.3
	Slime	17.2	60.7	5.9	6.1	16.2	50.0	28.7
Joda								
—50 mm washing and HMS	Sink	64.4	66.5	1.0	1.87	69.4	23.5	28.3
	Cl. sand	22.1	57.6	3.4	6.3	20.7	27.4	32.6
	Total conc.	86.5	64.2	1.61	3.0	90.1	50.9	60.9
	Float	7.4	46.4	6.9	12.9	5.6	18.6	21.1
	Slime	6.1	43.2	13.7	12.6	4.3	30.5	18.0
	ROM (Calc)	100.0	61.6	2.7	4.3	100.0	100.0	100.0
- 25 mm washing and HMS	Sink	53.7	67.7	1.0	1.3	58.9	20.1	17.7
	Cl. sand	30.9	58.6	2.5	5.6	29.3	28.9	43.8
	Total conc.	84.6	63.75	1.6	2.1	88.2	49.0	61.5
	Float	5.5	47.5	6.7	12.4	4.2	13.6	17.2
	Slime	9.9	47.5	10.1	8.5	7.6	37.4	21.3

Noamundi I								
—50 mm washing and HMS	Sink	45.1	65.6	0.55	2.49	48.9	10.8	20.2
	Cl. sand	29.0	60.6	1.9	5.6	28.9	23.8	29.4
	Total conc.	74.1	63.5	1.08	3.7	77.8	34.6	49.6
	Float	15.6	53.5	3.8	9.9	13.7	25.8	27.7
	Slime	10.3	49.6	8.9	12.8	8.5	39.6	22.7
	ROM (Calc.)	100.0	60.5	2.3	5.5	100.0	100.0	100.0
—25 mm washing and HMS	Sink	44.5	64.7	0.3	2.6	47.8	5.9	22.7
	Cl. sand	28.9	61.0	1.8	5.7	29.3	23.5	32.3
	Final conc.	73.4	63.2	0.9	3.8	77.1	29.4	55.0
	Float	12.0	50.0	3.7	10.1	9.9	20.0	23.8
	Slime	14.6	53.4	6.1	7.4	13.0	50.6	21.2
Gorumahisani								
—50 mm washing and HMS	Sink	61.2	59.9	2.3	3.19	64.3	34.3	41.5
	Cl. sand	17.7	56.0	4.9	5.2	17.4	20.6	19.5
	Final conc.	78.9	59.05	2.86	3.64	81.7	54.9	61.0
	Float	11.4	51.1	6.2	8.1	10.2	17.3	19.6
	Slime	9.7	47.7	11.8	9.4	8.1	27.8	19.4
	ROM ore (Calc.)	100.0	56.8	4.0	4.65	100.0	100.0	100.0
—25 mm washing and HMS	Sink	54.9	60.1	1.9	2.83	57.8	26.9	34.1
	Cl. sand	23.3	56.4	5.6	3.8	23.0	33.4	19.5
	Final conc.	78.2	59.0	3.0	3.12	80.3	60.3	53.6
	Float	9.6	51.5	4.2	9.2	8.6	10.3	19.4
	Slime	12.2	49.8	9.4	10.1	10.6	29.4	27.0
Badampahar								
—50 mm washing and HMS	Sink	59.9	61.8	1.6	2.6	62.5	31.8	45.8
	Cl. sand	16.5	59.4	2.9	4.3	16.6	16.2	20.6
	Final conc.	76.4	61.3	1.9	2.95	79.1	48.0	66.4
	Float	13.5	54.7	2.8	4.4	12.5	13.0	17.2
	Slime	10.1	49.0	11.4	5.6	8.4	39.0	16.4
	ROM ore (Calc.)	100.0	59.2	2.95	3.44	100.0	100.0	100.0
—25 mm washing and HMS	Sink	55.7	62.05	1.44	2.09	57.6	29.6	34.1
	Cl. sand	23.3	59.8	2.50	4.7	23.2	21.4	32.2
	Final conc.	79.0	61.4	1.75	2.86	80.8	51.0	66.3
	Float	8.8	57.1	3.5	3.9	8.3	11.3	10.1
	Slime	12.2	53.4	8.4	6.6	10.9	37.7	23.6

—9 mm Classified Products Treatment

The aluminous material contained in the —9 mm classified product could be rejected to some extent by jigging or tabling. The results of Noamundi I ore are given in Table 2.6. The trend would probably be similar with other ores for such treatment.

Sintering Studies

Sintering characteristics of -9mm size ore after dry screening of unwashed -50 mm size Noamundi grade I (soft), Noamundi grade II (hard), Joda, Badampahar and Gorumahisani iron ores and -9 mm size material obtained after washing, screening and classification of the above five

TABLE 2.6—JIGGING AND TABLING RESULTS OF —9 MM SAMPLE FROM —25 MM WASHED PRODUCT FROM NOAMUNDI I

Product	Wt. %	Assay %			Dist. %		
		Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
—9 mm+20 mesh							
Jig conc.	16.9	61.1	1.3	4.2	17.4	10.5	17.6
Jig tails	5.5	56.9	2.4	5.3	5.3	6.2	7.2
—20 mesh							
Table conc.	3.4	63.4	1.4	2.9	3.6	2.2	2.5
Table tails	3.1	56.6	3.1	6.5	3.0	4.6	5.0
Head (Calc.)	28.9	60.1	1.7	4.5	29.3	23.5	32.3

ores at -50 mm and -25 mm sizes, have been evaluated.

Experimental Sinter Plant

Optimum conditions for producing good and strong sinter, have been determined using a Laboratory Sinter Plant designed and fabricated at the NML. The plant consists of a combustion chamber with gas burner, a sinter box with two special cast-iron grates one above the other, and a wind box. It has a grate area of 20 cm square (8") and could be operated at 50 cm w.g. suction. The wind-box is connected by a pipe to a fan having a suction capacity of 1300 Cu. ft. of air per minute at N.T.P. A butterfly valve fitted in the suction pipe controls the suction. Arrangements for measuring the suction in the wind-box and temperature of exit gases are provided.

TABLE 2.7—PROPORTIONS OF —9 mm IRON ORE USED FOR SINTERING

Ore	WEIGHT %			
	Blast Furnace Mix.	From washed —50 mm ore	From washed —50 mm ore	From washed —25 mm ore
Noamundi II	40.0	39.8	40.4	39.2
Joda	25.0	23.3	25.8	28.4
Noamundi I	10.0	13.2	13.6	10.6
Gorumahisani	17.0	15.0	14.1	15.1
Badampahar	8.0	87	6.1	6.8
TOTAL	100.0	100.0	100.0	100.0

The raw materials used for the preparation of the sinter mixture were -9 mm size iron ore fines from the five iron ores as referred above, flue dust from TISCO, coke of -8 mesh size from TISCO. The iron ore proportions of -9 mm size material used in sintering are given in Table 2.7. The chemical analysis, proportion and sieve analysis of the different raw materials used are given in Tables 2.8, 2.9 and 2.10 respectively.

The results of the detailed sintering studies indicated that sintering rate was highest with 9%, 8.1% and 6% of water in the charge for the three iron mixes. 6%, 5% 5% of coke were considered optimum respectively for the three mixes taking into consideration of strength, sintering rate and the amount of return fines.

It may be mentioned that good quality sinters could be produced from -9 mm classified products obtained after washing. Chemical analysis of a few typical sinters is given in Table 2.11.

4. Further Studies on the Beneficiation of Iron Ore Sample from TISCO:

The investigation on five TISCO iron ore samples indicated that scrubbing followed by wet screening and classification would solve the ore-handling and screening problems and yield a clean product for sintering. Heavy media separation of the washed ore was found to eliminate practically all the laterite and shaly gangue material which constituted a large bulk of the alumina in the ore, and thus substantially to improve the grade of the ore by 2 to 3 units.

TABLE 2.8—CHEMICAL ANALYSIS OF RAW MATERIALS

Raw Material	ASSAY %					
	Fe	SiO_2	Al_2O_3	CaO	MgO	Others
Iron ore						
(1) —9 mm from —50 mm unwashed ores	57.21	2.85	5.76	0.16	0.12	P = 0.053; S = 0.03; Mn = Tr. LOI = 7.23
(2) —9 mm from —50 mm washed ores	59.8	2.6	5.6	0.3	0.1	P = 0.21; S = 0.06; LOI = 7.2
(3) —9 mm from —25 mm washed ores	60.4	2.5	4.8	0.2	0.10	P = 0.19; S = 0.06; LOI = 6.7
Flue dust	36.0	13.01	10.56	4.4	Trace	Moisture = 0.82; LOI = 19.58
Coke	—	12.5	6.4	1.0	0.5	Fixed C = 71.9; Ash = 24.9; Volatiles = 2.5; Fe_2O_3 = 4.1; Moisture = 0.8

TABLE 2.9—PROPORTION OF RAW MATERIALS IN SINTER MIX

Raw Material	Wt. %
Iron ore fines	59.7
Flue dust	5.8
Return fines	34.5
	100.0

The beneficiated ore was very low in total insolubles and would be more desirable and acceptable feed for smooth blast furnace operation. With the above encouraging results TISCO sponsored some more studies to be done on their other varieties of iron ore samples from their iron ore mines.

Eight samples were sent of which four were from Noamundi (i) Soft laminated ore flaky in nature. No. 5788; (ii) Lateritised soft ore No. 5789; (iii) ROM ore from mechanised mine face consisting of mixture of hard, soft and

TABLE 2.10—SIEVE ANALYSIS OF RAW MATERIALS

Mesh Size	WEIGHT %							
	(bracket total)	—9 mm mixed from —50 mm unwashed iron ores	—9 mm mixed from —50 mm washed iron ores	(bracket total)	—9 mm mixed from —25 mm washed iron ores	(bracket total)	Flue Dust	Coke
+ 3 mesh		2.1	9.1		7.3			
— 3+ 4 mesh		10.9	18.8		17.2			
— 4+ 6 ,,	39.9	9.8	12.8	60.7	15.9	62.8		
— 6+ 8 ,,		8.7	11.3		12.2			
— 8+ 10 ,,		8.4	8.7		10.2			16.8
— 10+ 14 ,,		7.0	6.6		7.3		0.4	16.5
— 14+ 20 ,,		5.7	6.0		5.0		0.7	13.5
— 20+ 28 ,,		6.1	4.6		5.0		1.6	12.4
— 28+ 35 ,,		4.8	3.9		3.7		7.7	9.6
— 35+ 48 ,,		4.8	4.0		3.4		16.5	8.5
— 48+ 65 ,,		3.6	3.3		2.8		19.5	5.5
— 65+100 ,,		3.6	2.7		1.6		21.5	4.9
—100+150 ,,	28.1	2.8	3.0	10.9	3.2	10.0	7.2	3.3
—150+200 ,,		2.8	2.1		2.1		13.2	2.7
—200 ,,		18.9	3.1		3.1		11.7	6.3
Head (Calc.)		100.0	100.0		100.0		100.0	100.0

lateritised ore No. 5790; (iv) Hard ore with different degree of lateritisation No. 5791.

Two from Joda East: (i) Soft laminated flaky—No. JE-1 (ii) Mixed hard spongy soft ore—JE-2.
Two-from Noamundi washery:

(i) -9 mm+3 mm washed product $(-\frac{3}{8}''+\frac{1}{8}'')$
(ii) -3 mm $(-\frac{1}{8}'')$ classifier sand.

The chemical analysis of the eight samples is given in Table 2.12.

Treatment of the First Six Samples

Washing and heavy media separation tests were conducted with the samples after crushing to —50 mm size on the —50 mm +6 mesh material in each case. No beneficiation work was attempted on —6 mesh fraction.

Heavy media separation tests with the washed products were conducted using a suspension of galena in water adjusted to specific gravity of 2.9 to 3.0.

Results

The six samples were in general poorer in grade than those investigated earlier and iron recoveries in the concentrates were relatively lower due to higher rejection of laterite and shale in the float.

The iron contents in the rejected laterite varied according to the degree of lateritisation. A brief summary of the results obtained by washing and heavy media separation is presented in Table 2.13.

TABLE 2.11—CHEMICAL ANALYSIS OF TYPICAL SINTERS

Product	ASSAY %					
	Total Fe	FeO	SiO_2	Al_2O_3	CaO	MgO
1. Sinter from —9 mm unwashed ore	60.1	25.3	7.3	6.8	0.5	0.9
2. Sinter from —9 mm washed ore (—50 mm)	61.6	22.9	6.8	6.2	0.4	0.8
3. Sinter from —9 mm washed ore (—25 mm)	60.8	22.9	5.9	6.4	1.0	1.3

TABLE 2.12—CHEMICAL ANALYSIS OF THE EIGHT IRON ORE SAMPLES FROM TISCO

Sample	ASSAY %					
	Fe	SiO_2	Al_2O_3	P	S	LOI
Noamundi						
1. Soft laminated No. 5788	58.0	2.2	7.4	0.13	0.2	7.1
2. Lateritised soft No. 5789	58.7	1.9	6.9	0.18	0.32	7.2
3. ROM mixture No. 5790	60.94	2.34	4.7	0.22	0.04	6.1
4. Hard ore No. 5791	62.0	2.2	3.9	0.13	Trace	4.8
5. **Joda East** Soft laminated flaky No. JE-1	56.8	8.0	5.8	0.06	0.3	4.8
6. Mixed hard spongy No. JE-2	56.8	2.4	5.5	0.27	0.35	9.5
Washery samples from Noamundi						
7. —9 mm+3 mm washed product	56.4	2.6	6.8	N.D.	N.D.	7.7
8. —3 mm classifier sand	55.0	3.0	7.7	N.D.	N.D.	9.4

TABLE 2.13—RESULTS OF THE SIX IRON ORE SAMPLES—WASHING AND H.M.S. OPERATION

Product	Wt. %	ASSAY %			RECOVERY %		
		Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
Noamundi							
1. Soft laminated ore (Head)	—	58.0	2.2	7.4			
(a) Washing conc.	86.0	59.7	1.52	6.7	88.1	58.2	76.6
(b) Washing+H.M.S. conc.	63.6	63.7	1.2	4.6	69.1	32.7	37.6
2. Lateritised soft ore (Head)	—	58.7	1.9	6.9			
(a) Washing conc.	92.6	60.1	1.26	5.98	93.8	75.8	84.5
(b) Washing+H.M.S. conc.	71.9	61.5	1.1	4.56	75.1	50.6	51.2
3. ROM Ore (Head) from mining face		60.94	2.34	4.7			
(a) Washing conc.	89.1	61.6	1.86	4.35	91.0	66.3	79.5
(b) Washing+HMS conc.	72.0	65.3	0.9	2.4	77.9	29.5	36.0
4. Hard ore with lateritisation (Head)		62.0	2.2	3.9			
(a) Washing conc.	96.0	63.8	1.9	3.3	96.6	89.9	90.7
(b) Washing+HMS conc.	82.5	65.7	1.06	1.74	87.1	43.2	42.0
Joda East							
5. Soft-Laminated (Head)		56.8	8.0	5.8			
(a) Washing conc.	78.5	63.4	3.6	3.6	87.8	32.5	45.6
(b) Washing+HMS conc.	73.9	64.9	2.5	2.6	84.1	22.3	33.3
6. Mixed hard and spongy ore (Head)		56.8	2.4	5.5			
(a) Washing conc.	94.8	57.7	2.1	5.4	95.2	86.5	93.3
(b) Washing+HMS conc.	59.9	61.2	1.04	3.8	63.8	29.6	41.5

As seen from the results (Table 2.13) it is confirmed that washing would solve the problem of handling and screening of wet and sticky ores and would thus produce a clean and sized product free from adhered fines and also a properly classified —9 mm material suitable for sintering. Washing by itself, however, might not yield a product with an optimum desirable alumina to silica ratio for efficient blast furnace operation. Heavy media separation process worked satisfactorily with all the ores having gangue either laterite or shale. Laterite was effectively rejected at specific gravity of 3.0 while shale at 3.1 sp. gr. considerable amount of insolubles were reduced and thus the grade of the final product was considerably improved.

Spiral test with float product obtained from ROM ore — Mechanised Mine Face Noamundi S. No. 5790, was conducted after grinding it to −65 mesh to see whether any liberation of nematite and goethite if any would be there after grinding, and produce a good grade spiral concentrate. The grade of the concentrate obtained was Fe= 49.3%, SiO_2=4.2% and Al_2O_3=11.4% from a feed with a grade of Fe=46.5%, SiO_2= 5.6% and Al_2O_3=13.3 and proved to be quite low and no useful purpose would be therefore served by treating the float product. The same would be the case with the rest of the float samples also.

Washery Samples from Noamundi

The two samples viz. −9 mm+3 mm washed product and −3 mm classifier sand were tested for jigging, H.M.S., humprey's spiral, magnetic separation and electrostatic separation.

−9 mm+3 mm washed product assayed 56.4% Fe, 2.6% SiO_2 and 6.8% Al_2O_3. Jigging followed by spiral treatment and also jigging followed by magnetic separation yielded almost similar grades of concentrates averaging over 62.0% Fe with slight variation in iron recoveries (61.8% and 63.6%) with total insolubles of 5.0% in both cases.

Heavy Media separation of the −9 mm +6 mesh product yielded a high grade concentrate assaying 67.0% Fe with 38% recovery. If, however, this sink product was mixed with −6 mesh fraction the grade came down to 61.7% Fe with increase of insolubles from 1.13% to 5.06%. This grade could be further improved by beneficiating the −6 mesh fraction also before mixing.

−3 mm classifier sand assayed 55.0% Fe, 3.0% SiO_2 and 7.7% Al_2O_3. Straight magnetic separation produced a concentrate assaying 60.4% Fe and insolubles of 6.32% with iron recovery of 56.7% in it. Jigging followed by magnetic separation improved the grade to 63.7% Fe and 3.83% insolubles with an iron recovery of 52.1%. Jigging followed by spiral treatment yielded a better grade of concentrate assaying 64.4% Fe, 1.26% SiO_2 and 1.8% Al_2O_3 with low Fe recovery of 39.5%. The above results indicated that the washed product as well as the classifier sand could be successfully beneficiated to produce a suitable material for sinter feed with low recoveries.

5. Beneficiation of Classifier Sand and Heavy Slime From the Noamundi Washing Plant, Tisco.

Two iron ore samples namely (i) −6 mesh classifier sand and (ii) heavy slime (taken from the settling tanks) of the Noamundi Washing Plant of TISCO were received to investigate the possibility of their upgrading by employing Humphrey spirals.

(i) −6 mesh classifier sand had the following chemical and sieve analysis:

Chemical analysis		Sieve analysis	
		Size	Wt. %
Fe	59.4%	6+ 8 mesh	8.9
SiO_2	1.95%	8+10 mesh	11.1
Al_2O_3	6.28%	10+14 mesh	13.3
L.O.I.	6.8%	−14+20 mesh	11.1
		−20+28 mesh	10.0
		−28+35 mesh	8.9
		−35+48 mesh	10.0
		−48+65 mesh	7.8
		−65+100 mesh	7.8
		−100 mesh	11.1
			100.0

As the sample was too coarse for Humphrey Spiral treatment, it was sized into two fractions −6+28 and −28 mesh. The −6+28 mesh fraction was subjected to jigging and the −28 mesh fraction treated in the spiral. The combined jig+spiral concentrate was 63.2% by weight and assayed 62.25% Fe, 1.27% SiO_2 and 4.32% Al_2O_3 with recoveries of 65.8% Fe, 43.1% SiO_2 and 42.9 Al_2O_3.

Straight jigging of the sample yielded a concentrate 80% by weight and assayed 61.01% Fe, 1.46% SiO_2 and 3.84% Al_2O_3 with recoveries of 82.6% Fe, 61.5% SiO_2 and 59.5% Al_2O_3. Recovery of iron is high in straight jigging than the earlier test.

(ii) Slime treatment— The slime assayed 59.12% Fe, 5.19% SiO_2 and 6.41% Al_2O_3 and contained 84.3% of −325 mesh material. When this was subjected to spiral treatment, the concentrate 28.8% by weight assaying 60.54% Fe, 3.14% SiO_2 and 5.49% Al_2O_3 was produced with a poor recovery of 29.9% Fe. in it. This poor recovery was due to its very fine nature for satisfactory separation of alumina by the spirals.

6. Beneficiation Studies of Top Bench Iron Ore and Kanga Iron Ore From the Western Ridge, Noamundi, Tisco.

Four samples of iron ore from the top bench of Noamundi as detailed below were received from TISCO for sink and float, as well as jigging test for comparative studies:

(i) R.O.M. ore from the top bench 21.10.61 (Mostly from laterite capping)

(ii) Kanga ore from the top bench 21.10.61

(iii) Feed to H.M.S. Plant from top bench on 29.10.61

(iv) Sink collected from the H.M.S. Plant treating washed ore of top bench on 29.10.61.

(i) The R.O.M. ore from the top bench assayed 51.07% Fe, 6.48% SiO_2 and 8.96% Al_2O_3. The original sample was of 150 mm lumps in size. Jigging of the sample after crushing to −3 mesh produced a concentrate of Wt% 50.1%, and assaying 57.0% Fe, 3.57% SiO_2 and 6.4% Al_2O_3 with a recovery of 55.9% Fe.

Heavy media separation of the sample upto +6 mesh after crushing to 2" (50 mm) size produced a concentrate assaying 63.59% Fe, 1.33% SiO_2 and 3.85% Al_2O_3 with a recovery of 49.0% Fe. Jigging of the −6 mesh fraction produced a concentrate assaying 56.24% Fe, 3.16% SiO_2 and 7.29% Al_2O_3 with an additional recovery of 3.8% Fe. The combined heavy media and jig concentrate would yield a combined concentrate assaying 63.01% Fe, 1.48% SiO_2 and 4.13% Al_2O_3 with an overall recovery of 52.8% Fe.

The comparison of the results obtained with heavy media separation and jigging tests indicated that the former yielded better results and its amenability to treat the ore at a coarse size.

(ii) Kanga ore assayed 64.08% Fe, 1.27% SiO_2, and 2.22% Al_2O_3 Crushing the sample to −50 mm size and screening out the 3 mesh fraction produced a −50 mm +3 mesh fraction assaying 65.63% Fe, 1.05% SiO_2 and 1.83% Al_2O_3 with a recovery of 91.3% Fe. The −3 mesh fraction assaying 57.33% Fe, 3.2% SiO_2 and 5.78% Al_2O_3 by jigging produced a concentrate assaying 62.5% Fe, 1.99% SiO_2 and 3.58% Al_2O_3 with an additional recovery of 6.9% Fe. The combined concentrate would assay 65.4% Fe, 1.12% SiO_2 and 1.96% Al_2O_3 with a total recovery of 98.2% Fe. The Kanga iron ore was already of high grade and no beneficiation was considered necessary.

(iii) The feed sample to H.M.S. Plant after crushing to 2"-3" size and the 1/8" fraction, assayed 60.5% Fe, 2.18% SiO_2 and 5.51% Al_2O_3. This sample after crushing to −3 mesh and jigging produced a jig concentrate assaying 65.83% Fe, 0.5% SiO_2 and 2.24% Al_2O_3 with a recovery of 66.8% Fe.

Heavy media separation of the sample as received at a medium of Sp.Gr. 3.0 produced a concentrate assaying 65.9% Fe, 0.76% SiO_2 and 2.0% Al_2O_3 with a recovery of 74.6% Fe. Thus the grade of Jig concentrate and H.M.S. concentrate are almost identical with more iron recovery with H.M.S. treatment. As such jigging of the sample appeared to be unnecessary. The H.M.S. float portion when subjected to jigging after crushing to −3 mesh yielded a concentrate assaying 57.2% Fe, 2.68% SiO_2 and 7.91% Al_2O_3 with an additional recovery of 5.7% Fe. Thus the combined H.M.S. and jig concentrate would assay 65.21% Fe, 0.91% SiO_2 and 2.48% Al_2O_3 with a total recovery of 80.3% Fe.

(iv) The H.M.S. sink product obtained at Noamundi H.M.S. Plant assayed 63.46% Fe, 1.14% SiO_2 and 3.45% Al_2O_3. This sample as received was subjected to Heavy media separation at a Sp.gr. of 3.0 and produced a sink assaying 65.55% Fe, 0.62% SiO_2 and 2.25% Al_2O_3 with a recovery of 77.3% Fe. This indicated that better results of Noamundi plant could be obtained by better operational control.

Conclusively heavy media separation proved to be more efficient when compared to jigging for beneficiating the top bench ore of the Noamundi iron mines of TISCO.

7. Studies on the Production of High Basicity Sinters From Noamundi Washed Iron Ore Fines and Incorporating Blue Dust

In view of the long range expanding programme of Noamundi Mines of TISCO, it was thought desirable by TISCO authorities to study the sintering characteristics of −10 mm fines from Noamundi ore only making both fluxing and non-fluxing sinters. The effective utilization of 'blue dust' mixed with the iron ore fines for sintering with out affecting the metallurgical quality of the sinter was another problem. These two problems were sponsored by TISCO for studies at NML. The results of these studies are as follows :

Sintering Studies

The sintering studies were undertaken in the laboratory sinter plant designed and fabricated at NML whose description of details are already dealt with earlier.

The raw materials required for sintering studies were all received from TISCO except dolomite. Their chemical analyses and sieve analysis are given in Tables 2.14 and 2.15.

Sintering tests with the washed iron ore fines with varying percentages of water, coke and return fines showed that 6% water, 4% coke and 25% return fines were optimum for the production of non-fluxing sinters.

Self-fluxing sinters were produced keeping the above optimum values of water, coke and return fines, changing the basicity ratio of the charge from 1.4 to 3.5 by adding varying amounts of limestone and dolomite (4 : 1 ratio). It was observed that the rate of sintering remained constant upto a basicity of 2.0 and then increased upto a basicity of 3.0. Sinter strength was maximum at a basicity of 2.0. The best result was obtained at 2.0 basicity considering both strength and rate of sintering. The addition of blue dust in the mix from 10% to 50% indicated that the rate of sintering decreased with the increase in the amount of blue dust. This was due to the introduction of more fines in the

TABLE 2.14—CHEMICAL ANALYSES OF RAW MATERIALS

Raw Material	ASSAY %					Others
	Fe	SiO_2	Al_2O_3	CaO	MgO	
1. Iron Ore						
i) Washed classifer sand (—10 mm)	59.1	1.72	4.95	0.33	0.48	L.O.I 8.2
ii) Blue dust (—10 mm)	68.6	0.66	1.00	0 14	0.27	
2. Flue dust	36.0	13.00	10.6	4.4	Trace	
3. Coke		12.50	6.4	1.0	0.5	Fixed C=71.9 ; Ash=24 9; V.M =2.5 Moisture=0.8
4. Limestone		8.3	1.7	45.9	3.6	Fe_2O_3=0.85; CO_2 =36.64
5. Dolomite		2.5	0.7	29.3	21.6	e_2O_3=0.73; CO_2=45.4 L.O.I=45.4

TABLE 2.15—SIEVE ANALYSIS OF RAW MATERIALS

Size	Wt %					
	—10 mm washed classifier sand	Blue dust	Flue dust	Coke	Lime Stone	Dolomite
+0.371″	—	12.5	—	—	—	—
—0.371″ +3 mesh	0.9	2.4	—	—	—	—
—3+4 mesh	12.0	5.0	—	—	4.6	3.9
—4+6	16.6	3.7	—	—	24.7	16.8
—6+8	16.2	3.6	—	2.3	17.6	17.7
—8+10	12.6	3.6	—	19.0	12.6	15.4
—10+14	11.7	2.9	—	18.0	8.4	10.1
—14+20	9.1	2.5	4.0	12.6	5.6	6.2
—20+28	6.7	1.6	7.1	11.4	4.5	4.6
—28+35	4.4	3.5	10.4	8.7	3.2	2.6
—35+48	3.1	2.6	15.7	6.0	3.1	1.8
—48+65	2.0	2.5	16.6	5.7	2.6	1.8
—65+100	1.3	2.0	18.1	5.1	2.7	1.2
—100+150	0.6	1.5	12.3	4.6	10.4	18.5
—150+200	0.5	1.8	6.8	2.2		
—200 mesh	2.5	48.3	9.0	4.4		

form of blue dust affecting the permeability, resulting in the decreased rate of sintering. Increase of water to 8% gave the optimum results with use of blue dust.

Introduction of blue dust in the sinter mix further minimised the flux requirements and yielded good metallurgical grade sinters of high strength with greatly improved chemistry. The results of sintering obtained with dry screened Noamundi iron ore fines, to produce fluxed as well as unfluxed sinters indicated that in view of the generally high delterious gangue content, they are of little metallurgical value and do not confer through their use any of the well established advantages expected from a sinter burden, such as increased iron output, lowered fuel and flux rates etc.

8. Pilot Plant Studies on the Beneficiation of Joda Flaky Iron Ore Sample From Tisco

About 100 tonnes of flaky iron ore from Joda mines was sent to NML by TISCO for washing and upgrading studies. NML has earlier studied the washing characteristics of iron ore from Joda on a pilot plant scale and the results given as I.R. No. 180/60.

The present sample was similar to the previous one in many respects except in having more fines and appeared to be more sticky in nature. Washing of the ore at −50 mm and −30 mm sizes produced upgraded lumps of suitable grade for use in the blast furnace.

The results of the tests are given briefly as follows :

The ore comprised of massive hematite as well as laminated type with an admixture of hematite and hydroxides of iron goethite, limonite and laterite materials. The finer fractions were expected to be comparatively enriched with aluminous and siliceous minerals than the lumps.

The chemical analysis of the R.O.M. sample is as follows :

Constituent	Assay %
Fe	62.92
FeO	Trace
SiO_2	3.4
Al_2O_3	4.0
S	0.044
P	0.054
CaO	Trace
MgO	Trace
TiO_2	0.21
L.O.I.	1.95

The ore was of a good grade with a total insoluble content of 7.4%. Chemical analysis of the sieve fractions of the original sample indicated progressive increase in Al_2O_3 and SiO_2 and decrease in Fe content with the increase in fineness. The screenability tests were conducted on with 25 tonne lots crushed −50 mm −30 mm samples varying moisture contents from 5% to 15%. The results indicated that except in summer months with absolutely dry ore feed, the screening should be done wet with above 15% moisture content or scrubbing of ore followed by wet screening should be adopted.

Washing tests were conducted with 22 tonne lots of −50 mm and −30 mm crushed samples. They resulted in washed lumps, classifier sand and slime in each case. The slime sample was treated in a cyclone to recover some more iron as cyclone underflow and reject as much of the insolubles in the overflow. The results of washing and cycloning are given in Tables 2.16.

The results indicated that washing at a comparatively large size of −50 mm would give suitable grade of Fe with satisfactory recovery than the other size. Some additional data on the samples are given in Table 2.17.

The crushing strength, shatter, tumbler and abrasion indices of the sample indicated that though the ore was looking compact in nature, it was comparatively softer and the friable variety was weaker in structure, while the laminated variety had the maximum crushing strength.

9. Pilot Plant Studies on the Beneficiation of Khondband Hard Ore Sample From Tisco

The sample consisted mostly of lumps varying in size from 100 mm down to fines. The ore was massive, lumpy and compact and comprised of hematite with goethite, limonite and laterite.

The chemical analysis of R.O.M. sample is as follows :

Constituent	Assay %
Fe	63.0
FeO	Trace
SiO_2	2.9
Al_2O_3	4.0
S	0.1
P	0.08
CaO	Trace
MgO	Trace
TiO_2	0.23
L.O.I.	2.75

The screenability tests were conducted on 25 tonne lot after crushing to −50 mm and −30 mm sizes. The results indicated that a moisture content of about 5% would give the best screenability in both the cases.

Washing tests were conducted with 22 tonne lot samples after crushing to −50 mm and −30 mm sizes. The slime resulted during

TABLE 2.16—RESULTS OF WASHING AND CYCLONING

Product	Wt %	Assay % Fe	Assay % SiO_2	Assay % Al_2O_3	Distribution % Fe	Distribution % SiO_2	Distribution % Al_2O_3
Washing at—30 mm size :							
(a) Washed lumps (—30+10 mm)	40.1	66.4	1.52	1.85	42.2	18.2	19.3
(b) —10 mm classifer sand	41.5	66.1	1.63	2.0	43.5	20.1	21.6
(c) Cyclone underflow	8.3	61.76	5.20	5.3	8.2	12.8	11.5
(d) Cyclone overflow	10.1	38.0	16.2	18.0	6.1	48.9	47.6
Head (Calc)	100.0	63.0	3.36	3.83	100.0	100.0	100.0
Washing at—50 mm size :							
(a) Washed lumps	42.0	66.5	1.7	1.95	44.2	21.2	21.0
(b) —10 mm classifer sand	41.1	66.0	2.0	2.1	42.9	24.4	22.2
(c) Cyclone underflow	6.6	61.0	4.9	5.1	6.4	9.6	8.6
(d) Cyclone overflow	10.3	39.4	14.65	18.2	6.5	44.8	48.2
Head (Clac)	100.0	63.1	3.37	3.89	100.0	100.0	100.0

TABLE 2.17—SOME ADDITIONAL DATA ON THE SAMPLES

Product/Sample	Bulk density tonnes/Cu.M.	Moisture content %	Angle of repose
1. R.O.M. Sample — 50 mm washing	1.95	3.0%	37°12′
2. Lumps	2.04	5.6%	37°
3. Classifier Sand — 30 mm washing	1.96	15.0%	36°54′
4. Lumps	1.96	5.1%	37°12′
5. Classifier Sand	1.94	13.4%	37°

washing operation was treated in a cyclone. Washing and cyclone results are given on Tables 2.18.

The above results indicated that crushing at finer size (−30 mm) and washing produced a product superior in quality to the one of −50 mm test, but the iron recovery was less in the former case. The classifier sand of −30 mm test was of superior quality and better recovery. The cycloning of the slime did not produce a concentrate of acceptable grade in either case. Washing at −30 mm size was found to be more beneficial for this sample as more of silica-alumina could be rejected than with the −50 mm size test.

The shatter, tumbler and abrasion indices for the washed products showed that the ore was compact and hard in nature. The physical properties of R.O.M. sample as well as for washed products are given in Table 2.19.

10. Pilot Plant Beneficiation Studies of Noamundi Hard Iron Ore Sample from Tisco

With their expansion programme TISCO wanted to assess the Noamundi hard iron ore for its utilization as blast furnace feed by conducting washing tests followed by physical tests, i.e. shatter, tumbler and abrasion indices at NML. The results of these studies are as follows :

The iron ore comprised of hematite (massive variety) followed by hydrated oxides of iron with argillaceous/arenaceous material. The chemical analysis of R.O.M. sample (100 tonne lot) is given below :

	Assay %		Assay %
Fe	64.0	S	0.04
SiO_2	1.86	P	0.085
Al_2O_3	3.30	TiO_2	0.2
CaO	Trace	L.O.I	3.60
MgO	Nil		

Product	Wt %	Assay %			Distribution %		
		Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
Washing at —50 mm							
1. Washed lumps (—50+10 mm)	77.6	66.0	1.15	2.7	81.7	29.4	52.1
2. Classifier sand (—10 mm)	16.4	57.96	3.68	6.2	15.1	19.8	25.3
3. Cyclone under flow	2.5	39.2	21.2	11.4	1.6	18.1	7.1
4. Cyclone overflow	3.5	29.8	26.7	17.4	1.6	32.7	15.5
Head (Calc)	100.0	62.8	3.04	4.03	100.0	100.0	100.0
Washing at —30 mm							
5. Washed lumps (—30+10 mm)	67.7	66.5	1.11	2.38	71.7	24.0	40.7
6. Classifier Sand (—10 mm)	22.9	61.0	2.54	4.27	22.4	18.6	24.8
7. Cyclone underflow	3.5	44.88	15.0	10.92	2.5	16.9	9.9
8. Cyclone overflow	5.9	36.2	21.6	16.57	3.4	40.5	24.6
Head (Calc)	100.0	62.7	3.12	3.95	100.0	100.0	100.0

TABLE 2.19—PHYSICAL PROPERTIES OF R.O.M ORE AND WASHED PRODUCTS

Product	Moisture content %	Angle of repose (Degrees)	Bulk density Tonnes/m^3
1. R.O.M. Ore	1.2	42°48′	2.1
2. **Washed Lumps**			
— 50 mm washed product	2.6	39°18′	2.33
— 30 mm washed product	3.0	37°	2.27
3. **Classifier Sand**			
— 50 mm test	11.0	38°	1.95
— 30 mm test	11.4	37°	2.05

The chemical analysis indicated that the ore was of good grade.

Tests were done on 25 tonne lot samples. One lot was crushed to — 50 mm and the other to — 30 mm size. Screenability tests with — 50 mm and — 30 mm samples indicated that the increase of moisture content screenability deteriorated and reached minimum (the % of — 10 mesh material) when it was 5% in the case of — 50 mm sample and 7.5% with — 30 mm samples. The best results were achieved with 15% moisture in both cases. As such the screening should be done wet with 15% moisture or scrubbing the ore followed by wet screening to be adopted.

Washing tests were done with 22 tonnes lot samples with the crushed — 50 mm and — 30 mm ore respectively. The results are given on Table 2.20.

The results indicated that both the tests produced washed lumps containing 66.0% and 66.4% Fe. The classifier sand obtained was also of suitable grade for sintering. It also indicated that washing of the sample at a finer size than 50 mm did not have any added advantage. Moreover the loss of iron value in the slime was comparatively more in the case of washing at— 30 mm size. Some additional data on the samples are given Table 2.21.

Treatment of Slime

The slimes obtained from washing at — 50 mm and — 30 mm sizes assayed 58.6% and 51.6% Fe respectively containing 15.1% and 16.4% of the total iron present in the sample. These were treated in a cyclone designed and fabricated at N.M.L. to recover some portion of iron from them. The conditions of the cyclone worked are (a) Nozzle diameter=9.5 mm ; (b) Pulp density of cyclone feed=10.7% solids ; (c) Operating pressure=25 psi. The results obtained in cycloning are given on Table 2.22.

The results indicated that 11.62 and 11.3 respectively of the total iron values lost in the slime would be recovered by cycloning with

TABLE 2.20—RESULTS OF WASHING TESTS (SCRUBBING AND WET SCREENING)

Product	Wt%	ASSAY %			Distribution %		
		Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
A. **—50 mm lot**							
—50+10 mm washed lumps	56.7	66.0	1.28	2.20	58.5	37.8	37.4
—10 mm classifier sand	26.8	63.2	1.77	4.43	26.4	24.8	35.6
Slime	16.5	58.6	4.33	5.60	15.1	37.4	27.0
Head (Ca c.)	100.0	64.0	1.92	3.34	100.0	100.0	100.0
B. **—30 mm lot**							
—30+10 mm washed lumps	52.5	66.4	1.1	2.1	55.2	29.2	32.1
—10 mm classifier sand	29.2	63.1	2.1	4.4	28.3	33.8	37.6
Slime	18.3	57.6	4.5	5.7	16.5	37.0	30.3
Head (Calc)	100.0	63.8	2.0	3.43	100.0	100.0	100.0

TABLE 2.21—SOME ADDITIONAL DATA ON NOAMUNDI HARD IRON ORE SAMPLES

	Bulk Density (tonnes/m^3)	Moisture content %	Angle of Repose (Degrees)
A. R.O.M. Sample	1.95	3.0	36°24′
B. — 50 mm washed test			
(a) Lumps	2.12	4.47	35°
(b) Classifier Sand	1.93	13.72	39°24′
C. — 30 mm washed test			
(a) Lumps	1.96	4.97	36°
(b) Classifier Sand	1.90	14.0	39°48′

grades of 62.1% and 62.0% Fe respectively in the underflow products. This fine concentrate could be mixed with classifier sand products for pelletizing or sintering.

The shatter, tumbler and abrasion indices for the washed products showed that the ore under investigation was medium hard in nature.

11. Pilot Plant Studies on the Beneficiation of Joda Hard Iron Ore Sample from Tisco

A 100 tonnes r.o.m. hard iron ore sample from Joda was sent to NML by TISCO for detailed studies including crushing, secreening and washing properties as well as physical properties. The results are summarised as follows:

The sample consisted mostly of lumps varying in size from 100 mm down to fines. It comprised of crystalline hematite along with some hydrated iron oxiodes and minor amounts of siliceous and aluminous minerals. The chemical analysis of R.O.M. sample is given below:

Constituent	Assay %	Constituent	Assay %
Total Fe	63.32	P	0.052
FeO	0.72	CaO	0.434
SiO_2	2.34	TiO_2	0.0134
Al_2O_3	4.00	MgO	Trace
S	0.08	L.O.I.	2.26

Physical Properties of R.O.M. Samples:

1. Bulk density=2.44 t/m^3
2. Moisture content=0.72%
3. Angle of repose=39°48'

Screenability and washing tests were conducted on 25 tonne lot sample at two different sizes namely —50 mm and —30 mm. The screenability tests indicated that the critical moisture content of the sample could be taken as 2.5%

TABLE 2.22—RESULTS OF CYCLONING

Product	Wt%	Wt% W.R.O.	ASSAY % Fe	SiO_2	Al_2O_3	Dist. % Fe w.r.o.
A. **Slime from —50 mm Test**						
Cyclone Underflow	66.4	10.95	62.1	1.9	4.34	11.62
Cyclone overflow	33.6	5.55	51.5	8.8	9.0	—
Head (Calc)	100.0	16.50	58.5	4.22	5.9	
B. **Slime from —30 mm Test**						
Cyclone underflow	57.4	10.5	62.0	2.1	4.4	11.3
Cyclone overflow	42.6	7.8	52.0	8.0	7.5	—
Head (Calc)	100.0	18.3	57.8	4.4	5.72	

to 3.0%. Some additional data on Joda hard ore sample are given in Table 2.23.

TABLE 2.23—ADDITIONAL DATA ON JODA HARD ORE SAMPLE

Product	Bulk density (tonnes/m^3)	Moisture content %	Angle of repose (Degrees)
—50 mm washed product			
(a) Lumps	2.55	1.8	38°
(b) Classifier sand	2.25	9.2	38°
—30 mm washed product			
(a) Lumps	2.4	2.1	39°12′
(b) Classifier sand	2.24	9.0	37°30′

Washing results are given below which included scrubbing and wet screening at —50 mm and —30 mm crushed ore sample. The slimes produced during washing were treated in a cyclone and the results are given in Table 2.24.

The results indicated that both the tests produced washed lumps containing 64.85% Fe and 65.50 indicating the enrichment of iron and elimination of claying materials slimes. The cycloning of slimes could not produce a concentrate of acceptable grade. The classifier sand obtained with —30 mm washing size produced a better grade than —50 mm test sample.

The shatter, tumbler and abrasion indices for the washed products showed that the ore sample was hard and compact in nature. Washing at —30 mm size was found more beneficial for this sample than at —50 mm size.

A comparative assessment of the four iron ore samples from TISCO is given in Table 2.25-2.33.

12. Davis Tube Tests with a Magnetite Sample received from M/s. T.R.F. Ltd. Jamshedpur.

A sample of magnetitie (of lumps 60 mm to 15 mm in size) was received at NML from M/s. T.R.F. Ltd., for carrying out Davis tube magnetite separation tests at 200 mesh size, to determine the percentage magnetics, the specific gravity of the magnetics and the magnetic succeptibility. The tests were carried out at NML in a Davis tube tester manufactured by Ding's Magnetic Separator Co., U.S.A. It consisted of an electromagnet between the poles of which, a glass tube was set at an angle of 45°. The tube was supported by an agitating mechanism, which was actuated by a small electric motor. The tube was simultaneously rotated and agitated between the magnetic poles when in operation. The speed of agitation could be changed according to the setting made on the governor-controlled constant speed motor.

TABLE 2.24—RESULTS OF WASHING TESTS AND CYCLONING

—50 mm test (A)

Product	Wt %	ASSAY %			Distribution %		
		Fe	SiO_2	Al_2O_3	Fe	SiO_2	Al_2O_3
(Washed lump (—50+10 mm)	77.0	65.50	1.7	2.74	79.7	52.4	53.0
Classifier sand (—10 mm)	17.1	59.70	2.86	6.04	16.1	20.0	26.0
Cyclone underflow	2.4	49.98	5.52	13.89	1.9	5.3	8.3
Cyclone overflow	3.5	39.58	15.86	14.50	2.3	22.3	12.7
Head (Calc)	100.0	63.22	2.50	3.97	100.0	100.0	100.0
—30 mm Test (B)							
Washed lump (—30+10 mm)	70.6	65.85	1.54	2.22	73.6	42.7	39.6
Classifier sand (—10 mm)	22.1	61.35	2.48	5.60	21.5	21.5	31.3
Cyclone underflow	3.1	49.00	5.81	13.92	2.4	7.1	10.9
Cyclone overflow	4.2	37.90	17.40	17.10	2.5	28.7	18.2
Head (Calc)	100.0	63.15	2.55	3.96	100.0	100.0	100.0

TABLE 2.25—CHEMICAL ANALYSES OF ORIGINAL SAMPLES (Assay %)

Constituents	Joda Flaky	Khondband	Noamundi	Joda Hard
Fe	62.92	63.00	64.00	63.32
SiO_2	3.40	2.90	1.86	2.34
Al_2O_3	4.00	4.00	3.80	4.00
L.O.I.	1.95	2.75	3.68	2.26

The tests were done with crushed and ground material of —200 mesh size. The results are given in Table 2.34.

The results indicated that magnetic concentrate analysing 68.8% total Fe could be successfully produced with a total recovery of 97.7% Fe at a field intensity of 2500 gauss (0.8 amp) and any further increase did not improve the results much.

TABLE 2.26—SIEVE ANALYSES OF —50 MM AND —30 MM CRUSHED SAMPLES

Size	Joda Flaky		Khondband		Noamundi		Joda Hard	
	WEIGHT %							
	—50 mm	—30 mm	—50 mm	—30 mm	—50 mm	—30 mm	—50 mm	—30 mm
+50 mm	—	—	4.7	—	1.4	—	3.3	—
—50+25 mm	16.5	9.7	48.6	24.3	31.3	14.0	47.7	24.5
25+12.5 mm	21.5	25.4	17.4	34.9	19.8	27.7	19.6	37.0
—12.5+10 mm	8.8	9.7	9.4	10.4	9.9	12.2	8.3	10.6
—10 mm+10 mesh	38.8	45.1	14.0	21.1	18.5	22.5	12.5	17.0
10 mesh	14.4	10.1	5.9	9.3	19.1	23.6	8.6	10.9

TABLE 2.27—RESULTS OF SHATTER TESTS

Product	Joda Flaky	Khondband	Noamundi	Joda Hard
— 50+10 mm washed lumps	10.45	7.80	9.816	5.04
— 30 mm+10 mm washed lumps	10.89	8.54	11.576	5.26

TABLE 2.29—CRUSHING STRENGTH RESULTS KG/CM²

Variety	Joda Flaky	Khondband	Noamundi	Joda Hard
Massive and compact	1250	2880-4400	2150-3500	2985-4500
Faminated	3375	2150-2350	1900-3100	2275-2415
Lriable (soft)	165	1285-1930	950-1400	1083-1790

TABLE 2.28—TUMBLER INDEX RESULTS AND ABRASION INDEX RESULTS

Product	Joda Flaky		Khondband		Noamundi		Joda Hard	
	Tumb. Index %+6.3 mm	Abras Index %—28 mesh	%+6.3 mm Tumb.	%—28 mesh Abras	Tumb. %+6.3 mm	Abras %—28 mesh	Tumb. %+63	Abras. %—28 mesh
—50 mm+10 mm washed lumps	63.0	12.6	83.5	6.75	75.44	11.47	85.55	6.25
—30 mm+10 mm washed lumps	59.6	17.6	83.45	7.15	73.67	13.29	85.45	6.45

TABLE 2.30—RESULTS OF SCREENABILITY TESTS

% Moisture	Joda Flaky —50 mm +10 mm	Joda Flaky —30 mm +10 mm	Khondband —50 mm +10 mm	Khondband —30 mm +10 mm	Noamundi —50 mm +10 mm	Noamundi —30 mm +10 mm	Joda Hard —50 mm +10 mm	Joda Hard —30 mm +10 mm
	Wt%	Wt%	Wt%	Wt%	Wt%	Wt%	Wt%	Wt%
0	53.2	55.2	19.0	27.40	37.8	46.1	21.1	27.9
2	—	—	18.7	26.70	—	—	—	—
3	—	—	16.55	25.35	—	—	20.1	25.7
4	—	—	17.25	25.00	—	—	—	—
5	50.0	49.5	20.00	27.15	29.8	43.5	21.7	27.0
6	—	—	21.15	28.30	—	—	—	—
7.5	7.7	6.0	—	—	33.0	41.8	22.0	27.3
10.0	14.8	14.4	—	—	34.66	42.4	22.2	27.5
12.5	30.9	29.1		—	35.70	34.4	—	—
15.0	53.0	52.0	—	—	37.50	46.0	—	—

TABLE 2.31—ADDITIONAL PHYSICAL CHARACTERISTICS

	Joda Flaky	Khond-band	Noamundi	Joda Hard
R.O.M. Sample				
Bulk density t/m³	1.95	2.1	1.95	2.44
Moisture content %	3.00	1.2	3.00	0.72
Angle of Repose	37° 12′	42° 48′	36° 24′	39° 48′
—50 mm washed product				
(a) **Lumps**				
Bulk density t/m³	2.04	2.33	2.12	2.55
Moisture content %	5.6	2.6	4.47	1.8
Angle of Repose	37°	39° 18′	35°	38°
(b) **Classifier sand**				
Bulk density t/m³	1.96	1.95	1.93	2.25
Moisture content %	15.0	11.0	13.72	9.2
Angle of Repose	36° 54′	38°	39° 24′	38°

—30 mm washed product

(a) **Lumps**				
Bulk density t/m^3	1.96	2.27	1.96	2.40
Moisture content %	5.1	3.0	3.97	2.1
Angle of Repose	37° 12′	37°	36°	39° 12
(b) **Classifier sand**				
Bulk density t/m^3	1.94	2.05	1.90	2.24
Moisture content %	13.4	11.4	14.0	9.0
Angle of Repose	37°	37°	39° 48′	77° 30′

The beneficiation study results of the various iron ore samples of Bihar are summarised and given in Table 2.35.

IRON ORE SAMPLES FROM BIHAR

References

1. Concentration of blast furnace flue dust from TISCO by S. B. Dasgupta & P. I. A. Narayanan, NML IR No. 62/55.
2. Beneficiation of classifier overflow from the Noamundi Iron Ore Washing Plant—by G. P. Mathur & P. I. A. Narayanan, IR No. 79/55.
3. Studies on the beneficiation of Iron Ores from TISCO—by G. V. Subramanya, G. P. Mathur, S. K. Banerjee, P. K. Sinha and B. L. Sengupta—NML IR No. 180/60.
4. Further studies on the beneficiation of iron ore samples from TISCO—by S. K. Banerjee, P. K. Sinha, B. L. Sengupta and P. I. A. Narayanan, NML IR No. 188/60.
5. Beneficiation of classifier sand and heavy slime from the Noamundi Washing Plant, TISCO—by S. B. Dasgupta, G. P. Mathur & P. I. A. Narayanan, NML IR No. 225/61.
6. Beneficiation of top bench iron ore and Kanga iron ore from the western ridge, Noamundi—by S. B. Dasgupta, G. P. Mathur and P. I. A. Narayanan, NML IR No. 227/61.
7. Studies of the production of high basicity sinters from Noamundi washed iron ore fines and incorporating blue dust—by P. K. Sinha, G. V. Subramanya & P. I. A. Narayanan, NML IR No. 272/63.
8. Pilot Plant studies on the beneficiation of Joda Flaky iron or sample from TISCO—by R. K. Kunwar, S. C. Maulik, B. L. Sengupta, S. K. Banerjee and G. P. Mathur, NML IR No. 707/72.
9. Pilot Plant studies on the beneficiation of Khond band hard iron ore sample from TISCO—by R. K. Kunwar, S. C. Maulik B. L. Sengupta, S. K. Banerjee and G. P. Mathur—NML IR No. 721/73.
10. Pilot Plant studies on the beneficiation of Noamundi hard iron ore sample from TISCO—by H. Patnaik, R. K. Kunwar, V. K. Sharma, B. L. Sengupta and G. P. Mathur, NML IR No. 739/73.
11. Pilot Plant studies on the beneficiation of Joda hard iron ore sample from TISCO—by S. C. Maulik, R. K. Kunwar B. L. Sengupta and G. P. Mathur—by NML IR No. 748/73.

TABLE 2.32—RESULTS OF WASHING TESTS

Feed : —50 mm material

Types of Ore

(1) Products	(2) Joda Flaky				(3) Khondband			
	Wt%	ASSAY %			Wt%	ASSAY %		
		Fe	S O_2	Al_2O_3		Fe	S O_2	Al_2O_3
—50 mm+10 mm lumps	42.0	66.5	1.7	1.95	77.6	66.0	1.15	2.7
—10 mm classifier	41.1	66.0	2.0	2.10	16.4	57.96	3.68	6.2
Slime	16.9	48.0	10.65	13.20	6.0	33.60	24.5	15.1
Head (Calc)	100.0	63.1	3.34	3.90	100.0	62.80	3.04	4.03
Feed : —30 mm material								
—30+10 mm lumps	40.1	66.4	1.52	1.85	67.7	66.5	1.11	2.38
—10 mm classifier sand	41.5	66.1	1.63	2.00	22.9	61.0	2.54	4.27
Slime	18.4	48.7	11.40	12.50	9.4	39.3	19.0	14.5
Head (Calc)	100.0	63.0	3.39	3.88	100.0	62.7	3.12	3.95

TABLE 2.33—RESULTS OF WASHING TESTS

Types of Ore

	(4) Noamundi				(5) Joda Hard			
	Wt%	ASSAY %			Wt%	ASSAY %		
		Fe	SiO_2	Al_2O_3		Fe	SiO_2	Al_2O_3
	56.7	66.0	1.28	2.20	77.0	65.5	1.7	2.74
	26.8	63.2	1.77	4.43	17.1	59.7	2.86	6.05

16.5	58.6	4.33	5.60	5.9	43.68	11.76	14.50
100.0	64.0	1.92	3.34	100.0	63.22	2.50	3.99
52.5	66.4	1.1	2.1	70.6	65.85	1.54	2.20
29.2	63.1	2.1	4.4	22.1	61.35	2.48	5.60
18.3	57.6	4.5	5.7	7.3	41.35	12.32	15.0
100.0	63.8	2.0	3.43	100.0	63.12	2.53	3.97

TABLE 2.34—DAVIS TUBE TEST RESULTS

Intensity Gauss	Product	Wt%	Assay % Total Fe	Distribution % Total Fe	Sp. Gr.
—	Samples as received	—	54.0	—	3.62
2500	Magnetic Fraction	77.0	68.6	97.7	4.55
3300	-do-	77.5	68.08	97.7	4.51
4250	-do-	77.6	68.07	97.6	4.50

TABLE 2.35—SUMMARY OF THE RESULTS OF BENEFICIATION STUDIES ON IRON ORE SAMPLES OF BIHAR

Sample and locality	Assay % R.O.M. Ore	Beneficiation Method	Concentrate Product: ASSAY %	Concentrate Product: Distribution/Remarks
(1)	(2)	(3)	(4)	(5)
1. Blast Furnace Flue dust from TISCO.	Fe=39.47; SiO_2=14.38; Al_2O_3=9.54; CaO=3.30; Mn=0.51; P=0.23; Free C=11.14; L.O.I.=15.31	Tabling	Fe=60.63; SiO_2=4.62; Al_2O_2=6.82; P=0.2	Fe=64.2 Can be mixed with sinter feed
2. Classifier overflow from Noamundi washery from TISCO.	Fe=51.42; SiO_2=8.51; Al_2O_3=12.80	Tabling after attrition grinding	Fe=64.18 (Fe_2O_3=91.7%); SiO_2=1.88; Al_2O_2=5.98	+200 mesh material present into 11-12% Fe=34% recovery. Not upto the grade to be used for paint manufacture
3. Noamundi II from TISCO.	Fe=64.2; SiO_2=1.9; CaO=Trace; MgO=0.08; L.O.I.=3.82; P=0.15	Washing at —50 mm	Fe=64.7; SiO_2=1.35; Al_2O_2=3.36	Fe=88.8; SiO_2=61.5; Al_2O_3=79.8
		Washing at —25 mm	Fe=65.1; SiO_2=1.2; Al_2O_3=3.16	Fe=83.8; SiO_2=50.0; Al_2O_3=71.9
		H.M.S. at —50 mm+Classifier sand	Fe=66.5; SiO_2=0.9; Al_2O_3=2.42	Fe=83.9; SiO_2=37.1; Al_2O_3=53.0
		H.M.S. at —25 mm after washing+classifier sand	Fe=66.4; SiO_2=0.84; Al_2O_3=2.6	Fe=80.0; SiO_2=32.8; Al_2O_3=55.0
4. Joda Ore TISCO.	Fe=61.6; SiO_2=2.7; Al_2O_3=4.3; CaO=Trace; MgO=Trace; L.O.I.=5.4	Washing at —50 mm	Fe=62.8; SiO_2=1.84; Al_2O_3=3.73	Fe=95.7; SiO_2=69.5; Al_2O_3=82.0
		Washing at —25 mm	Fe=63.3; SiO_2=1.9; Al_2O_3=3.45	Fe=92.4; SiO_2=62.6; Al_2O_3=78.7
		H.M.S. —50 mm+classifier sand	Fe=64.2; SiO_2=1.61; Al_2O_3=3.0	Fe=90.1; SiO_2=50.9; Al_2O_3=60.9
		H.M.S. —25 mm+classifier sand	Fe=63.75; SiO_2=1.6; Al_2O_3=2.1	Fe=88.2; SiO_2=49.0; Al_2O_3=61.5
5. Noamundi—TISCO.	Fe=60.5; SiO_2=2.3; Al_2O_3=5.5; P=0.18; CaO=Trace; MgO=0.5; L.O.I.=6.6	Washing at —50 mm	Fe=61.8; SiO_2=1.6; Al_2O_3=4.8	Fe=91.5; SiO_2=60.4; Al_2O_3=77.3
		Washing at —25 mm	Fe=61.4; SiO_2=1.3; Al_2O_3=4.7	Fe=87.0; SiO_2=49.4; Al_2O_3=78.8
		H.M.S. —50 mm+classifier sand	Fe=63.5; SiO_2=1.08; Al_2O_3=3.7	Fe=77.8; SiO_2=34.6; Al_2O_3=49.6
		H.M.S. —25 mm+classifier sand	Fe=63.2; SiO_2=0.9; Al_2O_3=3.8	Fe=77.1; SiO_2=29.4; Al_2O_3=55.0

TABLE 2.35 (*Contd.*)

(1)	(2)	(3)	(4)	(5)
6. Gurumahisani—Ore —TISCO.	Fe=56.8; SiO_2=4.0; Al_2O_3=4.65; P=0.12; CaO=Trace; MgO=0.11; L.O.I.=10.0	Washing at —50 mm	Fe=58.1; SiO_2=3.3; Al_2O_3=4.2	Fe=91.9; SiO_2=72.2; Al_2O_3=80.6
		Washing at —25 mm	Fe=58.2; SiO_2=3.1; Al_2O_3=3.8	Fe=89.4; SiO_2=70.6; Al_2O_3=73.0
		H.M.S. —25 mm+ classifier sand	Fe=59.05; SiO_2=2.86; Al_2O_3=3.64	Fe=81.7; SiO_2=54.9; Al_2O_3=61.0
		H.M.S. —25 mm+ classifier sand	Fe=59.0; SiO_2=3.0; Al_2O_3=3.12	Fe=80.8; SiO_2=60.3; Al_2O_3=53.6
7. Badampahar Ore —TISCO.	Fe=59.2; SiO_2=2.9; Al_2O_3=3.4; P=0.07; CaO=0.58; MgO=0.5; L.O.I.=8.4	Washing at —50 mm	Fe=60.9; SiO_2=2.0; Al_2O_3=3.2	Fe=91.6; SiO_2=61.0; Al_2O_3=83.6
		Washing at —25 mm	Fe=60.3; SiO_2=1.9; Al_2O_3=2.96	Fe=89.1; SiO_2=62.3; Al_2O_3=76.4
		H.M.S. —25 mm+ classifier sand	Fe=61.4; SiO_2=1.75; Al_2O_3=2.86	Fe=80.8; SiO_2=51.0; Al_2O_3=66.3
		H.M.S. —50 mm+ classifier sand	Fe=61.3; SiO_2=1.9; Al_2O_3=2.95	Fe=79.1; SiO_2=48.0; Al_2O_3=66.4
8. Noamundi Soft—laminated Ore 5788—TISCO.	Fe=58.0; SiO_2=2.2; Al_2O_3=7.4; P=0.13; S=0.2; L.O.I.=7.1	Washing	Fe=59.7; SiO_2=1.52; Al_2O_3=6.7	Fe=88.1; SiO_2=58.2; Al_2O_3=76.7
		Washing+H.M.S. of —50 mm+6 mesh	Fe=63.7; SiO_2=1.2; Al_2O_3=4.6	Fe=69.1; SiO_2=32.7; Al_2O_3=37.6
9. Noamundi lateritised soft ore 5789—TISCO.	Fe=58.7; SiO_2=1.9; Al_2O_3=6.9; P=0.18; S=0.32; L.O.I.=7.2	Washing	Fe=60.1; SiO_2=1.26; Al_2O_3=5.98	Fe=93.8; SiO_2=75.8; Al_2O_3=84.5
		Washing+H.M.S. of —50 mm+6 mesh	Fe=61.5; SiO_2=1.1; Al_2O_3=4.56	Fe=75.1; SiO_2=50.6; Al_2O_3=51.2
10. Noamundi R.O.M. Mixture No. 5790	Fe=60.94; SiO_2=2.34; Al_2O_3=4.7; P=0.22; S=0.04; L.O.I.=6.1	Washing	Fe=61.6; SiO_2=1.86; Al_2O_3=4.35	Fe=91.0; SiO_2=66.3; Al_2O_3=79.5
		Washing+H.M.S. of —50 mm+6 mesh	Fe=65.3; SiO_2=0.9; Al_2O_3=2.4	Fe=77.9; SiO_2=29.5; Al_2O_3=36.0
11. Noamundi hard ore with lateritisation No. 5791	Fe=62.0; SiO_2=2.2; Al_2O_3=3.9; P=0.13; S=Trace; L.O.I.=4.8	Washing	Fe=63.8; SiO_2=1.9; Al_2O_3=3.3	Fe=96.6; SiO_2=89.9; Al_2O_3=90.7
		Washing+H.M.S. of —50 mm+6 mesh	Fe=65.7; SiO_2=1.06; Al_2O_3=1.74	Fe=87.1; SiO_2=43.2; Al_2O_3=42.0
12. Joda East Soft laminated flaky No. JE-1.	Fe=56.8; SiO_2=8.0; Al_2O_3=5.8; P=0.06; S=0.3; L.O.I.=4.8	Washing	Fe=63.4; SiO_2=3.6; Al_2O_3=3.6	Fe=87.8; SiO_2=32.5; Al_2O_3=45.6
		Washing+H.M.S. of —50 mm+6 mesh	Fe=64.9; SiO_2=2.5; Al_2O_3=2.6	Fe=84.1; SiO_2=22.3; Al_2O_3=33.3
13. Joda East Mixed hard spongy No. JE-2	Fe=56.8; SiO_2=2.4; Al_2O_3=5.5; P=0.27; S=0.35; L.O.I.=9.5	Washing	Fe=57.7; SiO_2=2.1; Al_2O_3=5.4;	Fe=95.2; SiO_2=86.5; Al_2O_3=93.3
		Washing+H.M.S. of —50 mm+6 mesh	Fe=61.2; SiO_2=1.04; Al_2O_3=3.8	Fe=63.8; SiO_2=29.6; Al_2O_3=41.5
14. Noamundi Washery Sample —9 mm+3 mm washed product—TISCO.	Fe=56.4; SiO_2=2.6; Al_2O_3=6.8	Jigging Spiral/Magnetic separation H.M.S. of —9 mm+6 mesh+—6 mesh	Fe=62.0; Insolubles=5.0 Fe=61.7; Insolubles=5.06	Fe=61.8—63.6
		H.M.S. —9 mm+6 mesh	Fe=67.0	Fe=38.0
15. —3 mm classifier sand from Noamundi —TISCO.	Fe=55.0; SiO_2=3.0; Al_2O_3=7.7	Straight Magnetic Separation	Fe=60.4; Insolubles=6.32	Fe=56.7
		Jigging + Magnetic Separation	Fe=63.7; Insolubles=3.83	Fe=52.1
		Jigging+Spiral	Fe=64.4; SiO_2=1.26; Al_2O_3=1.8	Fe=39.5
16. —6 mm classifier sand from Noamundi —TISCO.	Fe=59.4; SiO_2=1.95 Al_2O_3=6.28; L.O.I.=6.80	Jigging + Spiraling after sizing	Fe=62.25; SiO_2=1.27; Al_2O_3=4.32;	Fe=65.8; SiO_2=43.1; Al_2O_3=42.9
		Jigging	Fe=61.1; SiO_2=1.46; Al_2O_3=3.84	Fe=82.6; SiO_2=61.5; Al_2O_3=59.5

TABLE 2.35 *(Contd.)*

(1)	(2)	(3)	(4)	(5)
17. Heavy Slime from Noamundi Washery—TISCO.	Fe=59.12; SiO_2=5.19; Al_2O_3=6.41	Spiralling	Fe=60.54; SiO_2=3.14; Al_2O_3=5.49	Fe=29.9
18. R.O.M. ore from top bench of Noamundi—TISCO.	Fe=51.07; SiO_2=6.48; Al_2O_3=8.96	Jigging at —3 mesh	Fe=57.0; SiO_2=3.57; Al_2O_3=6.4	Fe=55.9
		H.M.S. of —50 mm+6 mesh	Fe=63.59; SiO_2=1.33; Al_2O_3=3.85	Fe=49.0
		Jigging of —6 mesh	Fe=56.24; SiO_2=3.16; Al_2O_3=7.29	Fe=3.8
19. Kanga ore Noamundi, TISCO.	Fe=64.08; SiO_2=1.27; Al_2O_3=2.22	Crushing, to —50 mm +3 mesh and Jigging —3 mesh	Fe=65.4; SiO_2=1.12; Al_2O_3=1.96	Fe=98.2 Kanga ore already high grade
20. Feed to H.M.S. Plant after crushing and washing to Noamundi —TISCO.	Fe=60.5; SiO_2=2.18; Al_2O_3=5.51	Crushing, to —3 mesh Jigging	Fe=65.83; SiO_2=0.5; Al_2O_3=2.24	Fe=66.8
		H.M.S. at 3.0 Jigging of H.M.S. Float at —3 mesh	Fe=65.9; SiO_2=0.76; Al_2O_3=2.0	Fe=74.6
21. Joda Flaky iron ore from TISCO—Pilot Plant studies	Fe=62.92; FeO=Trace; SiO_2=3.4; Al_2O_3=4.0; CaO=Trace; MgO=Trace; TiO_2=0.21; L.O.I. =1.95	Washing at —50 mm | Lumps	Fe=66.5; SiO_2=1.7; Al_2O_3=1.95	Fe=44.2; SiO_2=21.2; Al_2O_3=21.0
		Cl. sand —10 mm	Fe=66.0; SiO_2=2.0; Al_2O_3=2.1	Fe=42.9; SiO_2=24.4; Al_2O_3=22.2
		Cyclone Underflow	Fe=61.0; SiO_2=4·9; Al_2O_3=5.1	Fe=6.4; SiO_2=9.6; Al_2O_3=8.6
		Cyclone overflow	Fe=39.4; SiO_2=14.65; Al_2O_3=18.2	Fe=6.5; SiO_2=44.8; Al_2O_3=48.2
22. Khondband hard iron ore — TISCO — Pilot Plant Studies	Fe=63.0; FeO=Trace; Al_2O_3=4.0; S=0.1; P=0.08; CaO=Trace; MgO=Trace; TiO_2=0.23; L.O.I.=2.75	Washing at —30 mm | Lumps and cycloning	Fe=66.5; SiO_2=1.11; Al_2O_3=2.38	Fe=71.7; SiO_2=24.0; Al_2O_3=40.7
		Classified sand	Fe=61.0; SiO_2=2.54; Al_2O_3=4.27	Fe=22.4; SiO_2=24.0 Al_2O_3=4.27
		Cyclone underflow	Fe=44.88; SiO_2=15.0; Al_2O_3=10.923	Fe=2.5; SiO_2=16.9; Al_2O_3=9.9
		Cyclone overflow	Fe=36.2; SiO_2=21.6; Al_2O_3=16.57	Fe=3.4
23. Noamundi hard iron ore TISCO—Pilot Plant studies	Fe=64.0; SiO_2=1.86; Al_2O_3=3.3; CaO=Trace; S=0.04; P=0.085; TiO_2=0.2; L.O.I.=3.60	Washing at —50 mm | Lumps and cycloning	Fe=66.7; SiO_2=12.8; Al_2O_3=2.2	Fe=58.5; SiO_2=37.8; Al_2O_3=37.4
		—10 mm Classified sand	F=63.2; SiO_2=1.77; Al_2O_3=4.43	Fe=26.4; SiO_2=24.8; Al_2O_3=35.6
		Cyclone Underflow	Fe=62.1; SiO_2=1.9; Al_2O_3=4.34	Fe=11.62
		Cyclone overflow	Fe=51.05; SiO_2=8.8; Al_2O_3=9.0	
24. Joda hard iron ore TISCO—Pilot Plant studies	Fe=63.32; FeO=0.72; SiO_2=2.34; Al_2O_3=4.0; S=0.08; P=0.052; CaO=0.434; TiO_2=0.0134; L.O.I.=2.26	Washing at —30 mm | Lumps and cycloning	Fe=65.85; SiO_2=1.54; Al_2O_3=2.22	Fe=73.6; SiO_2=42.7; Al_2O_3=39.6
		Classified Sand	Fe=61.35; SiO_2=2.48; Al_2O_3=5.6	Fe=21.5; SiO_2=21.5; Al_2O_3=31.3
		Cyclone underflow	Fe=49.0; SiO_2=5.81; Al_2O_3=13.92	Fe=2.4
		Cyclone overflow	Fe=37.9; SiO_2=17.4; Al_2O_3=17.1	Fe=2.5
25. Magnetite from TRF Davis Tube Test	Fe=54.0	Concentrate at field intensity of 2500 gauss	Fe=68.8	Fe=97.7