COAL

In the wake of the increasing energy crisis throughout the world, the necessity for search of alternate sources of energy has become very essential in recent times. It has become more so in the case of coal in its research and development, which is the foremost natural source of energy most widely used.

The dwindling reserves of good grade metallurgical Coking Coals in India have led to the upgrading and preparation of our washed inferior grade coals in the various washeries in the conventional way. Of late as a further next step in this direction utilisation of off-grade fines (Washery-rejects and middlings) produced at the various washeries in their day-to-day operation, as well as the huge tonnages lying accumulated all these years (about 3.2 million tonnes of middlings and 4.1 million tonnes of rejects) has gained more importance by way of beneficiation using forth flotation technique for effective separation of fine coal from ash minerals as compared to the gravity separation methods, which are less effective at the fine size range. The non-availability of good grade Coal to the industry makes the use of this process more and more attractive in the present context. NML was thus been requisitioned by the various agencies dealing with the exploration and exploitation of coal in India like M/s. Central Coal Fields Ltd., Bharat Coking Coals Ltd., Tata Iron & Steel Co. Ltd., etc., to take up the study of coal fines beneficiation by froth flotation process and develop optimum flow sheets for adding flotation plants in their various washeries.

The beneficiation results of some of the coal fines samples studied at NML in recent years have been included in the following pages, which cover the various other aspects of coal like grades, reserves, production, demand and future outlook.

RESERVES AND PRODUCTION

In India coal is the primary source of commercial energy and is the most important fossil fuel of the country. Like most of the developing countries, a much rapid growth of its energy base characterised by higher per capita consumption is essential for the success of our ambitiously drawn plans for industrialisation and economic development. The Indian energy scene is thus characterised by a need for rapid growth in the production of indigenous commercial sources of energy of which Coal is the foremost for containing their imports and for helping replace non-commercial sources.

India has fairly extensive reserves of coal compared with other conventional sources of energy such as oil, natural gas. Although India stands eighth in the matter of coal reserves amongst the leading coal producing countries of the world, the reserve situation in the country is such that it is poor in superior grade of Coal. In the matter of production India to-day ranks sixth in the world after U.S.A., U.S.S.R., China, Poland and U.K.

The coal reserves of the various countries and India's production programme are given in Tables 4.5 and 4.6 respectively.

Sector-wise demand and production of coal in the country is given in Table 4.7 At the present level of production the average ash content of the coking coal is rarely less than 24%. The average ash content of our metallurgical coals is normally specified to be in the range of 15-17%. So this excess ash of 7 to 9% in the raw coal is to be removed by washing and other beneficiation processes in order to produce a metallurgical coke of specified quality.

TABLE—4.5 : COAL RESERVES OF THE WORLD

Country	Total coal reserves all grades (in mil. ton.)	Percentage of World reserves
U.S.S.R.	5,713,681	53.0
U.S.A.	2,924,503	27.1
China	1,011,000	9.4
F.R.G.	287,054	2.7
Australia	198,567	1.9
U.K.	162,814	1.5
Canada	108,777	1.0
India	83,652	0.8
Poland	60,603	0.6
South Africa	44,339	0.4
Others	187,442	1.6
Total	10,781,832	100.0

TABLE—4.6 : INDIA'S STATE-WISE PRODUCTION PROGRAMME OF COAL (IN MILLION TONNES)

Sl. No.	State	1976-77	1978-79	1983-84	1985-86
1.	Assam	0.59	0.80	1.40	1.47
2.	West Bengal	24.72	28.54	39.20	43.19
3.	Bihar	40.64	47.70	63.62	69.16
4.	Orissa	2.48	3.38	7.49	7.93
5.	Madhya Pradesh	20.67	25.18	35.01	41.44
6.	Uttar Pradesh	—	1.50	3.82	6.33
7.	Maharashtra	3.77	5.45	10.99	13.82
	Total	92.87	112.55	161.53	183.34

TABLE—4.7 : SECTOR WISE DEMAND AND PRODUCTION OF COAL IN INDIA

(In million tonnes)

	Total demand	Production	Steel and hard coke	Power	Railways	Export	Fertilizer	Cement Plants	Brick burning	Soft coke/ LTO	Colliery
1976-77											
All India	102.7	—	23.1	26.7	14.1	1.5	1.3	24.74	4.16	4.10	3.0
				(1.30)							
Coal India	91.05	92.76	20	22.7	12.8	1.5	1.0	22.74	3.76	3.8	2.75
1978-79											
All India	125.03	—	29.73	35.5	13.5	2.5	3.1	23.0	4.5	5.0	3.1
				(3.1)				(0.8)	(1.0)	(0.6)	
Coal India	111.16	112.55	26.26	30.3	11.7	2.5	2.5	22.3	4.25	4.9	2.75
1983-84											
All India	178.81	—	37.31	60.2	13.2	5.0	5.1	30.8	6.5	10.5	3.8
				(6.5)				(0.8)	(1.3)	(0.6)	
Coal India	158.03	161.53	32.03	51.9	11.4	5.0	4.1	29.8	6.2	9.5	3.4
1985-86											
All India	203.37	—	41.07	71.5	13.0	5.0	7.0	34.5	7.4	12.7	3.9
				(7.9)				(0.3)	(1.0)	(0.6)	
Coal India	179.99	183.34	35.79	61.5	11.2	5.0	6.0	33.4	7.0	11.5	3.9

N.B.: (i) Coal India excludes Singareni, IISCO, TISCO and others.

(ii) Figures in brackets indicate allocation of washing middlings, which is additional to the raw coal requirements.

Plans are underway for expansion of the existing washeries and for setting up of new beneficiation plants both for the coking and non-coking coals in the country to meet the increasing demands of the different industries.

A brief summary on the beneficiation studies of the various coal fines samples undertaken at the NML is given in the following pages.

Beneficiation:

The ever increasing demands of coal by the steel and metallurgical industries coupled with the fast depletion of reserves of the prime coking coal, as a first step towards the better conservation and rational utilisation of the coking coal had prompted the industry to use the blend of prime and semi-coking coals. In addition the industries have been forced to accept slightly inferior grade of coal i.e. coals containing upto 17% ash as against the specified limit of 15%.

At the present level of production the average ash content of the coking coal is rarely less than 24%, which make them rather impossible to direct utilisation. Hence these coals, (even after blending) have to be washed in the conventional washeries in order to bring down the ash content to the specified limits. When the final washed coal is aimed at 15% ash, the reject losses were high, which also happens to be a reason to accept the 17% ash grade coals with a view of conservation and better utilisation.

Washing Process:

Presently, there are 14 washeries with a total rated capacity of 25.37 mt py in the country. (Tables 4.8 to 4.11). The raw coal was crushed to 75 mm top size and after sizing treated by heavy media separation and jigging process. During this process all the coal fines of 0.5 mm and below cannot be treated and hence they are rejected. Such rejected fines have been accumulated as waste stock piles at different washeries to a staggering figures of 3-4 million tonnes over years. In addition to these fines, the middling rejects of the heavy media separation process, which neither go to the tailing dumps nor to the concentrate side were also mounting up as dumps. And these two products form otherwise a large bulk of coal which find their use in the metallurgical industry. It is at this stage some of the public sector coal washeries and M/s. TISCO Ltd., have approached NML to take up for the beneficiation of these products by froth flotation process and develop optimum flow sheets for adding up flotation plants in their washeries , so that the concentrates may be finally combined with the lumpy washed coal for use in the metallurgical industry. This, in fact, is an essential step towards the conservation of our country's coking coal resources and minimise the losses at the washeries as 'rejects'. These 'rejects' can be utilised without beneficiation in the power plant as boiler feed.

In case of non-coking coal also, washing is gaining importance. As bulk of it is being used as industrial fuel-particularly in the thermal Power Stations and cement plants, the ash content has a definite bearing in their working. Washed coals which are low in ash do keep for better overall operation, economy and productivity, by reducing the transportation charges, improved thermal efficiency, reduced wear and tear of the boiler plates, tubes, and problem of fly ash etc.

Flotation Process :

Coal being a naturally flotable mineral, it is quite easy to separate it from the associated gangue minerals. During flotation small quantities of Kerosene oil as collector for coal and pine oil as frother are used. Some times sodium silicate is used as depressant for the gangue minerals. As the rejected fines of the washeries are always finer than 0.5 mm size, no grinding would be needed. However a grinding circuit is essential if the washery middlings are treated.

NML's Studies on Coal Fines Flotation :

Starting in 1975 more than a dozen samples have been studied at NML both in bench as well as pilot plant scale investigations. The samples received were from M/s. TISCO Ltd., Coal India Ltd., CMPDI, CCWO, CCL etc. Though initially with the available well equipped facilities, comprehensive studies employing washing, gravity as well as flotation techniques were conducted, later on more stress was given on studying the froth flotation characteristics of coal, particularly flotation, more to improve upon the recoveries of coking coal from middlings and fines from the washeries which are normally lost to metallurgical purposes.

BENEFICIATION STUDIES OF COAL SAMPLES

A. Coal sample from TISCO Ltd.

The sample assaying 29.72% ash was collected from Jamadoba collieries of M/s TISCO Ltd., and the tests were conducted as per the flow sheet suggested by them to produce a coal concentrate assaying not more than 16% ash.

TABLE NO. 4.8 : PRIME COKING COAL WASHERIES (9 IN NO.)

Washeries	Company	Year of completion (commencing)		Annual rated capacity mt/ year
Jamadoba	TISCO	1952	(Expn '73)	1.44
Lodna	BCCL	1955		0.40
Durgapur	HSL	1960		1.5
DUGDA I	BCCL	1961		2.4
Bhojudih	BCCL	1962	(Expn '64)	2.0
Patherdih	BCCL	1964		2.0
Durgapur	DPL	1967		1.35
Chasnala	IISCO	1968		2.0
Dugda II	BCCL	1968		2.4
				15.49

TABLE NO. 4.9 : PROPOSED WASHERIES IN PRIME COKING COAL SECTOR IN B.C.C.L.

Name	Raw Coal input capacity mt/year		Expected clean	Yield % Middling	Expected Year of commissioning.
Hurriladih	0.18	B	80	10	1977-78
Barora	0.48	B	55	25	1978-79
Sudamidih	2.0	A	75	15	1978-79
Monidih	2.0	A	70	20	1979-80
Katras	2.4	A	50	33	1983-84
Kankanee-Doyabad(N)	1.2	A	75	15	1984-85
	8.26				

NB: Washing with annual raw coal input capacity of

> 1.0 mt/year = Type A

< 1 mt/year = Type B

TABLE NO. 4.10 : EXISTING MEDIUM COKING COAL WASHERIES (4 IN NO.)

Washeries	Company	Year of completion/ commissioning.		Raw Coal input capacity mt/year.
West Bokaro	TISCO	1951		0.57
Kargali	CCL	1958	(Expn '66)	2.72
Kathara	CCL	1969		3.00
Sawang	CCL	1970		0.75
Gidi	CCL	—		2.84
				9.88

TABLE NO. 4.11 : PROPOSED WASHERIES.

Washeries	Company	Raw Coal input capacity mt/year.		Expected clean	Yield % Middling	Expected year of commissioning.
Junkundar	BCCL	0.48	B	60	25	1978-79
Mohuda	BCCL	0.40	B	60	25	1979-80
Ramgarh	CCL	3.0	A	60	22	1979-80
Kedla	CCL	2.60	A	50	25	1980-81
Nandan	WCL	1.10	A	55	30	1980-81
Asnapani	CCL	2.0	A	50	30	1985-86

The flowsheet consisted of reducing the ROM Coal to 75 mm top size and then sized to −75 mm+ 6 mm, −6 mm +0.5 mm and −0.5 mm fines. The coarse lumps were treated by heavy media separation and the reject obtained at 16% ash in the conc. were to be crushed to 6 mm top size. The crushed product is further sized on 0.5 mm screen. The coarser fraction was treated in a jig and the fines were treated by flotation. The jig tails were again ground to 0.5 mm size and treated separately by flotation.

Similarly the −6 mm +0.5 mm portion of R.O.M. were treated in jig and the jig tails were ground to 0.5 mm size and treated by flotation.

ROM −0.5 mm fines were also treated by flotation.

This flow sheet ensures the recovery of the carbon at all possible stages.

Results

The ROM coal sample assayed 29.72% ash. It was crushed to 75 mm top size and then sized to −75 mm +6 mm; −6 mm +0.5 mm and −0.5 fractions. The coarsest portion when treated by H.M.S. at specific gravities 1.3 and 1.4 produced concentrates assaying 12.75% and 14.87% ash with 9.31% and 27.16% yields respectively. The H.M.S. rejects were reduced to 6 mm size and the −6 mm +0.5 mm fines were treated by jigging where the concentrate analysed 24.32% ash and 29.8% ash respectively. Treatment of the jig tails after crushing to 0.5 mm by flotation yielded concentrates assaying 12.42% and 14.77% ash respectively. The −0.5 mm fines obtained while crushing the HMS rejects to

6 mm size, on flotation yielded concentrates assaying 8.16% and 11.98% ash respectively.

Jigging of the −6 mm +0.5 mm R.O.M. fines yielded a concentrate assaying 15.28% ash and the jig tailings on flotation after crushing to −0.5 mm size produced a concentrate assaying 9.73% ash.

Flotation of the −0.5 mm R.O.M. fines produced a concentrate assaying 7.55% ash only.

The test results were summarised in the following table.

Product	Sp. Gr. 1.3		Sp. Gr. 1.4	
	Wt. %	Ash %	Wt. %	Ash %
HMS Conc (Float)	9.31	12.75	27.16	14.87
Jig Conc. from HMS rejects	10.46	24.32	8.75	29.80
Flotation conc. from jig tails.	3.66	12.42	2.62	14.77
Flotation conc. from HMS fines	0.35	8.16	0.63	11.98
Flotation conc. from ROM	13.14	15.82	13.14	15.82
Flotation conc. from jig tails.	1.26	9.73	1.26	9.73
Flotation conc. from ROM —0.5 mm fines.	4.77	7.55	4.77	7.55
Total Conc.	42.95	15.77	58.33	16.57
Total Tails	57.05	39.32	41.67	47.37
	100.0	29.20	100.0	29.39

Although the highest acceptable ash limit was set at 16%, the results indicated the HMS tests conducted at Medium Sp. gr. 1.4 followed by the other steps may conveniently yield a concentrate assaying 16% ash.

B Coal fines from West Bokaro Coal Washery of TISCO Ltd.

Four different coal fines samples were received from M/s. TISCO to produce coal concentrates assaying less than 16% ash. Analysis of the various samples were as given under.

Seam no. Constituent	Seam V	Seam VI	Seam VII	Seam VIII
F.C.	N.A.	N.A.	49.1	54.2
V.M.	N.A.	N.A.	25.6	25.9
Ash	30.6	23.9	25.3	19.9

Batch flotation tests indicated that with 0.218 Kg/T of kerosene oil and 0.070 Kg/T of pine oil with 3 mts of flotation, concentrates assaying 18.2%, 17.0%, 13.8% and 13.3% ash may be produced from the fines of Seam V, VI, VII & VIII respectively.

Pilot Plant Tests

The following flow sheet was adopted for the treatment of the fines.

The sample was wet screened over a 20 mesh screen and the fines were conditioned along with 'Kerosene Oil'. This pulp was further diluted for flotation and treated in a 16 cell bank of Denver Sub-A type (No. 8) flotation cells. The tailings were rejected and the concentrate was dewatered in the thickener. The dewatered fines (concentrate) was partially dried in air and then despatched to M/s. TISCO.

Complete data of the over all tests is given as under.

	Seam V	Seam VI	Seam VII	Seam VIII
Amount of fines treated (Kg)	4400	6200	4500	7200
Analysis of the feed (% ash)	30.6	23.9	25.3	19.9
Amount of conc. produced (Kg)	2520	4200	2710	3058
Analysis of the conc. (% ash)	18.74	16.74	16.20	14.80

The amount of concentrates produced were slightly lower than those obtained in bench scale tests as the samples contained some sizable quantities of over size.

C Coal fines from Gidi washery

The coal fines received from the Gidi washery of Central Coal Fields Ltd., analysed as under.

Constituent	*Assay %*
Fixed carbon	48.30
Volatile Matter	22.02
Ash	27.39
Moisture	2.29

It was required to produce a concentrate assaying less than 17% ash, so that, it may be mixed with washed lumpy coal delivered for steel industry.

Although the fines were said to be of 0.5 mm size 28 mesh (Tylor standard), they contained about 30% of material coarse than 0.5 mm.

Flotation tests with the "as received" sample employing kerosene oil collector and pine oil as frother yielded a concentrate representing 47.1% of the feed and analysing 15.1% of ash. Similar test after grinding the sample to 65 mesh has yielded 75% of concentrate assaying 14.9% ash. Regrinding of the conc. followed by one cleaning had yielded a concentrate representing 61% of the total feed and analysing 11.2% ash. Tests with 65 mesh grind where in the concentrate was cleaned once and the cleaner tails were recirculated, with the fresh feed, the yield was 64.2% with an ash analysis of 12.05%. Further grinding of the sample to 150 mesh has increased the yield to 78.1% with an ash content of 16.10% in the concentrate. The concentrate when cleaned for 5 times, the yield was 52.6% with an ash of 8.02% in it.

Attempt to size the feed before grinding and flotation separately did not yield any encouraging results.

Gidi Coal Fines—Pilot Plant Tests

The 120 tonne coal fines sample received for pilot plant tests analysed as given under.

Constituent	*Assay %*
Fixed carbon	42.32
Volatile matter	28.40
Ash	28.00
Moisture	1.28

This sample also contained 31.4% of material coarser to 0.5 mm.; the sample was compact and contained hard clusters of coal fines which needed breaking before treatment. Different alternative flow sheets were tried for the treatment of the coal fines.

Flow sheet I

The sample was treated in a gravel washer and then wet screened on a 20 mesh screen. The −20 mesh portion was conditioned with sodium silicate, kerosene oil and pine oil. The +20 mesh portion was deslimed in a spiral classifier and the slimes were treated along with −20 mesh portion. The deslimed sand was ground to 20 mesh in a open circuit ball mill and combined with the −20 mesh portion and treated in flotation cells after conditioning with sod. silicate, kerosene oil and pine oil. The concentrate and the tails were collected in separate thickeners. The tails after dewatering were ground to 65 mesh and further floated where in the tailings were rejected. The concentrate obtained by this method varied from 16.1% to 16.8% in ash content having a yield of 75.5% to 77.9%.

Flow Sheet II

The whole feed was treated in an open circuit ball mill and treated in conditioner and flotation cells. The tails were reground to 65 mesh size and floated again. Coal concentrate obtained by this flow sheet varied in ash content from 16.7% to 17.3% with yields ranging from 71.6% to 76.5%.

Flow Sheet III

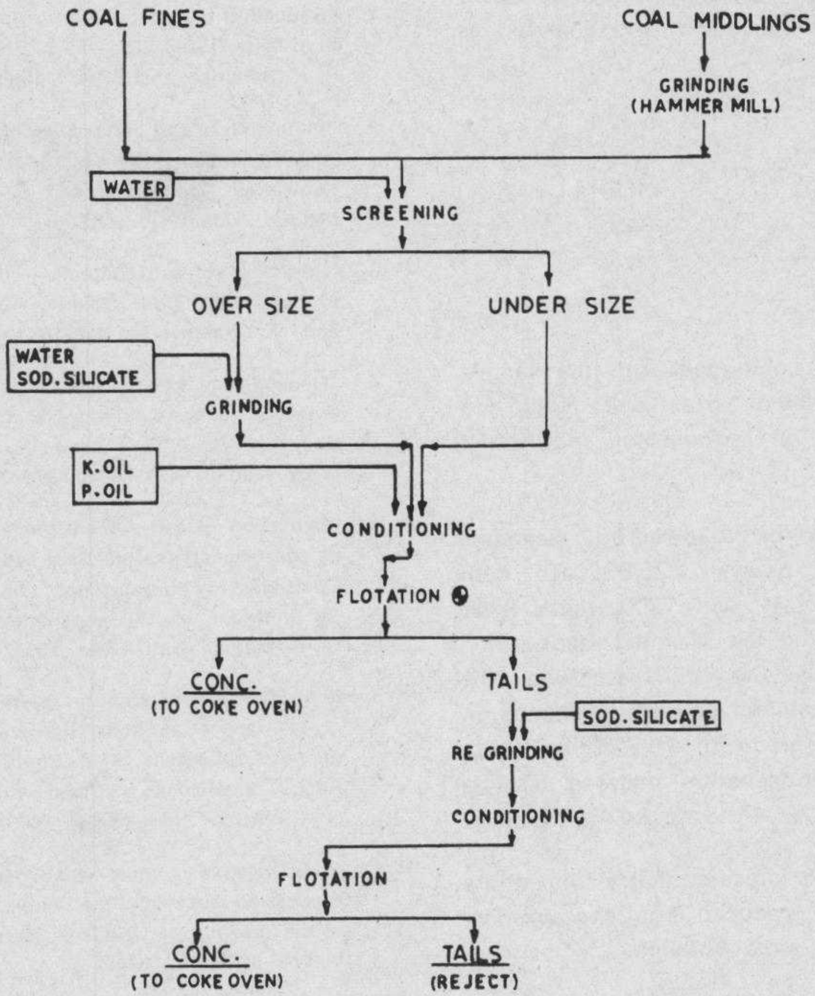
The feed was treated in a rake-classifier of a closed circuit ball mill where in the −65 mesh material is removed. The coarser portion, which formed the classifier sand was ground in the ball mill which discharged back into the classifier. The classifier over flow was conditioned with Sod. Silicate, Kerosene oil and pine oil, and floated. The tailings of this process were rejected. The concentrate obtained varied in ash content from 17.1% to 17.9% while the yields were ranging from 73.4% to 76.3%.

D Coal fines/(Slurry) from Pathardih washery

The sample was received from the Central Coal Washery Organisation and analysed as under.

Constituent	*Assay %*
Fixed carbon	62.22
Volatile matter	20.82
Ash	16.40
Moisture	0.56

The sample was subjected to flotation which produced a low ash concentrate of 7.8% ash with



❸ :- ALTERNATIVELY A REJECTABLE TAILING MAY BE PRODUCED WHILE THE CONCENTRATE IS TREATED AFTER GRINDING.

Fig. 4.2—General Flow Sheet for Coal washery Fines & Middlings

62% yield after five cleanings. However after one cleaning, the concentrate represented 76.2% of the feed analysing 9.8% ash. Attempts to recover some more coal from the primary and cleaner tails after regrinding were not successful.

E Dugda washery Middlings (Sink)

The sample was received from M/s. Coal India Ltd., for the recovery of coal. The sample consisted of lumps from 100 mm to 6 mm and analysed as under.

Constituent	*Assay %*
Fixed carbon	41.00
Volatile Matter	19.32
Ash	39.26
Moisture	00.42

Flotation tests were conducted with the sample after grinding to different sizes and employing kerosene oil and pine oil as collector and frother respectively.

Flotation with 35 mesh feed followed by 3 cleanings yielded a concentrate assaying 25.9% ash with 66.7% yield. Similar test with 200 mesh feed employing sod. silicate in the cleaning stages produced a concentrate assaying 18.0% ash with 60% yield. Further two cleanings i.e. five cleanings in all had improved the grade to 16.72% having a yield of 47%. This concentrate analysed 57.74% F.C., 16.72% ash, 23.30% V.M. and 0.24% moisture.

The over all test results indicated that a concentrate of 16.7% ash may be produced from the washery middling at 200 mesh size flotation.

These studies indicated that froth flotation of coal fines and middling rejects from washeries was a great success and an economically viable process. Based on these studies the various public sector and private agencies dealing with coal are setting up/ planning to add up flotation plants to their washeries for the treatment of middlings rejects and fines as well.

References

1. "Reduction of ash content" in a coal sample received from M/s. TISCO Ltd.,—P. D. Prasada Rao, Joga Singh, S. K. Banerjee and G. P. Mathur. NML-IR-No. 831/75.
2. "Reduction of ash content" from the coal washery fines of West Bokaro Colliery of M/s. TISCO Ltd.—R. K. Kunwar, P. D. Prasada Rao, S. K. Banerjee and G. P. Mathur. NML-IR-No. 853/76.
3. "Reduction of ash content" from the middlings (sink) of the Dugda Coal Washery—By P. D. Prasada Rao and N. Chakravorty. NML-RR-No. 377/77.
4. "Reduction of ash content" from the Coal fines of Gidi Washery received from M/s. Coal India Ltd.—K. K. Bhattacharya, P. D. Prasada Rao, N. Chakravorty and G. P. Mathur. NML-IR-No. 970/78.
5. "Reduction of ash content" in a 0.5 mm slurry sample of coal from Pathardih Coal Washery for M/s. Central Coal Washery Organization Ltd., by froth flotation.—By S. K. Sil, M. V. Ranganathan, N. Chakravorty and G. P. Mathur. NML-IR-No. 1001/78.
6. Pilot Plant investigation on the reduction of ash content of the coal fines from Gidi Washery—By B. L. Sengupta, S. C. Maulik, K. K. Bhattacharya, P. D. Prasada Rao, A. K. Mallick, N. Chakravorty, S. K. Banerjee and G. P. Mathur. NML-IR-No. 1006/78.
7. Coal Deposits of India—their reserves, production and processing by Prof. V. A. Altekar. A report presented at the meeting of UNCTAD Sub-Committee on Coal at Vienna in April, 1978.