The Problem of Supply of Coal for the New Steel Plants

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WITH depletion of the lower ash, good coking coals occurring in the upper seams of the Jharia coal field, which were the principal sources of supply of coking coals for the steel plants in the private sector, attention was focussed on the need for beneficiation of the higher ash Jharia coals. Three commercial coal washing plants (485 tons/hr. total capacity) were installed in recent years for supplying washed coal to the existing steel plants.

With the finalisation of the scheme for erecting new steel plants in the public sector and considering the comparative dearth of the Jharia coking coals, the Kargali seam coal occurring in the Bokaro coal field has been selected as an alternative source of coking coal meant for supplying the major requirement of the projected steel plants at Rourkela and Bhilai. A washing plant (500 tons/hr. capacity) has just been put into commission at Kargali to clean the Kargali seam coals. Plans have also been formulated to instal three more central washeries for beneficiation of the Jharia coals which will be used as such or in blends with the Kargali coal.

There are substantial reserves of the medium to high volatile coals in the western part of the Raniganj coal field representing coals of weakly to medium coking types. The majority of these coals are at present used for steam raising, export or gas making. Being located in the Raniganj area the steel plant under construction at Durgapur should, in the normal course of events, draw a substantial portion of its coking coal requirement from the Raniganj field.

On carbonisation, the high volatile coals by themselves give fingery, fissured and friable cokes, unsuitable for metallurgical use. The technique of blending high volatile weakly coking coals with lean coals of low volatile matter or with low temperature coke or char for the production of metallurgical coke has been reported to have been used in some countries short of good quality coal (e.g. certain parts of Japan, France, Germany, Poland and the U.S.A).

Such techniques are considered worth studying in India as this may open up the possibility of utilising the lower volatile, lower seam coals of the Jharia field which have so far been considered quite beyond the scope of being used in carbonisation plants for one reason or the other.

Recent studies show the occurrence of Kargali seam coals of good coking type in the Sawang areas. The Kathara area containing the same coal under development at present also shows signs of proving a prospective source of coking coal, though much higher in ash content in the out-crop side. These sources, when properly developed and the coals beneficiated, could meet the coking coal requirement of the projected fourth steel plant at Bokaro.

With the ultimate objective of conservation of coking coal, the Central Fuel Research Institute at Jealgora, and the Coal Blending and Coking Research Sub-Committee at Jamshedpur since their very inception have been actively engaged on investigations on the utilisation of sub-standard coals for coking in blends with normal coking coals. More recently tests were also undertaken on various straight coals and their blends at the request of the Central and State Governments for the specific requirements of the various steel plants now under erection. The present paper gives a summary of this work, and on suitable blends for the projected steel plant in the Bokaro area. Implementation of these recommendations by industries will effect considerable economy in the operational costs of the coke plants and also contribute in no small measure to the conservation of coking coal.

Pilot plants used for coking tests

The following pilot plants were used for the coking tests :

(*i*) *Electrically heated oven* : A charge of about 300 lb of coal contained in metallic retorts of 10″ width is carbonised at a temperature of 850–900°C

(*ii*) *Gas-fired half-ton oven* (*TISCO and IISCO*) : In this oven of 18″ width half a ton of coal is carbonised at a flue temperature of about 1,050–1,100°C.

(*iii*) *Multi-oven pilot coke plant* : In the middle oven of 16″ width of this pilot plant a charge of 1·1 tons of coal is carbonised at a flue temperature of about 1,200–1,250°C for a period of about 16–17 hours.

Results and discussion

Detailed results of laboratory analysis, coking tests, etc. are given in the Appendix. In the body are given the more salient features of the analyses, and tests and discussion.

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PART I

TESTS FOR THE ROURKELA AND BHILAI STEEL PLANTS

Run-of-mine samples of Kargali seam coal from the Kargali and Joint Bokaro collieries either individually or in mixtures of the two in the proportion of 1 : 2, either raw or in the washed state were used in the tests.

In the earlier tests the run-of-mine coal was crushed to about 3/4 in. size, screened on 1/8 in. meshes and the fraction 3/4 in. to 1/8 in. washed in a heavy medium cone separator. The clean coal recovered was mixed with the raw—1/8 in. fraction and used in the coking tests. In the second series of tests the run-of-mine coal was crushed to about 3 in., screened on 1½ in. mesh and the larger fraction 3 in. to 1½ in. and smaller fraction 1½ in. to 0 in. were separately washed in a heavy medium drum separator (pilot plant) and in a commercial feldspar jig plant respectively.

Properties of coals

A summary of the more important properties of the different coals used in the tests is given in Table I.

The percentage of ash in the washed Kargali seam coal in the two fractions large and small varied between 13 and 18, a 50 : 50 mixture of the two was used in most of the tests and the ash thereof was maintained at about 16%.

Most of the unwashed Jharia coals, has higher ash exceeding 16% except for a few coals, their mixture however as used in the coking tests was kept at about 17% ash. The percentage of ash in the Orissa and M.P. coals were generally lower except the Rakhikole coal from Kanhan valley which showed the highest ash of 21·5%.

The d.m.f. volatile matter was generally the lowest for most of the Jharia coals (24–31%) and the highest (40–46%) for the Orissa coals, the values for the other coals were intermediate between these two extremes.

Both in respect of percentage of carbon and volatile matter (on d.m.f. basis) the rank of the coals was roughly in the following descending order viz. Jharia, Kargali, Kanhan (M.P.), Jhilimili (M.P.), Korba (M.P.) and Orissa. The caking index was roughly in the same order ranging from 25 to 2.

The M.P. coals were conspicuous by a low phosphorus content of below 0·01%, the Jharia and Kargali coals had the highest phosphorus of about 0·1 to 0·3% whereas the Orissa coals had about 0·05 to 0·07% of phosphorus.

TABLE I

Properties of coals.

Particulars of coals/ properties of coals	BOKARO Kargali (washed)	JHARIA XII–XVI seams (washed and unwashed)	ORISSA Hirgir Rampur, Talchar and Ib. river	M. P. Korba	M. P. Jhilimili	M. P. Kanhan
ASH % (AIR-DRIED %)	13 – 18.2	11.3 – 18.8	11.5 – 13.0	12.6	13.1 – 16.1	16.5 – 21.5
VOLATILE MATTER (AIR-DRIED %)	25.6 – 27.9	21.5 – 29.9	31.4 – 38.9	30.7	29.7 – 31.7	26.9 – 31.7
VOLATILE MATTER (DRY mm. FREE) %	30 – 31.7	24.0 – 31.4	39.6 – 46.2	35.6 – 35.0	35 – 36.8	33 – 37.7
CARBON % (DRY mm. FREE)	87.7 – 88.7	89.0 – 90.5	81.85 – 82.47	84.28	85 – 86.8	85.2 – 88.8
CAKING INDEX	20 – 23	15 – 25	Less than 2	2	10 – 13	17 – 19
GRAY-KING ASSAY AT 600°C (COKE TYPE)	G/G_1	G/G_2	B	B	C	F – G

Coking tests

A summary of the coking tests on the straight coals and their blends is given in Table II.

Straight Kargali coals: Kargali seam coals from both the Kargali and *Jt.* Bokaro collieries, or mixtures of the two, either in large (3″–1½″) and small (1½″–0″) sizes separately or in mixtures gave hard and strong coke satisfying the I.S.I. specifications when carbonised in finer sizes of 100 per cent crushed through 3 mm selectively by recycling (Serial No. 1).

Coarser crushing and addition of coke dust tended to deteriorate some of the physical properties of the coke.

Blends of Kargali with Jharia coals: In blends with 25 per cent to 70 per cent of Jharia coals either washed or raw, a slightly improved quality of coke was obtained (Serial No. 2).

Straight M.P. coals and their blends: Hard coke of the metallurgical grade in respeot of physical properties could be obtained from the Rakhicole coal (Kanhan) by fine crushing, preferably after washing (Serial No. 3). The Damua-Kalichhapar coals gave medium hard coke (Serial No. 4).

As high as 80–85 per cent of the latter coals could however be utilised with Jharia coals when finely crushed and the blending coals were suitably selected. (Serial No. 5).

In blends with either Jharia or Kargali coals 20–40 per cent of the Jhilimili coals could be utilised to produce satisfactory coke (Serial No. 6).

10–20 per cent of the Ghordewa seam (Korba) coal in blends with Kargali coal with or without the addition of Jharia and Raniganj coal (Laikdih) likewise produced hard coke. Such blends could take 4–5 per cent of coke dust (Serial No. 7).

Blends of Orissa coals: 10–20 per cent of the non-coking Orissa coals could be utilised with the Jharia coking coals (Serial No.8).

TABLE II

Results of coking tests.

Particulars of Charge	PROPERTIES OF COKE: Shatter index cum % on 1½"	Shatter index cum % on ½"	Micum index cum % on 40 mm.	Micum index cum % Thr. 10 mm.	Haven stability factor cum% on 1'	Ash in coke (dry) %
	STRAIGHT KARGALI COALS & THEIR BLENDS WITH JHARIA					
1. Straight Kargali with or without coke dust	86.2 – 96.1	86.6 – 99.0	72.5 – 84.4	8.2 – 13.6	41.1 – 63.3	17.4 – 20.5
2. With 25-70 % Jharia (washed or unwashed) with or without coke dust.	88.3 – 96.0	97.3 – 98.4	75.1 – 85.3	8.8 – 14.1	52.8 – 62.6	19.4 – 21.5
	STRAIGHT M. P. COALS AND THEIR BLENDS					
3. (a) Rakhikole (Kanhan) unwashed (finely crushed)	96.0	98.2	87.2	10.6	59.2	27.9
(b) Rakhikole (Kanhan) washed (coarser crushed)	94.8	97.8	83.9	10.1	62.5	21.7
4. Damna and Kalichhapar (do) – 100 %	89.5 – 90	95.5 – 97.0	60 – 69	18 – 29	51 – 54	–
5. Jharia – 15 – 30 % M. P. Coals 70 – 85% (Kanhan Valley)	88.5 – 93.6	95.2 – 97.2	77.0 – 81.5	9.6 – 16.1	45.5 – 56.6	21 – 24.1
6. Jharia / Kargali – 60 – 80 % Jhilimili (M. P.) – 40 – 20 %	89.6 – 92.9	97.2 – 98.0	74.5 – 82.5	9.0 – 14.3	45.0 – 58.7	22.6 – 26.3
7. Kargali – 30 – 76 % Korba – 10 – 20 % Jharia or Laikdih – 26 – 35 % Coke-dust 4 – 5 %	92 – 94.3	97.3 – 97.9	76.8 – 80.1	11.6 – 12.2	51.5 – 54.2	18 – 20.2
	BLENDS OF ORISSA COALS					
8. Jharia – 80 – 90 % Orissa coals – 10 – 20 %	82.0 – 95.5	97.3 – 99.0	79.0 – 82.2	11.3 – 13.2	44.7 – 52.9	18.4 – 23.4
I. S. I. TENTATIVE SPECIFICATION NO. 439, 1953.	85	97	75	10–12	40	20–24

PART II

TESTS FOR THE DURGAPUR STEEL PLANT

For economic reasons and considering the comparative scarcity of lower ash good coking coals in the Jharia field, the Durgapur steel plant is expected to draw the maximum possible proportion of its coal requirement for the coke ovens from the Raniganj field.

Only a trifling percentage of the medium volatile coal of this area has so far found use for coking and the higher volatile weakly coking coals were never seriously tried so far for coking purposes.

Coking tests were accordingly carried out both on straight coals from different collieries and seams and on their various blends with Jharia coals.

The more important features of the investigation including a few tests done in the exploration of sources for low phosphorus coke for ferro-manganese manufacture are presented below.

Properties of coals

The properties of the different coals used in the tests are given in Table III.

TABLE III

Properties of coals.

Particulars of coal/ properties of coals	RANIGANJ: Laikdih / Laikdih deep W. Victoria	Ramnagar and Chanch / W. Victoria and Chanch	Sanctoria and Dishergarh / Seetalpur, Deoli Chinakuri etc.	JHARIA: O' seam	V–XVI seam (washed and unwashed	GIRIDI: Lower Karharbaree
Ash (air-dried%)	11.5–17.0	14.5–18	14.5–16.0	16–22	14.8–29	12.14
Volatile Matter (air-dried %)	24–30	28–29.8	33.5–36.5	18–21	17–28.6	26–26.5
Volatile Matter% (d.m.m. free)	28–33.5	33–34.5	39–42.5	21–24	21–33	29–32
Carbon % (d.m.m. free)	87.0–88.0	86.7–87.5	84–85.5	90–91	88–90.5	90.0
Caking Index	15–24	14–20	17–21	11–14	12–29	20–24
Gray-King Assay at 600°C (Type of coke)	$G–G_3$	G_1/G_2	G_1/G_2	E–F	$G–G_2$	G

The higher volatile Dishergarh and Sanctoria seam Raniganj coals had the lowest air-dried ash (below 16 per cent), lowest carbon (below 86 per cent) and highest volatiles (39–42·5 per cent) on d.m.f. basis.

Some of the medium volatile Raniganj coals (Laikdih seam, Laikdih deep colliery) had the lowest ash (below 14 per cent) whereas others from the same seam and from the Ramnagar, Chanch seams had higher ash. The percentage of carbon for the medium volatile coals ranged from 87 to 88 per cent and volatile matter from 28 to 34·5 per cent both on d.m.f. basis.

All the Jharia coals had the highest ash (often higher than 22 per cent) and highest carbon (88–91 per cent) and lowest volatile matter (21–35 per cent) on d.m.f. basis. The Giridih coal showed lower ash than most Jharia coals (particularly the "O" seam coals), had lower caking index and gave less swollen type of coke from the Gray-King assay. The Giridih coals generally showed higher caking index whereas the caking index of the Raniganj coals ranged from 15 to 24 and the Gray-King assay coke types were generally of the more swollen type.

The phosphorus content of the Giridih coal was the lowest (about 0·02 per cent), that of Laikdih seam also fairly low (about 0·04 per cent) whereas most other coals showed much higher phosphorus content.

Coking tests

Straight coals

A summary of the results of coking tests on the

straight Jharia and Raniganj coals are given in Table IV which shows that :

(*i*) Most of the "O" seam coals gave poor coke in respect of all the physical properties (Serial No. 1)(*i*).

(*ii*) All the upper seam Jharia coals gave hard metallurgical coke (Serial No. 1)(*ii*).

(*iii*) Most of the medium volatile, Raniganj coals (Laikdih, Ramnagar, Chanch, etc.) either washed or unwashed fulfilled the requirement of metallurgical coke. The Micum indices of the cokes from coals of higher ash were poorer (Serial No. 2).

(*iv*) The coke produced from both the high volatile Dishergarh and Sanctoria seam coals fell far short of the requirement of metallurgical coke in respect of physical properties (Serial No. 3).

(*v*) The percentage of ash in most of the Jharia cokes was higher than the limit for metallurgical cokes.

TABLE IV

Properties of coke from straight coals.

Particulars of charge	PROPERTIES OF COKE				Haven stability factor cum % on 1"	Ash in coke dry %
	Shatter index cum. %		Micum. index cum. %			
	on 1½"	on ¾"	on 40 mm.	Thr. 10 mm.		
1. LOW VOLATILE COALS (Jharia)						
(i) 'O' Seam	86.5–90.2	91.5–96.6	58.2–75.0	13.8–36.5	32.8–62.1	21.5–23
(ii) V–XVI Seam	91.3–96.6	96–98.1	75–84.5	9.0–13	31.6–61.4	20.3–34.2
2. MEDIUM VOLATILE COALS (Raniganj)						
(i) Laikdih Seam	86.7–96.0	96–98.8	76–84.5	9.0–12.5	50.0–64.0	18–24
(ii) Chanch, Ramnagar & Chanch-Begunia Seams (washed & unwashed)	91–94	97.6–98.2	74.6–83.2	9.0–11.5	45.7–64.0	18–24.0
3. HIGH VOLATILE COALS (Raniganj)						
(i) Sanctoria & Dishergarh Seams	68–80.6	94–97	44–60	11–15	11.0–23.0	18–23

Ternary blends of Raniganj and Jharia coals

Results of blending tests are shown in Table V.

Blends containing 25–50 per cent of the medium volatile Raniganj (Laikdih, Ramnagar, Chanch, etc.), 25–30 per cent of the high volatile Raniganj (Dishergarh and Sanctoria) and 20–25 per cent of the Jharia coals produced metallurgical coke satisfying the normal specifications (Serial No. 1). The Laikdih seam coal from the Laikdih deep colliery gave generally better results.

There was a trend of increase in the minus 10 mm Micum index when the percentage of ash in the Raniganj coals was excessive. The use of Giridih coal in replacement of the Jharia coals gave slightly better results (Serial No. 2).

TABLE V

Properties of cokes.

Sl. No.	Particulars of blend	PROPERTIES OF COKE					Ash in coke %
		Shatter index cum %		Micum index cum %		Haven stability factor on 1"	
		on 1½"	on ¾"	on 40 mm.	Thr. 10 mm.		
1.	Blend of High Volatile Coals (Raniganj)–25–50% Medium Volatile Coals (Raniganj) –30–50% Low Volatile Coals (Jharia) –20–30%	89–95.7	96.5–96.7	75–81.5	11–15	42–62	19.5–24
2.	Blend of High Volatile coals (Raniganj)–15–50% Medium Volatile Coals (Raniganj)–40–70% Giridih –10–30%	88.9–94.0	97.3–98.5	75.2–82	10.5–12.4	51.7–56.8	16.7–18.4

Binary blends of Dishergarh coals

A summary of the results of tests are shown in Table VI.

Blends with low volatile coals : Hard coke satisfying the requirement of metallurgical coke could be obtained from most of the blends containing 70 to 80 per cent of the Dishergarh coal and 20 to 30 per cent of the lower volatite (20–30 v.m. on d.m.f.) Jharia coals (Serial Nos. 1 to 3).

It was observed in connection with these tests that the use of oxidised low volatile, lower seams coals of Jharia lying in storage for a longer period resulted in coke of poorer properties.

The tests using 50 per cent blend of a mixture of XII to XIV coal with Dishergarh also gave hard coke (Serial No. 4).

TABLE VI

Properties of coke from blends of Dishergarh with other coals.

Sl. No.	Percentage of Dishergarh in blends	PHYSICAL PROPERTIES OF COKE				Haven stability factor % on 1"
		Shatter index %		Micum. index %		
		on 1½"	on ¾"	on 40 mm.	Thr. 10 mm.	
1.	80	89–92	97	75–80	9–12	40–54
2.	75	92–94	98	79–80	11–12	40–51
3.	70	89–94	97–98	76–80	8–13	45–55
4.	50	93	97	80	10–12	53–54

Binary blends of Dishergarh with low temperature coke

In Table VII are shown the results of carbonisation tests on blends of Dishergarh coal with semi-coke or char (crushed to minus 1 mm size) produced from low temperature carbonisation of different non-coking to weakly coking coals.

The improvement in the quality of the coke with an addition of 15–20 per cent of l.t.c. coke to the Dishergarh coal will be apparent from the table given above.

TABLE VII

Properties of blends of Dishergarh coal with l.t.c. coke.

Percentage of Dishergarh in blends	PHYSICAL PROPERTIES OF COKE					
	Shatter index %		Micum. index %		Haven stability factor % on 1"	Ash air dry %
	on 1½"	on ½"	on 40 mm.	Thr. 10 mm.		
80	92	97.8	74.0	11.0	48.0	21-23
85	91-93	97-98	75-78	11-12	39-47	

It has been observed from detailed investigation that best cokes in respect of physical properties are obtained from blends containing 15–20 per cent of l.t.c. coke having about 11–15 per cent volatile matter prepared in rotary ovens.

PART III

TESTS FOR THE FOURTH STEEL PLANT AT BOKARO

Recent drilling operations have proved the existence of Kargali seam coal in the Kathara area, East Bokaro field. Tests on bore-hole samples of this coal showed it to be of the caking type similar in nature to the Kargali seam coal at other areas.

Recent tests carried out on the Kargali seam coal at the Sawang area also showed this coal to possess excellent coking properties.

There are substantial reserves of coals in both these areas. When suitably beneficiated these coals are, therefore, expected to prove major sources of coking coals for the fourth steel plant contemplated to be erected at Bokaro.

There is a further prospect of utilising the weakly coking Argada seam coals of the South Karanpura coal field and the lower volatile Jharia coals in blends with these coals.

Below are discussed results of recent tests carried out on run-of-mine and seam samples from the Sawang and bore-hole samples from the Kathara area including coking tests done on the straight coals and their blends.

Properties of coals

A summary of the properties of the different coals is given in Table VIII.

In comparison with the Kargali seam coals from the Joint Bokaro and Kargali Collieries, the coals from the Sawang and Kathara areas are found to have higher volatile matter (34 to 36 per cent) and lower carbon (85·6 to 87·2 per cent) on d.m.f. basis. While the caking index of these coals is found to be generally lower and the type of the cokes obtained from the Gray-King assay generally more shrunken in nature, it was observed that the caking index of the Kathara area coal increases with depth and improved types of coke are obtained from the Gray-King assay as the depth of the seam increases.

An overall study of the properties of these Kargali coals show them to be similar to the medium volatile coking coals of the Raniganj field.

The "O" seam Jharia coals are conspicuous by a higher percentage of ash, a lower percentage of volatile matter, a lower caking index and more shrunken nature of the coke from the Gray-King assay.

TABLE VIII

Properties of coals from Bokaro, Karanpura and Jharia fields.

Properties of coals	KARGALI SEAM			ARGADA SEAM	"O" SEAM	Tata's Coke Oven mixt.	X SEAM
	Sawang Colly.	Kathara area	Kargali and Jt. Bokaro Colly.	Sirka and Religora Colly.	Jharia field		W. Bokaro (washed)
Ash (Air-dried%)	15.2-21.7	15.3-24.4	14.2-14.8	16-20	16-22	15.8-17.0	13.5-14.5
Vol. Matter (" %)	27.7-30.1	26.7-31.0	26.9-27.9	31.4-33.5	18-21	26.0-27.0	27.9-29.0
Vol. Matter (d.m.m.f.) %	34.2-35.5	32.0-26.0	30.9-31.7	35.7-40.0	21-24	31.5-32.0	30.9-32.0
C% (d.m.m.f.)	86.4-87.1	85.6-87.2	87.8-88.3	82.6-84.1	90-91	-	-
Caking Index (B.S.)	17-22	15-23	20-22	3-10	11-14	21-24	20-24
Grey-King Assay (600°C) Coke type	F	E-G	G/G_1	B-C	E-F	-	-

Coking tests

The results of coking tests are shown in Table IX.

TABLE IX

Properties of coke from straight coals and blends.

Particulars of charge	PROPERTIES OF COKE					
	Shatter index (cumulative %)		Micum index (cumulative %)		Haven stability factor (cumulative on 1"	Ash in coke (dry %)
	on 1 1/2"	on 1/2"	on 40 mm.	Thr 10 mm		
	STRAIGHT KARGALI COALS					
1. Sawang 100%	92.2-92.7	97.1-97.2	78.3-79.0	11.6-12.2	56.0-56.2	26.1-28.2
2. Kargali & Jt. Bokaro (washed) =100%	88.5	97.5	76.5	11.0	54.7	19.6
3. Kathara	84.8	95.7	72.4	13.5	42.0	19.2
	BLENDS OF KARGALI WITH OTHER COALS					
4. Sawang 80% + 'O' Seam 20%	93.2	97.1	80.4	12.5	55.1	25.5
5. Jt. Bokaro + Kargali (50:50) -70% + 'O' Seam -30%	90.6	96.7	78.5	11.8	53.1	21.1
6. Sawang 80% + Argada 20%	92.0	95.3	77.5	16.7	53.2	25.6
	BLENDS OF ARGADA WITH OTHER COALS					
7. Argada - 25% + Tatas Coke Oven Coal Mixture or W. Bokaro washed -75%	91.5-94.2	96.7-98.0	77.6-79.7	12.1-13.5	39.7-43.4	19.5-22.3
8. Argada -20% + Tatas Coke Oven Coal Mixture or W. Bokaro washed -80%	91.6-93.6	97.8-98.1	77.7-78.2	12.8-13.0	42.3-43.4	19.5-22.7

Straight Sawang and Kathara coals

The Kargali Sawang coal gave "hard" coke of the metallurgical grade except for the high percentage of ash which could be reduced by washing the coal. Some of the physical indices were even slightly better than those of cokes from the washed Kargali coals from the Joint Bokaro and Kargali collieries (Serial Nos. 1 and 2).

The Kathara colliery coal was tested in 1949 in a commercial coke oven at TISCO (Serial No. 3). The poorer physical properties of the coke were due to the coal sample being collected from the outcrop.

Blends of Sawang with other coals

Equally satisfactory coke could be obtained from blends of the Kargali seam coals with 20–30% of the lower volatile "O" seam Jharia coals (Serial Nos. 4 and 5).

The poorer quality of the coke (in respect of some of the physical properties) obtained from a blend with 20 per cent of Argada coal is suspected to be due to the weathering of the Argada coal which was lying in stock for 4 to 5 months. This is shown by the drop of the caking index of the Argada coal from 9 to 4 (Serial No. 6).

Blends of Argada with other coals

Hard and strong coke was obtained from blends containing 20–25 per cent of Argada coal with Tata's coke oven coal mixture or washed West Bokaro coal (Serial Nos. 7 and 8).

It was also observed from these tests that better quality of coke is ensured by crushing the coals 100 per cent through 3 mm.

Special studies

Low phosphorus coke for ferro-manganese manufacture

Indian coals, because of their generally high phosphorus content, offer difficulty in producing low phosphorus coke for manufacture of ferro-manganese by the blast furnace technique.

Investigations showed that either binary blends of Laikdih and Dishergarh or ternary blends containing Giridih coal in addition to the other two coals with 5 per cent coke dust produced satisfactory coke ranging in ash from 17–18 per cent and about 0·05–0·06 per cent phosphorus, being thus suitable for ferro-manganese manufacture.

Since there is an insufficient reserve of Giridih coal, the possibility was explored of using suitably selected, low phosphorus Jharia coals in place of Giridih. The examples cited in Table X show rather high ash in the cokes but this could be reduced by the washing of the Jharia coals.

TABLE X

Properties of coke.

PERCENTAGE OF COALS IN BLENDS				PROPERTIES OF COKE				Haven stability factor on 1"	Analysis of coke dry %
				Shatter index		Micum index			
Laikdih	Dishergarh	Giridih	Jharia	on 1½"	on ½"	on 40 mm	Thr. 10 mm		Ash %
40–70	15–30	0–30	–	88.9–94.5	97.3–98.5	80.0–82.0	10.5–11.4	51.7–58.4	16.9–18.0
50–60	–	–	40–50	91.2–92.1	97.4–97.6	77.4–79.3	9.6–10.5	55.0–55.6	22.3–22.6

Influence of fineness of crushing on coke quality

From various investigations, it was generally observed that finer crushing of the components of the coking mixture brings about an improvement in the coke quality. This has been shown in Table XI by examples chosen from the results of tests reported in this paper.

Both in the case of straight coals and in their blends crushed to 100 per cent through 3 mm or even finer effected improvement in most of the physical test indices—the factor of greater importance is the lesser abradability of the cokes shown by the decrease in the Micum index through 10 mm.

TABLE XI

Properties of coke.

Sl. No	Coals and their Grain size		Micum index %		Shatter index %		Haven stability factor % on 1"
			on 40 mm.	Thr. 10 mm.	on 1½"	on ½"	
1.(a)	Dishergarh 70% '10' Seam 30%	* Coarse	71.0	17.0	89.6	96.1	40.7
(b)	-do-	*** V. Fine	73.8	13.7	90.1	96.8	48.0
2.(a)	Rakhicole Colly.	Coarse	79.0	13.0	95.8	98.8	45.4
(b)	-do-	**Fine	89.5	8.6	96.0	98.2	59.2
3(a)	Talcher seam coal –15% wash. Jamadoba Bok. Mixt. –85%	Coarse	76.4	13.6	92.3	98.0	44.2
(b)	-do-	Fine	79.7	13.3	91.8	97.5	47.4

(a) * Coarse indicates 65–80% thr. 3 mm.
(b) ** Fine indicates 100% thr. 3 mm.
(c) *** Very fine indicates 100% thr. 1.5 mm.

Effect of flue temperature

Even when carbonisation is done in the oven of the same width, the difference in the flue temperatures affects the coke quality to a greater or lesser extent.

The changes in the properties of the coke due to this factor will be seen from Table XII. In all the tests, the Shatter index on 1½", Micum index on 40 mm showed an increase with decrease in flue temperature. The other physical test indices were affected to a less extent. If blocky coke is desired then lower flue temperatures have to be employed affecting the throughput. A quicker rate of carbonisation at a higher flue temperature gives coke of more uniform size which in spite of its slightly lower Micum index on 40 mm is more suitable for the blast furnace.

TABLE XII

Properties of coke.

	Test No. 1		Test No. 2		Test No. 3		Test No. 4	
	Higher Flue	Lower Flue	Higher Flue	Lower Flue	Higher Flue	Lower Flue	Higher Flue	Lower Flue
Shatter on ½"	89.5	93.4	92.5	95.4	89.9	94.4	89.2	94.6
Index (cum%) on ½"	97.7	97.7	97.5	97.3	97.9	98.0	97.8	97.9
Micum on 40 mm.	76.6	84.5	77.5	81.3	76.0	81.2	76.1	83.3
Index cum % thr. 10 mm.	10.7	10.4	14.1	14.1	12.1	12.7	10.4	10.7
Haven Stability factor on 1"	55.8	57.8	51.9	53.7	52.8	55.5	58.2	57.4

Higher flue temperature 1200-1250°C.

Lower flue temperature -1075-1125°C.

Influence of oven width and carbonising time on coke quality

In the preceding table, results were presented of tests done in the same oven of 16″ width varying the flue temperature by about 150°C and the carbonising time by about 4 hours.

In the example given in Table XIII results are compared of tests carried out on the same blends of coals (containg 80 per cent of high to medium volatile Raniganj coals) and 20 per cent of Jharia coals carbonised in the pilot plant oven of 18″ width and also in "box tests" in a commercial oven of 20″ width.

TABLE XIII

Effect of width of oven and flue temperature.

Type of plant		Pilot plant	Commercial plant
Oven width	...	18″	20″
Flue temperature	...	1,230°	1,050°
Carbonising period	...	19–00	39 hrs.
Properties of coke			
Shatter index on 1½″		94·2	Not done because
% on ″		98·0	of poor quality of coke.
Micum index on 40 mm		80·7	72·4
% thr. 10 mm		10·2	20·0
Haven stability factor			
% on 1″		52·8	37·8

The flue temperatures were about 1,230°C for the pilot oven and 1,050°C for the commercial oven. The carbonising time was about 19 hours and 30 hours respectively. The overall poor quality of the coke obtained from the box test compared to the quality of the oven coke is apparent. The appearance of the coke which was recovered in a pebbly form showing coarse and gritty texture bears out the poor properties of the coke.

Thus such blends of higher volatile coals need carbonisation in narrower ovens at higher coking rate. The properties of cokes from lower volatile Jharia coals will on the other hand not be affected to the same degree but might rather show an improvement on carbonisation at a slower rate.

Summary and conclusion

Coking tests carried out in smaller electric and gas fired ovens and in the multi-oven pilot coke plant at the Central Fuel Research Institute show the following :

1(a) Hard and strong coke suitable for blast furnace use can be made from the washed Kargali seam coals from the Kargali and Joint Bokaro collieries. Improved quality of coke is obtained from blends with Jharia coking coals (from the upper seams).

In these and all subsequent tests it has been seen that finer crushing of the coals (preferably selectively) 100% through 3 mm. considerably improves the coke quality.

Addition of crushed coke dust (1 mm. in size) is possible to most coal blends, to the extent of 4%–5% and this improves some of the physical properties but makes the coke generally more abradable.

Carbonisation at slower heating rate with lower flue temperature makes the coke more blocky and improves some of the physical properties of the coke. But the coke of more uniform size, though smaller in average size, obtained from higher heating rate with higher flue temperature, is considered more suitable for blast furnace practice.

(b) Washed Rakhicole coal of the Kanhan valley (M.P.) produces coke of the metallurgical grade on its own.

80–85% of the Damua, Kalichhapar coals (Kanhan) can be utilised for coking with low volatile Jharia coals.

(c) A maximum of 20 per cent of the non-coking Ghordewa seam, Korba (M.P.) and Hingir Rampur, Ib. River or Talcher coals, Orissa and 40% of Jhilimili coals, M.P. could be used in blends with good coking coals including the Kargali coals. These findings are thus worth considering for implementation in the Bhilai and Rourkela steel plants.

(d) The low reserves and small production of the Kanhan valley coals and the comparatively low yield of clean coal obtained from Rakhicole coal as well as the distance of this coal area from Bhilai discourage the use of Kanhan coals for coking in the new steel plant. The use of Korba and Jhilimili coals is considered more economical in these respects.

2(a) Ternary blends containing 80% of mixtures of high and medium volatile Ranigang coals and 20% of Jharia coking coals produce metallurgical coke.

(b) Satisfactory coke can be made from binary blends containing 70 to 80% of the high

volatile Dishergarh seam (Raniganj) coal and 20 to 30% of low volatile Jharia coals from the "O" seam Jharia coals produce soft and weak cokes on their own and these results thus point to the possibility of utilising for coking purpose two substandard coals by judicious preparation and blending.

(*c*) Equally good coke is obtainable from blends containing 80 to 85% of the Dishergarh coal and 15 to 20% of low temperature coke or char made from non-coking to weakly coking coals. This points to the possibility of utilising economically in the Durgapur steel plant the fines from any low temperature carbonisation plant that may be established in the Raniganj area in future.

(*d*) Suitable selection of coal (particularly containing Giridih and Laikdih of low phosphorus contents) also enables the production of low ash, low phosphorus coke for ferro-manganese manufacture.

3. (*a*) The Kargali seam coal from Sawang colliery produces hard and strong coke except for the high ash which could be reduced on washing the coal.

(*b*) 20–25% of "O" seam Jharia coal or Argada seam coal from the Karanpura field can be used with these Kargali seam coals thus offering the prospect of utilisation of substandard coals for coking and leading also to economy in the use of the washed Kargali coal.

(*c*) Coals from both these areas (Sawang and Kathara) when suitably beneficiated would thus prove suitable for use in the fourth steel plant at Bokaro.

A coal washing plant should be installed at Kathara ; the middlings and rejects can be used in the Bokaro power plant and/or at Dugda power plant (under consideration).

The output from the Sawang colliery should be increased and the coal washed with the Kathara coal for the fourth steel plant in the public sector.

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APPENDIX I

Particulars of Sample	Overall A	Float(3/4"-1/8") B	Raw-1/8" C	Total portion (B+C) used for carbonisation tests.
Loyabad Colliery, Yield% . XII - XV seams.	-	48.1-60.3	23.3-35.3	71.4-95.6
Ash%	: 15.2-22.8	14.0-14.7	12.5-15.1	13.4-14.8
Joint Bokaro & Kargali Collieries, Kargali seam Yield%	: -	40.0-53.3	19.2-26.7	61.7-80.0
Ash %	: 19.0-?^.	1.4-14.7	14.6-17.1	14.5-15.6

	Bokaro	Kargali	Bokaro and Kargali mixed.
Sp.gr. of Barytes medium:	1.40	1.40	
Sp.gr. of Separation:	1.514	1.500	
Wt. % of cleams:	68.83	52.47	64.70
Ash % of cleams:	16.8	19.4	17.3
Wt. % of sinks:	31.17	47.53	
Ash % of sinks:	39.0	40.7	
Ash of feed:	23.7	29.5	25.2
% of 0.1 N.G. materials:	48.56	57.87	
Efficiency (F & Y)	95.6	89.7	

	Raw coal	Cleams	Middlings	Rejections
Yield %	-	72.9	21.7	5.4
Ash %	20.7	13.4	31.4	60.8

TABLE I

Washing test on Kargali and Jharia coal.

Washed in the heavy medium pilot washer at Central Fuel Research Institute. (Size of coal $^{3}/_{4}"-^{1}/_{8}"$).

TABLE II

Typical results of washing in the pilot drum washer at Central Fuel Research Institute. (Size of coal $3"1-\frac{1}{2}"$).

TABLE III

Results of washing of slack coal ($1\frac{1}{2}"-0"$) in the Lodna Jig Washery. (Coal crushed to $-\frac{1}{2}"$ for washing)

APPENDIX II

Results of proximate analysis and caking index.

	Particulars of coal	Proximate Analysis of Coal - %					Caking Index (B.S.)
		Moist.	Ash	V.M.	F.C.	V.M. (Dry M.M. free)	
ORISSA	Talchar seam	4.3-4.6	11.7-13.0	33.4-38.9	43.8-49.8	41.1-46.2	Non-caking to 2
ORISSA	Ib. River "	56 - 10.1	12.5-16.2	31.4-33.4	44.8-46.0	39.5-43.6	Less than 2
ORISSA	Hingir-Rampur seam	7.9-10.8	11.5-15.7	31.0-31.7	45.4-46.0	39.9-42.8	"
BOKARO	Joint Bokaro(Kargali Seam) (washed)	0.9	14.2	27.9	57.0	31.7	22
BOKARO	Kargali(Top & Bottom) (washed)	1.5	14.8	26.9	56.8	30.9	20
BOKARO	Mixt. of Jt. Bokaro & Kargali (2:1)						
BOKARO	i) Washed large (3"-½")	13-1.6	15.7-18.2	25.6-27.0	54.7-55.9	30-31.4	20-23
BOKARO	ii) Washed slack (½"-0)	1.0-2.2	13 - 13.8	27.1-27.6	56.8-58.6	30.6-31.6	22-23
BOKARO	iii) Mixt. of large & slack (50:50)	1.4-1.9	14.2-15.3	26.4-27.5	56.3-57.0	30.5-31.7	21-22
BOKARO	Sawang (Kargali seam)	1.5-2.2	15.2-21.7	27.7-30.1	49.1-52.5	34.2-35.6	17-22
BOKARO	Kathara (")	0.9-1.9	15.3-24.4	26.7-31.0	44.7-51.8	32-36	15-23
	Karanpura:						
	Sirka, Religara Collieries (Argada Top seam)	2.8-3.2	16-20	31.4-33.5	47-49	35.7-40	3-10
RANIGANJ	Laikdih deep (Laikdih) (seam)	0.8-1.6	11.4-14.2	27.7-29.2	56-57.7	31.9-33.4	20-24
RANIGANJ	West Victoria (")	1.2-1.5	16.6-19.8	24.3-26.3	54.7-57.4	28.2-30.4	14-16
RANIGANJ	West Victoria(Ramnagar Seam)	1.5	14.4-17.1	28-29.8	53.4-54.3	33-34.3	15
RANIGANJ	Chanch (Chanch Seam)	1.5-1.9	15.7-17.9	28-31.0	52-53	33.7-35.8	19-21
RANIGANJ	Seetalpur (Sanctoria Seam)	1.5-2.3	14.9-17.6	35-36.6	45.9-46.2	41.7-42	16-19
RANIGANJ	Deoli (")	2.4-2.5	13.6-14.5	33.5-33.8	49.6-50.1	39.3-39.5	16-20

(Contd.)

1	2	3	4	5	6	7
Chinakuri (Dishergarh)	1.7-2.9	13.0-15.5	35.7-37.6	45.6-48.2	40-43.0	17-22
Seetalpur (")	1.8-2.1	15-16	35.2-36.9	45.9-47.0	41.5-43.5	20-21
M.P. COALS						
KANHAN VALLEY						
Damua Colliery	2.2	16.5-18.5	31.7	49.6	37.7	16.5-17
Kalichhapar Colliery	2.6	16.5-17.6	31-32	49.9	37.0	16.5-18
Rakhicole Colliery	1.4	20.2-21.5	26.9-28	50.2	33.0	19-19.5
JHILIMILI						
Katkona seam	2.6	15.4	29.7	52.3	35.0	13
Sardih seam	3.1	13.1	31.7	52.1	36.8	13
Bandakhoh seam	3.2	16.1	31.6	49.1	35.9	10
KORBA						
Ghordewa seam (small sample, bulk sample)	3.4-7.5	11.3-12.6	30.7	50.5-53.3	35.6-36.9	3-7
GIRIDIH						
Lower Karharbaree	0.8-1.0	11.2-12.8	26.2	60-61.8	28.9-29.3	19-20
JHARIA						
Bastacolla Colliery 'O' seam	1.0-1.4	16.5-19.7	18.2-19.7	59.6-63.8	20.6-22.9	11-13
East Bastacolla " 'O' seam	0.8	18.7	19.9	60.6	22.9	12
Monaitand " 'O' seam	1-1.1	17.7-19.6	18.6-19.9	60.3-62.2	22.1-23.1	10-15
Bera Colliery, 'O' seam	1.2	18.7	20.2	59.9	23.4	11

(Contd.)

1	2	3	4	5	6	7
Khaskuia Colliery, 'O' seam	0.9	16.0	20.8	62.3	23.6	15
Central Salunga Colliery, 'O' seam	0.8-1.1	14.6-24.1	20-21.4	54-62.5	24-25.5	12-16
Pure selected Bansjora Colliery, V seam	1.3	29.1	17.1	52.5	21.3	12
East Ena Colliery, VII & VIII seam	0.7	27.6	17.6	54.1	21.5	13
Pure Jharia Colliery, VII & VIII seam	0.9	23.4	18.6	57.1	22.2	14
Busserya Colliery, X seam	1.1	19.7	20.8	58.4	24.4	19
Central Joenagora Colly., X seam	2.0	21.1	23.1	53.2	28.9	19
Sendra Bansjora Colliery, XI seam	0.9	21.5	19.3	58.3	22.4	15
Loyabad (washed) " XII-XV seam	1.4-1.5	13.5-14.9	21.5-23.2	60.7-63.4	24-26.2	15-21
" (unwashed) " XIII-XV seam	0.9-1.0	13-21.2	22-23.9	55.8-63.9	24.8-28.4	16-18
Bararee (unwashed) " XIV seam	0.7	17.8	26.9	54.6	29.1	19
Katras Choitidih " XII seam	0.9-1.2	17.5-18.5	21.5-23.1	58.2-59.1	24.9-25.0	19
" XIII seam	0.7-1.2	17.6-17.9	24.1-24.9	56.8-57.2	28.2-28.5	20
Pootkee Colliery, XV seam	1.1-1.4	15.4-18.8	23.5-23.7	56.6-59.5	27.2-27.6	22
Balihari Colly.,XV seam	0.8	11.3	24.0	63.9	26.4	24
Burragarh " XV seam	1.7	12.9	25.2	60.2	28.4	-
South Balihari - Kendwadih Colliery, XV seam	1.0-1.6	12-13.4	22.8-23.0	62.2-64.0	25.5-25.7	24
Burragarh Colliery, XVI seam	1.2-1.7	16.7-19.5	29.1-29.5	50.7-52.6	34.0-34.6	24
Balihari Colliery, XVI seam	0.8-1.6	15.0-15.9	27-27.5	55.5-56.7	31.4	25
South Balihari Kendwadih XVI seam	1.1-1.3	16.5	27.3-27.5	54.9	32.0-32.3	25

APPENDIX III

Results of ultimate analysis C. V. etc.

Particulars of sample	Ultimate Analysis Dry M.M. free basis %					Phosphorus % (Dry)	Calorific Value B.Th.U./lb.	
	Carbon	Hydrogen	Sulphur	Nitrogen	Oxygen (by diff.)		Air-dried	Dry M.M. free
ORISSA								
Talcher seam	82.30	5.58	0.82	1.63	9.67	0.073	-	-
Ib - River seam	81.85	4.91	0.83	1.48	10.93	-	-	-
Himgir Rampur seam	82.47	5.09	0.87	1.53	10.34	0.056	-	-
BOKARO								
Joint Bokaro (Kargali) washed.	87.76	5.11	0.86	2.08	4.19	0.070	12,840	15,380
Kargali(Top & Bottom) washed.	88.26	5.18	0.84	2.05	3.67	0.08	12,755	15,480
Mixt. of Jt. Bokaro and Kargali (2:1)								
i) Washed large(3"-1½")	88.16	5.13	0.70	1.89	4.12	0.079	12,580	15,412
ii) Washed slack(1½"-0)	88.70	5.11	0.76	2.04	3.39	0.091	13,020	15,509
Sawang (Kargali).....	86.30-87.09	5.3 - 5.40	0.68-0.82	1.80-1.88	5.35-5.76	0.112-0.178	-	15,207-15,360
Katharaf ").....	85.55-87.15	4.90-5.35	0.57-0.85	1.79-2.02	5.59-6.23	0.06 - 0.30	-	15,260-15,350
SOUTH KARANPURA								
Sirka, Religara(Argada Top)	82.63-84.12	5.24-5.35	0.73-0.78	1.56-2.00	7.90-9.70	0.08-1.27	- -	14,460-14,630
RANIGANJ								
Laikdih deep (Laikdih)	87.28-87.74	4.88-5.12	0.51-0.12	1.72-1.91	4.66-5.41	0.035-0.017	12,790-12,990	14,838-15,338
West Victoria (")	86.7-89.31	4.91-5.61	0.44-0.55	1.81-2.08	3.50-4.8	0.100-0.133	11,810	15,150-15,450
West Victoria (Ramnagar)	86.70	5.13	0.56	2.08	5.47	0.096	11,850	14,540
Chanch (Chanch)	87.81	5.93	0.52	2.24	3.50	0.137	12,100	15,374
Seetalpur (Sanctoria)	83.36-84.61	5.32-5.51	0.41-0.42	2.42-2.45	4.21-8.29	0.114-0.174	11,990-12,410	14,910-14,950
Deoli (")								
Chinakuri (Dishergurh)	84.44-85.00	5.54-5.63	0.34-0.42	2.39-2.55	6.56-7.13	0.124-0.140	12,450	15,060
Seetalpur (")	83.8-85.21	5.61-5.83	0.30-0.38	2.35-2.79	6.04-7.79	0.093-0.155	12,280-12,420	14,990-15,290
M. P. KANHAN VALLEY								
Damua Colliery	85.21	5.40	0.75	1.99	6.65	0.121	12,090	15,180
Kalichhapar Colliery	85.98	5.35	0.71	1.77	6.19	0.073	12,080	15,240
Rakhicole Colliery	88.80	5.38	0.56	1.86	3.40	0.0217	11,750	15,680
JHILIMILI								
Katkona seam	86.78	5.00	0.42	1.62	6.18	0.005	12,130	15,080
Sardih seam	85.02	5.01	0.52	1.65	7.80	0.004	12,240	14,840
Bandakhoh seam	85.92	5.17	0.57	1.68	6.66	0.003	11,830	14,960
KORBA								
Ghordewa seam (small sample, Bulk sample)	84.28-84.68	5.04-5.08	0.48-0.52	1.56-1.81	8.16-8.39	0.004-0.006	11,680-12,120	14,590-14,650
JHARIA								
'O' seam Bastacolla.	91.17	4.48	0.45	1.73	2.17	0.018	12,110	15,599
'O' seam Monaitand	91.56	4.76	0.71	1.51	1.46	0.045	12,400	15,704
VII & VIII seam East Ena	90.69	4.58	0.45	1.98	2.30	0.078	10,750	15,690
'X' seam, Central Jeenagora	89.29	5.54	0.84	1.80	2.53	0.025	-	-
'XI' seam, Sendra Bansjora	91.07	4.64	0.89	2.04	1.36	0.036	11,850	15,758
'XIII' seam, Loyabad (unwashed)	90.04	4.84	0.68	2.01	2.53	0.273	12,540	15,853
'XIV' seam (")	90.48	5.03	0.60	2.05	1.84	0.179	13,440	16,095
'XIV' seam, Bararee (unwashed)	88.98	5.03	0.62	2.06	3.31	0.209	12,350	15,530
'XV' seam, Loyabad (unwashed)	89.72	4.79	0.61	2.06	2.82	0.205	11,800	15,945
Mixt. of 'XII' 'XIII' 'XIV', 'XV' seams (washed)	89.62	4.86	0.70	2.08	2.74	0.094	12,742	15,560
Mixt. of 'XII-XVI' seams (unwashed)	88.69	5.23	0.60	2.17	3.39	0.159	-	-
GIRIDIH								
Lower Karharbaree	90.01	4.46	0.46	1.76	3.31	0.006	13,740	15,806

APPENDIX IV

Analysis and fusion range of ash.

Particulars of sample		Ash analysis %									
Colliery	Seam	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	SO_3	P_2O_5	Alkalies (by diff.)	Ash fusion range °C in mildly reducing atmosphere
JHARIA											
(i) Sendra Bansjora	XI	57.86	24.01	11.69	1.52	1.10	1.39	0.97	0.42	1.04	1160-1300
(ii) Kustore	XI(washed)	55.80	22.91	13.80	1.50	1.40	1.20	1.63	0.36	1.40	-
(iii) Bhalgora	XI	51.17	21.24	18.31	1.24	2.12	1.33	0.77	1.26	2.96	1100-1250
(iv) Loyabad	XII,XIII,XIV, & XV(washed)	53.90	26.90	9.15	2.18	1.22	2.48	0.90	1.50	1.87	1280-1400
(v) Bararee	XIV	45.54	21.84	14.61	1.99	6.15	2.52	2.83	2.66	1.86	1260-1410
RANIGANJ											
(i) Laikdih deep.	Laikdih	46.00	34.93	6.32	2.38	3.71	2.86	2.43	0.57	0.80	Over 1400
(ii) Seetalpur	Sanctoria	49.11	16.65	15.66	1.40	6.60	3.68	1.93	1.42	3.51	1100-1240
(iii) -Do-	Dishergarh	54.55	21.75	7.44	1.55	5.68	2.80	1.89	1.43	2.91	1160-1260
(iv) Chinakuri	Dishergarh	49.41	19.42	9.23	1.72	9.64	3.24	1.72	2.51	3.11	1120-1200
(v) West Victoria	Ramnagar	-	-	-	-	-	-	-	-	-	1180-1260
M. P.											
(i) Damua		55.01	25.84	8.77	1.55	3.66	0.56	0.71	1.64	2.26	1260-1420
(ii) Kalichhapar	...Kanhan Valley	55.42	25.19	7.93	1.61	4.84	0.72	1.22	0.99	2.08	1230-1330
(iii) Rakhicole		63.02	24.91	7.45	1.58	0.87	0.50	0.29	0.23	1.15	Over 1400
	Jillimilli										
	Katkona	63.36	23.03	7.11	2.53	0.93	0.93	0.30	0.07	1.74	Over 1400
	Sardih	59.02	31.29	5.59	1.95	0.68	0.64	0.30	0.07	0.46	Over 1400
	Bandakhoh	69.22	21.24	5.21	1.66	0.56	0.95	0.57	0.04	0.55	Over 1400
	Korba										
	Ghordewa	62.68	27.62	2.37	2.80	1.08	0.55	0.66	0.11	2.13	Over 1400
BOKARO											
Joint Bokaro (washed)	Kargali seam	53.56	33.55	6.71	2.60	1.11	1.16	0.19	1.14	1.88	Over 1400
Kargali(Top & Bottom)(washed)	-Do-	51.80	31.10	7.00	2.70	1.94	1.07	0.34	1.58	2.47	
Sawang(unwashed)	Kargali seam	55.01	33.44	6.13	0.93	2.09	1.27	-	1.16	Trace	1200-Above 1400
GIRIDIH											
Karharbaree	Lower Karharbaree	69.80	18.70	5.60	2.20	1.00	1.00	1.00	0.07	0.63	1260 to over 1400
ORISSA											
	Talcher seam	-	-	-	-	-	-	-	-	-	Over 1400°
	Ib. River "	-	-	-	-	-	-	-	-	-	Over 1400°
	Hingir Rampur "	-	-	-	-	-	-	-	-	-	Over 1400°

APPENDIX V

Results of coking test on straight coals.

Particulars of sample		Fineness of coal (% thr. 3 mm.)	Properties of Coke					Ash in Coke %
			Shatter Test cum %		Micum Test cum %		Haven Stability Factor cum % on 1"	
Seam	Colliery		on 1½"	on ½"	on 40 mm.	Thr. 10 mm.		
JHARIA								
'O'	Bastacolla	100	88.0	91.5	58.2	36.5	32.8	20.3
'O'	Monaitand	100	87.3	94.3	67.3	19.0	37.0	22.9
'O'	Bora	100	86.5	91.7	61.2	31.9	26.7	22.7
'O'	Khas Kuia	100	89.0	96.2	73.5	14.7	62.1	22.1
'O'	Central Salunga	100	90.2	96.6	75.0	13.8	58.7	21.4
'VII-VIII'	East Ena	100	94.1	97.5	82.8	11.8	56.6	34.1
'VII-VIII'	Pure Jharia	100	94.3	97.1	78.8	11.6	52.0	27.7
'X'	Busserya	100	91.3	98.0	80.3	10.2	60.3	25.3
'X'	Central Jeenagora	100	94.0	97.9	82.9	10.5	61.4	17.1
'XI'	Sendra Bansjora	95	96.6	98.1	84.5	9.0	59.2	26.0
'XIV'	Bararee	100	93.3	98.0	79.1	8.4	64.2	23.3
'XII-XV' (washed)	Loyabad	100	93.5	98.5	82.7	8.5	57.9	18.3
RANIGANJ								
Laikdih	Laikdih deep	100	83.9-91.0	97.4-97.5	76.2-77.7	8.6-8.8	48.8-58.0	17.7-18.3
Laikdih	West Victoria	90	92.7	96.5	76.0	16.5	50.2	23.8
Ramnagar	West Victoria	90	94.0	97.6	77.3	15.2	51.8	22.4
Chanch	Chanch	90	94.0	98.2	76.8	11.5	45.7	24.3
Sanctoria	Seetalpur	100	85.5	96.6	56.9	12.3	22.9	24.0
Sanctoria	Deoli	85	94.0	98.2	76.8	11.5	45.7	24.3
Dishergarh	Chimakuri	90	77.6	95.6	52.5	15.5	21.1	19.9
Dishergarh	Seetalpur	100	78.0	96.8	59.5	15.1	14.1	21.4
M. P. (Kanhan Valley)								
Damua		100	87.0	94.5	72.1	20.9	38.2	22.0
Kalichhapar		100	89.0	95.3	72.4	17.6	50.5	22.7
Rakhicole		100	96.0	98.2	87.1	10.6	59.2	27.0
BOKARO								
Joint Bokaro(Kargali seam) (washed)		100	91.8	97.9	78.5	8.2	62.3	19.3
Kargali (Top & Bottom) (washed)(Kargali seam)		100	92.1	98.2	77.4	11.2	54.7	20.5
Mixt. of Jt. Bokaro & Kargali (2:1)								
i) Washed large(3"-1½")		80	88.3	97.5	74.7	10.9	56.7	20.4
ii) Washed slack(1½"-0)		80	87.0	96.6	73.1	10.6	53.6	17.4
iii) Mixt. of large & slack		80-100	88.8-88.5	96.8-97.5	73.2-76.5	12.8-11.0	49.2-54.7	20.5-19.6
Sawang Colly. (Kargali seam)		100	92.2-92.7	97.1-97.2	78.3-79.0	11.6-12.2	56 -56.2	26.1-28.2
Kathara Colly. (")		85	84.8	95.7	72.4	13.5	42.0	19.0
GIRIDIH								
Lower Karharbaree		100	88.8	98.4	75.0	8.0	60.6	14.8

APPENDIX VI

Results of coking tests on different blends.

PARTICULARS OF BLEND	FINENESS OF COAL % PASSING THR. 3 MM.	PROPERTIES OF COKE						
		SHATTER TEST CUM %		MICUM TEST CUM %		HAVEN STABILITY FACTOR CUM % ON 1"	ASH IN COKE %	POROSITY %
		ON 1¼"	ON ½"	ON 40 MM.	THR. 10 MM.			
With Orissa Coals								
Blend of Tafcher 15%) Washed Jamadoba-Bokaro mixt. 85%)	80	92.3	98.0	76.3	13.5	44.3	20.1)	45.2
	100	91.8	97.5	79.8	13.2	47.4	19.5)	
-Do- 20%)	80	90.2	96.8	75.6	14.6	45.3	19.5)	46.5
80%)	100	91.2	97.3	78.7	13.9	46.9	-)	
Blend of Ib- River-15%) Washed Jamadoba-Bokaro mixt. -85%)	80	90.3	96.5	78.2	13.6	47.4	20.5)	49.5
	100	82.0	99.0	79.4	14.8	52.9	20.2)	
-Do- 20%)	80	90.0	96.0	77.8	13.0	44.7	20.6)	47.3
80%)	100	90.8	97.8	76.3	13.5	48.9	19.8)	
Blend of Hingir-Rampur 10% Sijua XII -90 %	80	92.0	-	76.0	-	48.6	20.3	-
Hingir-Rampur -10% Choitodih XII-XV Seam -90%	80	95.5	-	77.1	-	45.5	23.4	-
Hingir-Rampur -10% West Bokaro 'X' seam-90%	80	91.0	-	77.1	-	47.7	18.5	-
Hingir-Rampur-15% Washed Jamadob-Bokaro mixt-85%		90.7	96.5	80.0	11.7	49.2	-	46.4
-Do- 20% 80%		93.0	97.3	79.3	13.0	45.6	-	50.7
Hingir-Rampur-20% Sijua XIV- 80%	80	95.0	-	79.2	-	49.4	18.4	-
With Bokaro Coals								
Kargali - 76%) Korba(Washed)-20%) Coke dust- 4%)	100	94.3	97.9	80.1	11.6	54.2	18.0	50.0
Kargali-65%) Korba(Washed)-30%) Coke dust 5%)	100	95.2	98.0	74.9	18.1	50.0	18.8	-
Kargali(washed) 70-75% Loyabad - 20-25% (washed) with or without 5% coke dust.	100	92.5-96.0	98.1-98.4	81.8-85.3	8.8	59.8-62.6	19.4 - 19.6	49.4 - 50.7
Kargali(washed)large & slack(50:50) -75% Loyabad mixt.- 25% with or without 5% coke dust	90	89.5 92.5	97.5-97.7	76.6-77.5	10.7-14.1	51.9-55.8	20.0-20.4	44.9 - 46.0
Kargali washed large & slack(50:50) -70% Mixt. of Jharia-(excluding Loyabad)- 30%	85	92.4	97.5	77.1	12.6	55.7	20.5	42.6
-Do- - 50% 50%	85	89.9	97.9	76.0	12.1	52.8	20.7	42.1
-Do- 30% 70%	85	94.6	97.9	83.3	10.7	57.4	20.8	43.8
Kargali washed -40-50% Korba - 10-20% Laidih or Bararee XIV 26-35% C.D. 4%	100	92-94	97.3-97.8	76.8-77.8	11.6-12.2	51.5-53.0	19.2-20.2	51.4
Kargali(washed) -40% Korba - 30% Bararee 25% C.D. 5%	100	91	95.6	77.9	14.9	45.0	20.0	50.2
Kargali(washed)large & slack-30% Jharia mixt.- 70% (unwashed)	85	88.3-90.2	97.5-98.1	75.1-77.1	10-11.1	56.8-60.0	21.2-21.5	42-45
Sawang -80% 'O' seam Jharia -20%	100	93.2	97.1	80.4	12.5	55.1	25.5	48.0
WITH KARANPURA COALS								
Argada Top seam -20% (Sirka Colliery) Sawang- 80%	100	92.0	95.3	77.5	16.7	53.2	25.6	49.0
Argada Top Seam-25% (Sirka Colliery) Tata's C.O.mixt. -75 %	100	92.5	97.3	77.6	14.2	46.8	21.6	-

APPENDIX VI (*Contd.*)

PARTICULARS OF BLEND	FINENESS OF COAL % PASSING THR. 3 MM	PROPERTIES OF COKE						
		SHATTER TEST CUM %		MICUM TEST CUM %		HAVEN STABILITY FACTOR CUM % ON 1"	ASH IN COKE %	POROSITY %
		ON 1½"	ON ½"	ON 40 MM.	THR. 10 MM.			
Argada Top Seam (Religara Colliery)-20% Tata's C.O.mixt. -80%	100	91.6	98.1	77.7	12.8	42.3	22.7	-
Argada Top seam (Religara Colliery) 20% West Bokaro washed - 80%	100	93.6	97.8	78.2	13.0	43.4	19.5	-
-Do- -25% -75%	100	91.5	96.7	77.6	13.5	39.7	19.7	-
Argada Top seam (Religara Colliery) -25% Tata's C.O. mixt. -75 %	100	94.2	98.0	79.7	12.1	41.8	22.3	
Kargali(washed) large & slack(50:50) -70% 'O' seam Jharia-30 %	85	90.6	96.7	78.5	11.8	53.1	21.1	-
WITH M.P. COALS (Kanhan Valley) Kalichhappar- 85% 'X' seam, Bhowrah -15%	100	88.5	95.5	80.3	9.6	56.2	-	-
Damua - 70% - 'X' seam,Bhowrah-30%	88 100	90.7 90.7-93.6	95.2 96.7-97.2	77.9 81.1-81.5	16.6 11.5-11.7	45.5 52.9-56.6	20.1 21.2-23.2	- -
Jhilimili Jhilimili - 20% 'X' seam, Bhowrah-80%	100	92.4	98.0	-	-	56.0	26.3	-
-Do- -30% 70%	100	91.2	97.4	-	-	58.7	25.9	-
Jhilimili -30% Kargali slack -70%	100	89.6	97.2	74.6	14.3	45.0	22.6	-
-Do- 35% 65% With 5% coke dust	100	92.1	96.0	70.8	20.3	45.1	23.0	-
Jhilimili -40% 'X' seam, Jharia-60%	100	92.9	97.5	82.5	9.0	52.3	25.4	-
Jhilimili - 40% Kargali slack-60%	100	90.8	97.2	74.5	13.4	49.1	23.3	-
Jhilimili - 50% XI seam (washed)-50% Bhalgora	100	87.2	91.3	64.8	26.8	40.5	20.5	-
-Do- 60% 40%	100	82.7	89.2	61.3	30.4	33.8	20.3	-
With Korba Korba - 10 - 20% Kargali-50 - 70% (washed) Laikdih or XIV, Bararee 26-35% Coke dust 4-5 %	100	92-94.3	97.3-97.9	70.8-80.1	11.6-12.2	51.3-54.2	18 - 20.2	50-51.4
Korba - 30% Kargali - 40-65% (washed) XIV Bararee 0 - 25% Coke dust - 5 %	100	91 - 95.2	95.6 - 98.0	74.9 - 77.9	14.9 - 18.1	45 - 50	18.8 - 20	50.2
Dishergarh (Raniganj)with Jharia Sjetalpur - 80% 'O' seam, Bera - 20%	90	88.6	96.3	67.8	15.2	37.0	24.4	-
Perbelia - 80% 'O' seam,Central Salunga -20 %	100	86.0	97.2	74.7	9.0	45.7	24.4	-
Seetalpur -80% Vseam, Pure selected Banjora -20%	100	92.3	96.8	74.2	12.3	39.5	20.4	-
Methani -80% VII-VIII seam,Pure Jharia -20%	100	92.0	97.0	79.4	10.3	54.4	21.4	54.5
Mixed Dishergarh - 80% VIII seam,Golukdih- 20%	100	89.5	96.7	70.0	11.0	49.0	-	-
Chinakuri - 80% Coal mixt. from Bhowrah - 20%	85	88.8	97.0	75.5	11.1	40.4	22.3	-
Seetalpur -75% 'O' seam,Bastacolla -12.5% 'X' seam, Busserya -12.5%	90	91.6	98.0	79.3	10.8	51.2	24.5	-

APPENDIX VI (*Contd.*)

PARTICULARS OF BLEND	FINENESS OF COAL % PASSING THR. 3 MM.	PROPERTIES OF COKE						
		SHATTER TEST CUM %		MICUM TEST CUM %		HAVEN STABILITY FACTOR CUM % ON 1"	ASH IN COKE %	POROSITY
		ON 1½"	ON ½"	ON 40 MM.	THR. 10 MM.			
Chimakuri -75% VII & VIII seams, East Ena -20% H.T.Coke dust- 5%	100	93.5	97.7	80.2	12.1	40.4	22.9	51.0
Seetalpur -70% 'O' seam, Bera-30%	90	92.2	96.3	72.7	13.2	44.7	23.0	-
Seetalpur -70% 'O' seam,Monaitand -30%	90	93.2	97.4	79.0	12.5	49.2	24.0	42.4
Seetalpur -70% 'O' seam Khashula -30%	90	91.2	97.0	78.3	10.6	48.1	22.9	51.3
Seetalpur -70% 'O' seam,Central Salunga -30%	90	93.5	98.0	79.7	8.4	55.4	24.4	49.2
Perbelia -70% 'X' seam,Sindih-30%	100	94.0	97.8	-	-	54.4	24.0	-
Seetalpur -70% 'X' seam,Central Jeenagora -30%	90	89.1	96.9	71.2	14.2	39.9	22.7	-
Dishergarh(Raniganj)with Jharia								
Seetalpur -70% 'X' seam Busserya-30%	90	92.4	97.0	78.2	10.8	51.7	25.3	-
Seetalpur -70% 'XI' seam Bendra Bansjora -30%	90	92.0	96.8	77.6	12.7	45.0	25.7	52.0
Chinakuri -70% Coal mixt.from Bhowrah -30%	85	89.0	97.0	75.5	9.3	46.3	22.0	-
Chinakuri - 70% Loyabad XIII(washed) - 30%	100	95.3	98.0	85.2	8.3	56.8	18.6	-
Seetalpur -70% Bokaro Kargali,washed -30%	90	87.5	96.7	67.4	14.5	35.0	23.4	47.6
Dishargarh -50% XII- XIV seams,Choitidh -25% XII-XVI seams,mixed(washed) -25%	90	93.8	97.3	78.6	10.9	47.4	24.1	-
Dishergarh -50% XVI seam Jamodoba(washed) -50%	90	92.5	97.3	80.2	11.5	52.8	21.8	-
DISHERGARH WITH KARGALI								
Dishergarh -50% Bokaro Kargali(washed) -50%	90	89.7	95.6	74.0	16.0	47.8	22.8	-
DISHERGARH WITH LT.CHAR								
Chinakuri -85% L.T. Coke from Sanotoria coal-15%	100	91.4	97.5	75.4	12.0	44.0	20.5	45.9
Chinakuri -85% L.T.Coke from Koithee coal -15%	100	93.3	98.0	77.8	11.4	47.4	23.0	-
Chinakuri -85% L.T.Coke from mixed non-coking Raniganj coals -15%	100	92.4	97.2	78.1	11.6	39.0	-	-
Blend of Chinakuri -25% Laikdih deep -50% XI seam,Jogta -12.5% 'O' seam Bastacolla -12-5% with 5% H.T.Coke dust	90	92.5- 93.5	97- 97.6	77.3- 81.5	11- 14.3	42.4- 45.3	19.3- 20.2	47.1- 49.8
Blend of Deoli -25% Laikdih deep -50% XIseam,Jogta- 12.5% 'O' seam Bastacolla -12-5% with 5% H.T.Coke dust.	100	93.4	97.1	76.0	15.0	48.0	19.4	46.5
Blend of Chinakuri -25% West Victoria -50% (Laikdih seam) XI seam Jogta with 4% coke dust. -25%	90	95.0	97.2	81.2	14.8	47.2	26.0	49.0

APPENDIX VI (*Contd.*)

PARTICULARS OF BLEND	FINENESS OF COAL % PASSING THR' 3 MM	PROPERTIES OF COKE						
		SHATTER TEST CUM.%		MICUM TEST CUM %		HAVEN STABILITY FACTOR CUM % ON 1"	ASH IN COKE %	POROSITY %
		ON 1½"	ON ½"	ON 40 MM	THR. 10 MM			
Blend of Chinakuri-25% West Victoria -50% XI seam, Jogta -12.5% 'O' seam, Bastacolla-12.5% with 4% coke dust.	90	94.1	96.5	77.6	17.5	51.8	24.0	46.1
Blend of Chinskuri-25% West Victoria -25% Laikdih deep -25% XI seam Jogta -12.5% 'O' seam Bastacolla-12.5%	90	89.8- 91.2	97- 97.5	77.5- 78.4	10.9- 12.9	58.1- 60.1	22.1- 22.3	42.4- 43.4
Blend of Seetalpur -30% Chanch -30% Laikdih deep -7.5% Lower Karharbaree -7.5% XI seam Jogta - 25%	85	92.5	97.6	79.4	10.8	53.2	22.9	47.2
Blend of Seetalpur-30% Chanch -30% Laikdih deep -7.5% Lower Karharbaree -7.5% 'C' seam Monaitand-25% with 5% H.T.Coke dust.	85	95.6	96.6	75.3	19.4	37.2	21.9	-
Blend of Seetalpur-50% Chanch -30% 'O' seam Monaitand-20%	100	94.2	98.0	80.0	10.2	55.6	22.1	46.5
-do- with 3% H.T.Coke dust	85	94.5	97.8	77.5	14.3	47.3	22.4	46.0
Blend of Seetalpur-50% Chanch -30% O' seam,Monaitand -10% 'X' seam Busserya -10%	90	90.2	96.8	75.6	11.8	46.0	22.9	45.7
Blend of Seetalpur-30% Chanch -16% West Victoria -16% (Laikdih) Laikdih deep - 8% XI seam, Sendra -15% 'O' seam Central Salunga- -15%	80	88.2- 90.9	95.4- 97.4	75.6- 77.0	14- 15.3	49.9- 55.4	23.5	49- 49.6
Blend of Seetalpur-30% Chanch -20% West Victoria -20% (Ramnagar) Laikdih deep -5% 'X' seam Busserya-12.5% 'O' seam,East Bastacolla- 12.5%	100	91.0 92.1	96.5- 97.0	77.3- 78.	12.7- 15.1	55.3- 56.0	24.4	46.7
(BLEND OF LAIKDIH,DISHERGARH,GIRDIH OR JHARIA)								
Laikdih deep -70% Seetalpur -15% Lower Kar- Hartaree -10% H.T.Coke dust - 5%	100	94.0	98.0	81.7	10.7	56.8	17.8	49.0
Laikdih deep-60% Seetalpur -30% Lower Karhar- baree -10%	100	88.9	97.3	77.3	12.4	55.8	16.7	51.8
Laikdih deep-50% Seetalpur -30% Lower Karhar- baree -20%	80 100	89.6 92.5	97.2 98.8	74.4 78.8	11.3 10.0	43.8 53.3	18.6 18.5	- -
-Do- with 3% H.T.Coke dust	80 100	92.3 92.0	96.5 97.6	77.2 78.1	11.5 10.6	46.7 49.6	19.5 18.7	- -
-Do- with 5% H.T.Coke dust	80	94.3	97.7	79.7	9.1	49.4	18.9	-
Laikdih deep -50% Seetalpur -20% Lower Karhar- baree- 25% H.T.Coke dust 5%	100	94.3	98.3	80.3	19.6	56.4	16.9	53.7
Laikdih deep- 40% Seetalpur - 50% Lower Karhar- baree- 10%	100	90.6	97.7	75.2	12.2	51.7	18.7	52.3
Laikdih deep- 40% Seetalpur - 25% Lower Karharbaree-30% H.T.Coke dust -5%	100	94.5	98.5	81.3	10.6	58.3	17.0	53.7
Laikdih deep -50% Seetalpur -25% XI seam,Bhalgora (washed) -20% H.T.Coke dust-5%	80	93.7	97.0	79.1	13.5	44.0	30.9	50.6
Laikdih deep - 40% Seetalpur - 50% XI seam, Bhalgora(washed)-5% H.T.Coke dust -5%	80	92.0	96.9	77.6	13.5	44.5	20.3	50.9