INDIAN COALS FOR SPONGE IRON PROCESS

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Abstract

IN CONTRAST to conventional two stage process of steel making via blast furnace, direct steel making with pre-reduced iron ores or agglomerates have attra cted attention in recent times. ***This is particularly so for developing countries*** *where there is availability of other raw materials for iron making but there is dearth of or limited resources of coking coal and abundant supply of other type of non coking coals. In terms of energy equivalent, availability of solid fuel is many hundred times more than that of natural gas. Extensive attempts have therefore been made to utilise non coking coals to produce iron by non conventional methods such as direct reduction processes. The solid iron produced by reduction technique known as 'sponge' can then be transformed into steel by melting.*

An attempt has been made in the paper to indicate the available resources of Indian coals, their nature and property which may be considered suitable for the production of sponge iron either as such or after beneficiation. Indications have also been given for the possibility of utilising char from the fluid bed carbonisation of non coking coal where such material can be obtained from an integrated formed coke plant.

Introduction

The Conventional two-stages process of steel making via blast furnace has been in vogue over a century. In recent times, for reason of economy and productivity, large sized blast furnaces have been installed, which calls for stringent specifications for the raw materials, particularly the coke. For coke with superior physical properties, good quality coking coals have to be used. The shortage of such coking coals the world over, therefore, becomes the chief bottleneck in the expansion of iron and steel industry. Attempts are being made to conserve this valuable raw material in the following ways:

i) By reducing intake of good quality coking blend by incorporating medium and pre-determined blends, followed by improved techniques of coal preparation and carbonisation.

ii) By injecting auxiliary fuels like coal, oil, coal-oil slurry, gas etc. at the tuyeres of the blast furnaces with improvement in operation such as by raising the blast temperature, oxygen content of the blast, humidification of the blast and by high top pressure of the blast furnace.

iii) By utilising alternate fuels prepared from non coking coals in the form of 'formed coke.'

iv) Lastly, attempts are being made to bypass the blast furnace technique altogether by adopting direct reduction technique for the production of iron-(sponge iron) followed by melting in electric furnace.

The idea to produce iron without the use of the blast furnace has been a favoured objective of the metallurgist during the past several decades. Numerous processes[1,7] have been suggested and reviewed which aim at producing iron in the soild form and not in the liquid state as in the blast furnace practice.

In a recent analysis Miller (3) has forecast that while steel production in the world would reach a total of 735 million tons in 1975 and 915 million tons by 1980, the production and consumption of pre-reduced ore would equal to 11 million and 62 million tons respectively in those years.

Direct Reduction Processes

Directly reduced iron ore is neither iron nor ore as one normally understand either of the components. It is nothing more than the reduction of oxygen in the ore below the melting and fusion point of the ores, pellets or agglomerates. For a given mass of ore, the total iron weight remains unchanged even though metallic iron is increased by a reduction in the oxygen combined with it. With oxygen removal a honeycombed microstructure remains which is called 'sponge iron.' The term is used inter-changeably with pre-reduced agglomerates and directly reduced iron ores.

It is possible to use reducing agents (solid or gaseous reductants) other than coke, which are also cheaper in most of the cases. In this context, it will be worthwhile to consider the quantum of "available" reductants in the world[5] against the "total" reserve in India (expressed in terms of 10^{15} K. cals).

Reductants	World	India
Coal	47000	461.7
Lignite	11000	5.6
Oil	730	1.7
Natural Gas	—	0.8

From the above it is seen that the reserves of coal are about several hundred times larger than that of natural gas. Due to this and also in view of the ability of the processes utilising solid reductants to handle a variety of raw materials, many plants[4,5] are in operation in various countries as may be seen in Table 1.

The limited resources of coking coal in India are well known. The imbalance between the availability[1,8,9] of quality iron ore and good quality coking coal has been emphasised many a time. In Fig. 1 is given the distribution of the iron ore and coal resources of India. In the years to come it is also likely that pig iron plants may be installed in locations away from the coking coal areas. In this context, two points of great significance emerge. They are (i) the production and utilisation of formed coke[10] from non coking coals as an alternate fuel for blast furnaces and (ii) consideration of the increasing application of non conventional techniques for the reduction of iron oxide, by passing the standard blast furnace route.

In the Krupp-Renn process,[4] reduction is carried out in an inclined rotary kiln, fired by pulverised coal, and coke is used as the solid reductant. Though this process is adopted in several countries, the consumption of fuel is high. It is stated that about 150-250 kg of coke per ton of 'luppen' produced is required for which about 350 kg of coal dust is also fired in the kiln.

The SL/RN process[4], for which also an inclined rotary kiln is employed for reduction, has been adopted in many countries. Almost any solid carbonaceous material may be used as heating and reducing agent. Low rank high volatile coals having low strength and with fusion temperature of ash above 1150°C may be used with advantage for the reduction. It has, also been mentioned that heat requirement varies from 2.37×10^6 to 3.5×10^6 K. cal per ton of sponge iron.

Considering this, it may be pointed out that the large reserves of non coking coal (about 80% of the total reserve) available in the country and even char made of low temperature by fluid bed carbonisation may be used as reductants for the production of sponge iron. Ghosh and Lahiri[2] have also suggested suitability of the solid reduction technique in India. Recently Miller and Koring[7] have reiterated that direct reduction technique can make a good impact for the ambitious iron and steel plans India is drawing up. In the direct reduction process, for the manufacture of sponge iron, high volatile, non coking coals with relatively high ash fusion point particularly the initial deformation (I.D.) temperature (> 1150°C) appear to be most desirable. In addition the coals should be low to medium in ash, with relatively low sulphur ($< 1.0\%$) and phosphorus ($< 0.1\%$)

Resources of Indian Coals Available for Direct Reduction

A detailed study of the available information on the nature and composition of coals occurring in India shows that unlike coking coals, non caking coals are well distributed all over the Lower Gondwana coal basins of the peninsular India (Figure 1). In Table II are compiled the nature, composition and resoure potentialities[11,12] of the solid minerals fuels ranging from lignite to bituminous coals which are likely to conform to the specifications of solid fuels suitable for the manufacture of sponge iron by the direct reduction process.

Non coking coals with ash ranging normally between 11% and 24% (on air dried basis), and volatile matter between 25% and 35% (on air dried basis) have been largely selected. Moreover, due

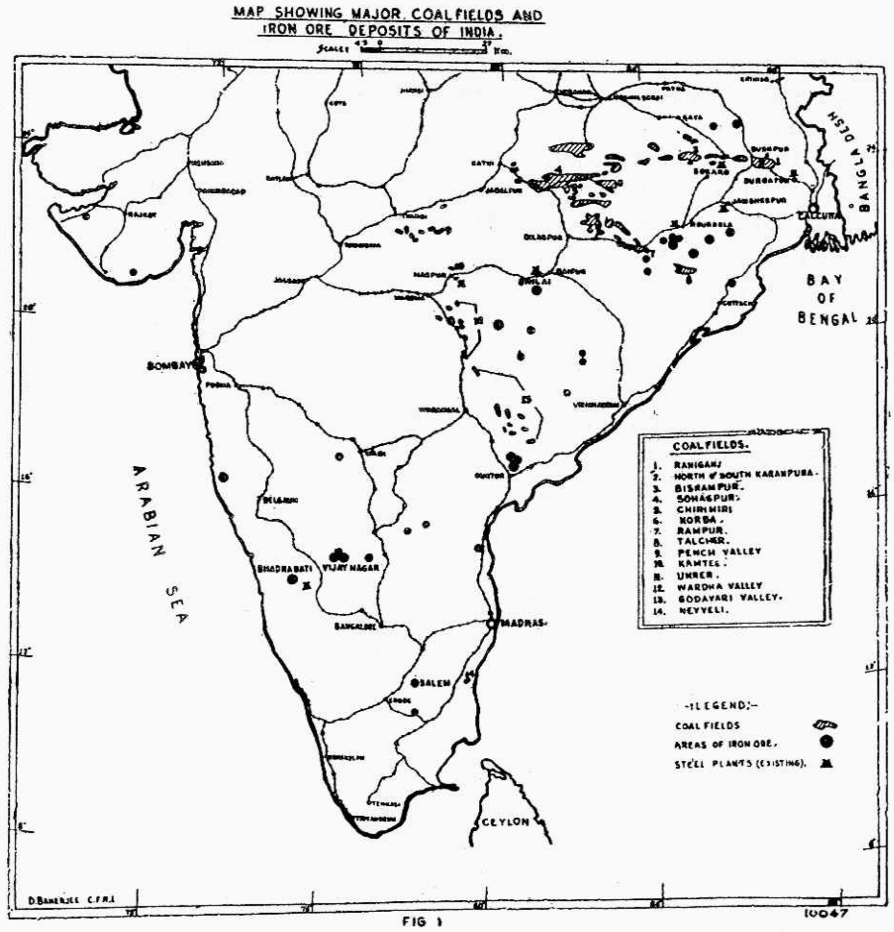

FIG 1

consideration is necessary for lower contents of total sulphur, phosphorus and relatively higher initial deformation temperature of the ash in mildly reducing atmosphere (> 150°C). The areas of occurrence of coal seams containing coals of the specifications are restricted to central and eastern sectors of the Raniganj Measures coals of Raniganj coalfield in the East, Sone Mahanadi valley coalfields of Madhya Pradesh and Orissa, and the Pench Valley coalfields in the West. The coals also are found to underline in the South in the Kamptee, Wardha valley coalfields of Maharashtra and the Godavari valley coalfields of Andhra Pradesh. In further South, there occurs the lignite deposit of Neyveli in Tamil Nadu. The proved reserves of sucn coals from seams under exploitation total to over 5600 million tonnes excluding 600 million tonnes of proved reserves of Neyveli lignite. This estimate excludes all coking, medium coking, semi to weekly coking coals of Jharia. Raniganj, East and West Bokaro, Ramgarh, Jhilmili and Kanhan valley coalfields and the semi to weakly-coking, high sulphur tertiary coals of Assam.

i) Raniganj coalfield

The Central and Eastern part of Raniganj coalfield accounts for a total reserve of non coking coals of over 2300 million tonnes available from 7 to 8 working coal horizons. Thickness of the seams generally varies between 1.2 and 9 metres. The coals are high in volatile (31 to 35% air dried) with ash mostly below 20%. The I.D. temperatures of the coal ash are often somewhat lower, ranging between 1100°—1210°C.

ii) North and South Karanpura Coalfields

The total reserves of the working coal horizons of these two coalfields amount over 1000 million tonnes. In north Karanpura coalfield, 8 to 9 coal horizons (viz—Bachra, Karkata, Bisrampur, Bukbuka, Dakra, etc.) generally ranging in thickness between 1.5 and 6 metres are being exploited. The ash in these coals vary widely—even from the same coal horizon, which at times exceeds 28%. The I.D. temperature of the coal ash is, however, high (above 1250°C).

In South Karanpura coalfield 10 to 12 upper coal horizons (Argada 'A' and above) are being exploited whose thickness ranges generally between 2 and 7 metres. Argada seam is a thick coal horizon (11 to 54 metres). The ash of the coals from the seams also varies widely and often tends to go quite high. The initial deformation temperature of the coal ash is at times lower which ranges between 1100° to 1280°C.

iii) Sohagpur Coalfield

In Sohagpur coalfield of Madhya Pradesh, Burhar, Kotma and Jhagrakhand are the three potential areas which account for a total reserve of over 260 million tonnes of coals. These are available from 1 to 3 working coal horizons whose thickness range between 2 to 8 metres. The coals there from are fair to medium in quality, the percentage ash being mostly below 20%. The coals are high in volatiles (24 to 31% air dried) and low in sulphur (below 0.8%) and phosphorus (below 0.01%). The initial deformation temperature of the coal ash is between 1120°C to 1350°C.

Of the three, Burhar area appears to be promising as the coals can be had from a single source (i.e. Dhanpuri Seam) of a composite unit. In the single unit there is a reserve of over 100 million tonnes of coal. The volatiles and fusion temperatuhe (I.D.) of the coals are also on the higher side.

iv) Chirimiri Coalfield

This coalfield accounts for a total reserve of over 430 million tonnes of non coking coals from 1 to 3 working coal horizons (viz. Korankoh/Bijora/Gorghela/Main, 3A, Sonawani etc.) whose thickness generally range between 1.5 and 8 metres. The coals are low to moderate in ash, being mostly below 20% and high in volatiles (25 to 33% air dried). The I.D. temperature of the coal ash is above 1200°C. The coals are low in sulphur (below 0.7%) and phosphorus (below 0.01%). The coal resources of Chirimiri coalfield thus appear to be quite promising.

v) Korba and Bisrampur Coalfields

These two coalfields account for a total reserve of over 130 million tonnes of fair to medium quality non coking coals. The coals are relatively low in ash (below 18%), sulphur (below 0.6%) and phosphorus (below 0.01%). The I.D. temperature of the coal ash is also high (over 1200°C). Although the coals are slightly lower in volatiles (25 to 28% air dried) as compared to other coals, it is important to note that the productions in both the coalfields come from a single seam i.e. from Pasang seam in Bisrampur coalfield and Ghordewa (G-III) seam in Korba coalfield. Furthermore, the production potentialities of this coalfield are high. The present annual production target of coals are 2.7 million tonnes from Pasang seam (from 3 collieries) of Bisrampur coalfield and a little over 2 million tonnes from Ghordeva seam (3 collieries) of Korba coalfield.

vi) Rampur Coalfield

Rampur coalfield of Orissa working Rampur and Ib seams has a total reserve of about 40 million tonnes of low to medium ash coals. The seams are generally 2 to 3 metres in thickness. The coals from Ib seam is relatively low in ash (below 16%) but is also somewhat low in volatile matter (23 to 25% air dried). The coals from both the seams are low in sulphur (0.2 to 0.5%) and phosphorus (0.005%). However, the I.D. temperature of the coal ash sometime shows a lower trend of 1130°C or so.

vii) Talcher Coalfield

The Bottom seam (2 to 7.5 m) worked in 3 collieries of Talcher coalfield of Orissa has a total proved reserve of about 110 million tonnes. The coals are comparatively low in ash (13 to 18%), high in volatiles (33 to 35% air dried) and low in sulphur (0.4 to 0.7%) and phosphorus (below 0.01%). The I.D. temperature of the coal ash is also fairly high (above 1150°C). The present production target of this seam, from the 3 collieries is over 1.4 million tonnes per year.

viii) Pench Valley Coalfield

Situated in the western part of Madhya Pradesh, the Pench Valley coalfield accounts for a total reserve of about 190 million tonnes of fair to medium quality (ash 14 to 24%) coals, produced from 3 to 4 working coal horizons. The coals are fairly high in volatiles (27 to 33% air dried) with I.D. temperature of the coal ash always above 1200°C. The sulphur content of the coals at times higher (unto 1.9%).

ix) Umer and Kamptee Coalfield

Situated in the state of Maharashtra, these two areas near Nagpur account for a total reserve of about 120 million tonnes of medium quality (ash 14 to 21%) coals worked in two collieries viz. Umrer and Silewara (Kamptee) mines. The coalash generally shows somewhat lower range of fusion temperature, although the I.D. temperature is always over 1100°C.

x) Wardha Valley Coalfields

The 7 working collieries of Wardha coalfield, working different sections of a thick composite seam, account for a total reserve of over 140 million tonnes of coal. Although the coals contain ash below 20%, the sulphur content of the coals is generally on the higher side (0.8 to 1.8%). The coal ash shows somewhat lower range of fusion temperature, although the ID temperature is always above 1150°C.

xi) Godavari Valley Coalfields

Situated in Andhra Pradesh, the Kothagudium Tandur and Ramagundam areas of Godavari Valley coalfields are the other potential regions having coals suitable for sponge iron industry.

Of these, Kothagudium area, working Queen and King seams, with a reserve of about 220 million tonnes appears to be important. The ash in the coals lies between 15 and 24% with sulphur mostly below 1% and phosphorus below (0.01%). The I.D. temperature of the coal ash is high (above 1340°C).

The other two areas working Seam No. I to IV have a total reserve of over 578 million tonnes. Although the coals of these two areas are also similar in quality the sulphur content of Ross Seam (i.e. Seam II) in Tandur area is generally high (upto 2%). In Ramagundam area, the I.D. temperature of coal ash sometimes shows the tendency to be on the lower side (below 1100°C).

xii) Neyveli (South Arcot) Lignite Field

Situated further south in Tamil Nadu, the Lignite deposit of Neyveli has a proved mineable reserve of over 600 million tonnes which also appears to be attractive. The lignites at a moisture level of 15 to 20% (air dried) has ash of 4 to 6%. They are low in sulphur (generally below 1%) and phosphorus (below 0.01%). The I.D. temperature of the coal ash is relatively high (1180°—1220°C), although the ash fusion range is somewhat low (1180°—1380°C).

Availability of low ash coals

It is apparent from Table II that the ash limits of coals suitable for sponge iron manufacture have been considered generally upto 24%. However, if it is desired that the ash in the raw coals should be low, say, upto 16% or so, the potentialities of the areas containing such coals, along with their properties, are given in Table III.

Thus, relatively low ash coals are available from Sohagpur (Jhagrakhand and Kotma areas), Bisrampur. Chirimiri and Pench Valley coalfields of Madhya Pradesh, Talcher and Rampur coalfields of Orissa and Raniganj coalfield of West Bengal. These coals are mostly low in sulphur (below 0.7%) and phosphorus (below 0.01%). The phosphorus contents of Raniganj coals are comparatively high (around 0.1%). The I.D. temperature of the coal ash is also generally high (above 1150°C), except those of Raniganj, Kotma and Rampur coals where it is generally between 1100° and 1200°C. The total reserves of such low ash coals (ash below 16%) would be well over 1200 million tonnes. Of these, Bisrampur, Talcher, and Jhagrakhand areas appear to be attractive.

Use of medium ash coals after beneficiation

Studies on the available data on cleaning characteristics of coals of medium ash group (ash 17 to 25%) indicate that these are amenable to washing with reasonably good yield of cleans.

A broad generalisation of the cleaning possibilities such medium ash coals are given in Table IV:

Table IV
Cleaning possibilities of medium ash coals.

Particulars	Ash%	Sp. Gr. cut around	Cleans		Sinks	
			Wt%	Ash%	Wt%	Ash%
Overall raw coal	17 to 25	1.50	60 to 80	13 to 15	20 to 40	30 to 45

It is possible to have 60-80% yield of cleans with ash 15% or below at a specific gravity of separation around 1.50. The corresponding sinks with 30-45% ash may be considered suitable for pulverised fuel firing in large boilers. At times when the coals contain distinct shale bands the ash of the sinks may be still higher (50-55%) with consequent increased recovery of cleans. The clean coals can thus be used after dewatering to a reasonable moisture content.

Use of low temperature char as solid reductant

As indicated earlier, use of formed coke[10] produced from chars of non coking coals as alternate fuel for blast furnaces can be effective means of conserving coking coals whose availability is limited. In an integrated scheme, formed coke may be used as substitute of coke in the conventional blast furnace and sufficient 'char' may be manufactured for use as solid reductant in sponge iron plant. The 'char' from a typical Indian non coking coal by fluid bed carbonisation at 500-550°C has the properties given in Table V below:

Table V

Properties of L.T. char from a typical non coking Indian coal

M	3-5%	Real density:	1.6-1.8 g/c.c.
A	20.24%	Bulk density:	365-415 kg/m^3
VM	10-12%	Reactivity to CO_2—	180-185.

The char being a reactive solid, may be suitable for the purpose of reduction of iron ores, where the heat required for the process can be supplied by firing pulverised coal of the type from which char is produced.

Conclusion

In view of the attempts that are being made to by-pass the conventional blast furnace route of steel making and the increasing importance of the direct reduction technique for the production of sponge iron, it is thought worthwhile to assess the quality and quantity of solid reductants available in India suitable for the purpose. It is felt that the coals from Talcher, Bisrampur and Jhagrakhand coalfield may be eminently suitable for the process because of their superior quality. The coals from Kothagudium area of Godavari Valley coalfield and the lignites from Neyveli also deserve attention because of their geographical positions. Char obtained from integrated 'formed coke' plant produced by carbonising non coking coals in fluid bed at low temperature may also be utilised with advantage.

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Discussion

Mr. A. N. Naik (Tata Iron & Steel Co. Ltd., Jamshedpur). i) What is the crushing strength of formed coke and its cost of production as compared to the conventional blast furnace coke that is now produced in integrated iron and steel plants, ii) How long will it take to instal new coke ovens for the production of formed coke if it is more economical than B.F. coke as none is at present existing?

Mr. K. K. Raychaudhuri (Author) (i) The crushing strength of formed coke is not fixed. It depends on the type of formed coke and its use, i.e. whether for domestic, industrial or metallurgical purposes. For example the point crushing strength of formed coke prepared from non-coking Indian coals has been found to be 275 kg, which is suitable for metallurgical purpose.

The cost of production is also dependent on the process or scheme followed for the preparation of formed coke and the capacity of the plant. However, the cost of production of formed coke by adopting a particular process may be comparable to that of the commercial coke price as at present. (ii) A commercial formed coke plant can be set up at least 3 years after final decision is taken for installing such plant and necessary action is initiated.

Mr. T.V.S. Ratnam (M.N. Dastur & Co. P. Ltd., Calcutta). You have mentioned about large blast furnaces and the quality of the new materials required. Will the coke produced from the Indian coals have adequate strength for use in large blast furnaces? What are your views in regard to the strength of the coke for large blast furnaces?

Mr. T.V. S. Ratnam (M.N. Dastur & Co. P. Ltd., Calcutta). Coke produced from 100% washed Jharia coals (Prime caking) conform to the stringent international specification of Physical characteristics of coke required for large blast furnaces. Although we do not have much experience of using cokes produced from Indian coals for large blast furnaces, cokes produced from blend of 50% prime coking coals (Jharia) and 50% medium coking coals (Kargali) both washed, are successfully being used in 2000 cu.m. blast furnace of Bokaro Steel. The Russian specification for cokes to be used in such furnace is Micum, M_{40}-79 to 80 and M_{10}-10 of less. How these cokes would behave in blast furnaces of larger capacity cannot be envisaged at the moment.

Table I. SOME DIRECT REDUCTION PROCESSES WHERE SOLID REDUCTANTS ARE USED

PROCESS	IN OPERATION AT	REDUCTANT	AVERAGE ANALYSIS OF FUEL				
			M%	A%	V.M.%	F.C.%	S%
1. Krupp-Renn	EAST AND WEST GERMANY, POLAND, CZECHOSLOVAKIA, NORTH KOREA, GREECE, JAPAN, SPAIN AND U.S.S.R.	Coke	-	-	-	55.0	-
2. SL-RN	U.S.A, CANADA, BRAZIL, PERU, SOUTH AFRICA, AUSTRALIA, NEW ZEALAND, JAPAN, SOUTH KOREA	Lignite	31.5	4.0-7.0	30.0-46.0	31.0-50.0	0.5
		Coal	-	8.0	36.0	55.0	-
		Anthracite	-	-	10.0-17.0	68.0-70.0	0.6-0.7
	INDIA (NML)	Coal (Maharashtra)	9.5	16.5	31.2	42.8	-
		Coal (A.P.)	6.0	28.3	21.6	44.2	-

TABLE-II

QUALITY, PROPERTIES AND POTENTIALITIES OF COALS

Coalfield	Seams	On 60% R.H. at 40°C basis							Dry mineral free basis			LTC coke type	Ash fusion temperature oC (under mildly reducing atmosphere)	Total proved reserves (million tonnes)	Remarks
		Moist %	Ash %	V.M. %	F.C. %	Calorific value (K.cal/kg)	Sulphur %	Phosphorus %	V.M. %	Carbon %	Hydrogen %				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Raniganj (Central & Eastern Sector)	All working seams (of Raniganj series)	4 to 10 *	12 to 22	31 to 35	40 to 45	5700 to 6350	0.3 to 0.6	0.02 to 0.18	39 to 44	79 to 83	5.0 to 5.6	A to B	I.D.- 1100-1210 H.P. 1350- over 1400	**2317	* Ash mostly below 20 % ** Classified- 1291 mt unclassified-1026mt 2317 mt
N. North Karanpura	*All working seams.	8 to 10	14 to 28	26 to 29	37 to 45	4600 to 5400	0.6 to 0.8	0.04 to 0.20	34 to 40	79 to 83	4.3 to 4.9	A	I.D.-1250-over 1400 H.P.- 1330-over 1400	** 252	* Excluding Churi top seams(high ash) ** Reserves include Churi Top seam.
South Karanpura.	Upper coal horizons upto Argada A (working)	3 to 8	15 to 25	27 to 31	39 to 45	5050 to 6400	0.5 to 0.8	0.05 to 0.20	37 to 40	81 to 84	4.8 to 5.3	A to C	I.D.-1100-1280 H.P.-1360-over 1400	820	
Talcher	Bottom	7 to 9	13 to 18	33 to 35	41 to 44	5900 to 6100	0.4 to 0.7	0.002 to 0.009	39 to 44	81 to 82	5.2 to 5.8	A to B	I.D.- 1150-1280 H.P.-1390-over 1400	114	
Rampur	Rampur & Ib	6 to 8	11 to 22	23 to 30	44 to 57	5550 to 6300	0.2 to 0.6	0.003 to 0.004	29 to 38	81 to 84	4.3 to 5.0	A to B	I.D.- 1130- 1330 H.P.- over 1400	39	
Korba	Ghordewa (G-III)	5 to 7	11 to 18	25 to 28	49 to 53	6000 to 6300	0.3 to 0.5	0.003 to 0.006	29 to 34	82 to 85	4.3 to 4.8	A	I.D.- 1240-1340 H.P.- over 1400	60	
Bisrampur	Pasang	9 to 10	12 to 15	25 to 28	49 to 52	5650 to 5800	below 0.6	below 0.004	31 to 35	81 to 82.5	4.3 to 4.8	A	I.D.- 1210-over 1440 H.P.- over 1400	78	
Chirimiri	All	3 to 8	10 to 22	25 to 33	44 to 56	5600 to 6750	0.3 to 0.7	0.002 to 0.009	29 to 40	81 to 86	4.4 to 5.3	A to B	I.D.- 1210-1400 H.P. over 1400	436	
Sohagpur k) Jhagrakhand area	A & B	4 to 7	13 to 21	25 to 30	45 to 55	5800 to 6600	0.5 to 0.6	0.004 to 0.005	20 to 36	83 to 86	4.6 to 5.2	A to B	I.D.- 1160-1240 H.P.- over 1400	88	* including indicated reserve of 55 m. tonns for Rajnagar colly.
ii) Kotma Area	All working seams.	7 to 9	11 to 20	24 to 30	48 to 54	5730 to 6350	0.4 to 0.7	0.003 to 0.005	30 to 36	81.5 to 84	4.5 to 4.9	A	I.D.- 1120-1340 H.P. over 1400	65	
iii)Burhar area	Dhanpuri	5 to 9	15 to 22	27 to 31	44 to 50	5700 to 6400	0.5 to 0.8	0.004 to 0.006	34 to 40	82.5 to 84	5.0 to 5.3	A to B	I.D.- 1170-1350 H.P. over 1400	108	
Pench Valley	*All working seams.	5 to 8	14 to 24	27 to 33	38 to 49	5200 to 6400	0.5 to 1.9	0.003 to 0.053	36 to 42	81 to 84	4.9 to 514	A	I.D.- 1200 over 1400 H.P.- over 1400	**192	* Excluding Datla West and Palachauri collieries. ** Includes Datla West and Palachauri collieries.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Kamptee (Silewara	IV	9 to 10	19 to 21	30 to 31	39 to 41	5110 to 5175	1 to 1.1	0.005 to 0.01	41 to 42	78 to 80	4.5 to 4.8	A	I.D-1110-1345 H.P.- 1245-1400	35	
Umrer	Top, Middle and Bottom	12 to 14	14 to 20	25 to 29	42 to 46	5000 to 5400	0.5 to 1.0	0.02 to 0.03	35 to 39	77 to 81	4.3 to 4.7	A	I.D.- 1170-1240 H.P.- 1260-1380	85	
Wardha valley (7collieries)	All working sections of a thick-seam.	9 to 12	15 to 20	29 to 32	39 to 42	5280 to 5720	0.8 to 1.8	0.002 to 0.1	39 to 43	78 to 81	4.8 to 5.3	A	I.D.-1150-1295 H.P.- 1285-1390	141	
Godavari valley															
i)Ramagumdam area (South Godavari)	6 All working to-8 Seams.	6 to 8	15 to 23	27 to 31	40 to 47	5250 to 5890	0.4 to * 1.4	0.001 to 0.009	35 to 41	80 to 83	4.5 to 5.4	A	I.D.- 1080-1380 H.P.- 1270-over 1400	378	* S% mostly low.
ii)Kothagudium area.	All working seam.	7 to 9	15 to 24	24 to 30	42 to 49	5310 to 6100	0.3 to *1.1	upto 0.006	30 to 40	82 to 83	4.5 to 5.0	A	I.D.- 1340-1400 H.P.- over 1400	219	* S% mostly low.
iii) Tandur area	All working seams	7 to 8	16 to 24	26 to 33	40 to 44	5200 to 5800	0.3 to * 1.9	0.001 to 0.005	34 to 42	80.5 to 83	4.6 to 5.4	A	-	200	* S% in Ross seam mostly high
Neyvlie	Lignites	15 to 20	4 to 6	40 to 43	35 to 40	4725 to 5300	0.7 to 1.1	0.001 to 0.006	53 to 55	70.0	5.0	A	I.D.- 1180-1220 H.P.- 1340-1380	over 600	

TABLE III

QUALITY, PROPERTIES AND POTENTIALITIES OF LOW ASH COALS

Coalfield	Collieries	Seam	On 60% R.H. at 40°C basis							On d.m.f. basis	LTC coke type	Ash fusion temperature oC (under midly reducing atmosphere)	Total proved reserves (Million tonnes)	Remarks
			Moist %	Ash %	V.M. %	F.C. %	Calorific value (K.cal/kg)	Sulphur %	Phosphorus %	V.M.%				
Raniganj	Collieries in eastern sector.	Upper Kajora. Jambad-Bankola, Samla.	7 to 10	12 to 17	31 to 37	42 to 46	5700 to 6300	0.3 to 0.6	0.04 to 0.13	39 to 45	A	I.D.-1080-1220 H.P.-over 1400	Over * 900 (approx.)	*Proved class II quality
Talcher	Talcher, Deulbera, Handidua	Main (Bottom)	7 to 8	11 to 15	33 to 36	44 to 46	6100 to 6650	0.6 to 0.7	0.003 to 0.007	42 to 46	B	I.D.-1150-1280 H.P.-1390-over 1400	46	
Rampur	Orient	Ib	7 to 8	11 to 14	23 to 25	54 to 57	6050 to 6400	0.3 to 0.6	0.003 to 0.004	29 to 30	A	I.D.-1120-1180 H.P.-over 1400		Reserve figure not available.
Bisrampur	Kumda Inclines, Pasang Joynagar Quarry and inclines.	Pasang	9 to 10	12 to 15	25 to 28	49 to 52	5650 to 5800	below 0.6	below 0.004	31 to 35	A	I.D.-1210-over 1400 H.P.- over 1400	78	
Chirimiri	West Chirimiri New Chirimiri Chirimiri Kurasia, Duman Hill Sonwani	No.3 (Karakoh, Main or Gothela) No.3A (No.4) Sonwani.	3 to 7	11 to 15	25 to 29	51 to 58	6200 to 6750	0.4 to 0.7	0.002 to 0.004	29 to 34	A to B	I.D.- 1170-1250 H.P.- over 1400	97	
Sohagpur i) Jhagrakhand area	Rajnagar and Ramnagar.	'A'	5.5 to 7	12 to 16	25 to 30	49 to 55	6100 to 6550	below 0.5	below 0.004	30 to 34	A	I.D. 1160-1240 H.P. over 1400	*71	*Indicated reserve
ii) Kotma area	Kotma	Kotma Top, Kotma Bottom, Silhara.	8 to 9	11 to 16	25 to 30	48 to 53	5800 to 6250	0.4 to 0.7	0.003 to 0.004	31 to 35	A	I.D. 1120 -1280 H.P. over 1400	39	
Pench valley	Jatachhapar Ekehara Rawnwara, Ranwara, khas, Ambara.	Pench seam (Seam 1) Pench Bottom Seam, (Seam 2) Seam-3 Seam-4	6 to 9	13 to 16	31 to 33	44 to 49	6100 to 6500	0.6 to 1.5	0.005 to 0.05	38 to 42	A to B	I.D. 1200-over 1400 H.P. over 1400	-	Separate reseve figure not available.