RESOURCES OF LOW-GRADE COALS IN INDIA

BY M. A. TIRUNARAYANAN, B.SC., B.E.

(Research Assistant, Department of Internal Combustion Engineering, Indian Institute of Science, Bangalore-3)

SUMMARY

The resources and the availability of low-grade coals in India are indicated and their adaptability as pulverised fuel is discussed briefly. It is concluded that much preliminary work on the characteristics of pulverised Indian Coals is needed for their successful adoption as a fuel for power generation. It is also recommended, that natural coal dust be tried, for pulverised fuel firing.

1. INTRODUCTION

The object of this report is to assess the availability and resources of low-grade coals in India, with a view to their utilisation, in the field of Internal Combustion Engineering. Pulverisation of these fuels seems to be the best method of their utilisation in this particular field and therefore their adaptability to pulverisation is briefly discussed. In this connection, natural coal dust offers a very good source of low-grade pulverised coal, in India.

2. RESOURCES AND PROPERTIES OF INDIAN COALS[1]

2·1. *Coal Resources*

The total annual output of coal in India is about 28 million tons, which is nearly 0·18% of the total estimated reserves of 16,500 million tons.* Only a fraction of these estimated reserves, is said to be good quality coal, which could be accepted for producing metallurgical coke. Such coals should therefore be conserved as best as possible, for without them, the progress of the metallurgical industry, and consequently other industries also is at stake. At present, there is an output of 10 million tons of good grade coking coal per annum, of which hardly one-third is used for making coke.

A glance at the consumer's list shown in Table I will reveal that Indian Railways are the major consumers of coal. About 11 million tons of coal are used in power production, including Railways, but it must be stressed that these consumers can very well use the inferior grades of coal, whose annual production stands at a figure of 18–20 million tons.

* The indices refer to references listed at the end of the Report.

TABLE I*

	Use		Millions of Tons (Approx.)	Percentage (Approx.)
1	Railways	..	10·0	34
2	Mills and Works	..	4·5	15
3	Iron and Steel Works	..	4·5	15
4	Electricity Gen.	..	1·0	3
5	Collieries	..	2·0	7
6	Cement Works	..	0·5	2
7	Brick Burning	..	1·0	3
8	Chemicals, Glass, etc.	..	1·0	3
9	Bunker and Export	..	2·0	6
10	Domestic, etc.	..	3·5	12
	Total	..	30	100

* The output is taken as 30 million tons per annum for the purpose of this table. This is taken from *Indian Coals*— a CSIR publication.

The main coalfields of India are found in the Damoder Valley, and the country adjoining the area. There are about a dozen fields in the whole of India, three of them being located in the Damoder Valley and the remaining dispersed in C.P., Hyderabad, Assam and the Punjab. Table II shows the output of India's coal fields. Of the total output of 28 million

TABLE II*

Coalfields		Annual output in million tons
Damoder Valley :—		
Raniganj	..	8·0
Jharia	..	12·0
East and West Bokaro, Karanpura	..	4·0
Total	..	24·0
Other Fields :—		
Rewa and Korea	..	0·4
C.P., Orissa and Eastern States	..	1·08
Assam	..	0·3
Hyderabad	..	1·0
Punjab	..	0·5
Total	..	4·0

* This table is taken from *Indian Coals*—a CSIR publication.

tons, the Damoder fields contribute about 24 million tons, which forms nearly 86% of India's output.

TABLE III*

No.	Name of Coal field	Proximate Analysis				Variety	Sulphur S%	Phosphor P%	Ash Fusion Temp. °C	Calorific value	Swelling
		Moisture	Ash%	Vol. Matter %	Fixed Carbon%						
1	Raniganj— (*a*) Raniganj Measures	2% 10%	9 15	30 40	50 60	Poorly caking			1150– 1300°C.	12,500–13,500 B.T.U./lb.	Kopper's swelling test harmless
	(*b*) Barakar Measures	1–3	10–15	25–30	50–60	Partly caking and Non-caking	0·3 0·55	0·1 0·4	1250– 1300	11,500 13,000	Harmless
2	Jharia— Raniganj Measures	1–3	12–20	33–37	50–53	Mostly caking	0·35 0·5	0·1 0·2	1250– 1300	12,000 13,000	do
3	Bokaro— East	2	15–18	23–28	51–62	Strongly caking	0·5 0·6	0·07 0·2	1250– 1400	12,500	do
	West	1–2	16–29	25–27	45–55	Non-caking	0·5 0·7	0·07 0·3	1250– 1300	10,500 11,500	do
4	Karanpura ..	3–5	11–25	25–35	45–55	Partly caking and Non-caking	0·5 0·91	0·07 0·35	..	11,500 12,500	do
5	Girdih ..	1·5	10–20	20–28	50–70	Non-caking	0·4 3·5	0·003 0·01	1220 –1290	9,000 10,500	..
6	Palamau ..	6–12	9–35	23–34	26–57	do	0·4	..			
7	Central India and C. P.	3–8	6–38	25–35	40–60	do	0·3 1·7	Trace	1250 –1400	10,500 12,500	Harmless
8	Orissa ..	2–13	8–20	28–38	43–55	do	..	..	..	12,000 13,000	do
9	Hyderabad ..	5–12	13–24	25–48	42–55	do	0·3 1·0	..	..	10,500	do
10	Punjab ..	1·5–16	2–46	28–48	23–48	Caking	3 10	..	..	8,000 12,000	..
11	Kashmir ..	1·55	5–11	12–14	70–80	Anthracitic	0·91	..	..	..	..
12	Assam ..	1·5–5	0·8–6	40–50	41–58	Caking	2–8	..	..	8,000 14,000	..

* Compiled by author from analyses given in *Indian Coals*— a CSIR publication.

2·2. *Nature of Coals*

There are two types of seams found in the Damoder Valley, namely, Raniganj or upper measures and Barakar or lower measures. The seams of the Raniganj measures which are best developed in Raniganj fields—are of a less mature type than those of the Barakar beds. The former contain 3 to 10% moisture in general, and yield 35 to 40% volatile matter expressed on a pure coal basis. The Barakar measures are best developed in Jharia field, where the chief coking coals are found. Tables III and IV show the average composition of Indian Coals and their physical characteristics.

TABLE IV*

Barakar Measures of Jharia (I to X Seams only)

Seam	Average Proximate Analysis				Variety	S Sulphur %	Ash Fusion Temp. °C.	Calorific Value BTU/lb.	Swelling
	Moist %	Ash %	Vol. Matter %	Fixed Carbon %					
I	1·5	35–36	17–18	46–47	Non-caking	0·62	1400–1470	9,000	Harmless
II	0·8	31	18	51	,,	0·56	1270–1340 1340–1440	10 150	,,
III	0·7	36·5	12–18	45–46	,,	0·40	1400–1470	9,250	,,
IV	0·6–1·0	28·5	16·5–18·5	52–57	,,	0·51	..	10,500	,,
V	1·0	29	18–19	51–52	,,	0·46	1400–1470	10,450	,,
VI	1·0	27	19·5	53	,,	0·33	,,	10,700	,,
VII	1·3	27·5	20·5	52	,,	0·33	,,	10,700	,,
VIII	2·2	28	22	48·5	,,	0·46	1400–1490	10,250	,,
IX	1·3	26	20·5	53	,,	0·45 0·8	1400–1490	11,000	,,
X	1·1	26	21	52–53	,,	0·4 0·5	1400–1470	11,000	,,

* Taken from *Indian Coals*— a CSIR publication.

(1) *Raniganj Fields*

(*a*) *Raniganj measures.*—The coals contain generally from 2 to 10% moisture, volatiles between 30 and 40% and ash between 9 and 15%. They belong to a very poorly caking class.

(*b*) *Barakar measures.*—The moisture content here is less than 3% and the coals are partly caking and non-caking.

(2) *Jharia Field*

(*a*) *Raniganj measures*.—The coals are mostly caking varieties. Their ash content is less than 20% and moisture is also low.

(*b*) *Barakar measures*.—There are eighteen seams in these measures, the first ten of which are high in ash content but remarkably low in moisture. The coal from these seams are non-caking varieties. Table IV shows the properties of these coals. The seams X to XVIII, of course, contain good quality coal suitable for metallurgical coke production. These are very good caking coals.

(3) *The Bokaro Field*

There is a definite change in the properties of these coals to be noted when going from the eastern to the western fields. The coals from the west contain higher ash content, and are non-caking, whereas those from the east are strongly caking.

(4) *Karanpura Coalfield*

The coals of this field have higher moisture content, usually between 3 and 5%. Ash content is as high as 25% in some cases, and are mostly non-caking varieties. These are not suitable for coke production.

(5) *Girdih Coalfield*

These are also non-caking, and have low moisture content. Ash content reaches a figure of 20% in some cases.

(6 and 7) *Palamau, Central India, and C.P.*

The coals usually have very high moisture content, ranging generally from 3 to 12%. Ash reaches the figure of 38% in some cases and the coals are non-caking varieties. The sulphur content of C.P. Coals touches a figure of 1·7% in some cases.

(8 and 9) *Orissa and Hyderabad Coalfields*

The moisture content is usually very high ranging between 2 and 13%. The ash content of Hyderabad coals ranges from 13 to 24% and the coals are non-caking. Sulphur content of Hyderabad coals is less than 1% but occasionally equals that figure. The calorific value of Hyderabad coals is very low, an average figure being, 10,500 BTU/lb. (as received).

(10) *Punjab Coalfields*

The moisture content of these coals vary very widely from 1·5% to 16%. The ash content in certain cases touches a figure of 46%. Though these coals are strongly caking, they are not suitable for coke production, in view of their high sulphur content, which ranges from 3 to 10%.

(11) *Kashmir Fields*

The coals of this field are anthracitic in nature, and possess very low moisture and ash contents.

(12) *Assam Fields*

The coals of this field though strongly caking are unsuitable for coke-production, in view of their high sulphur content. Sulphur ranges from 2 to 8% in these coals. The ash content usually is very low (say, below 6%).

2.3. *High-Grade Coals*

The primary requisite of a good coking coal is that it should primarily belong to the caking variety or class, and for Indian conditions, the coals should have a caking index of 15 or over, volatiles about 26%, and ash below 17%. We notice from Table III, that tnese requirements are satisfied by coals from three fields. They are:

(1) Raniganj fields—Barakar measures.

(2) Jharia fields—Raniganj measures.
—X–XVIII seams of Barakar measures.

(3) East Bokaro fields.

The coals from the Punjab and Assam fields, though strongly caking are unsuitable as their sulphur content is high.

2.4. *Low-Grade Coals*

The coals from fields other than those mentioned above, are not suitable for metallurgical coke production; and thus they are available for purposes such as power production, process-steam raising, cement kiln firing, etc. For the extensive utilisation of these coals, proper grading is needed. At present this is done by the Coal Commissioner and the grades shown in Table V are generally obtained in India.

It is unfortunate that, so far, rational grading has not been attempted. The scheme suggested by the Fuel Research Institute, which quite suits the purpose, will provide an incentive to the extensive utilisation of high-ash, high-moisture coals.

Grades II, III A, III B are low-grade coals from the point of view of their ash content.

TABLE V*

Coal Grading

For Coals of Raniganj Measures

Grade	Ash *plus* Moisture %	Remarks
Selected A ..	<17·5	Calorific values are not required
Selected B ..	17·5–19·0	
No. I ..	19·0–24·0	

For Coals of Other Seams

Grade	Ash %	Remarks
Selected A ..	<15	The moisture shall not exceed 2% as delivered calorific values are not required
Selected B ..	15–17	
Grade I ..	17–20	
Grade II ..	20–24	
Grade III_A ..	24–28	
Grade III_B ..	28–35	

* Reproduced from *Indian Coals*— a CSIR publication.

3. PULVERISATION OF INDIAN COALS

3.1. *Case for Pulverised Coal*

Coals are generally used in two forms either in lumps or in pulverised form. Fuel in pulverised state is being used extensively in preference to the former. The chief advantages of using pulverised fuel are:

(1) the possibility of mixing fuel and air intimately.

(2) ability to burn fuel at high rates of combustion;

(3) flexibility of control allowing quick response to varying demands;

(4) the practicability of using a wide variety of fuels including many of the poorer and cheaper grades;

and (5) the absence of moving metallic parts, etc.

The importance of pulverised fuel firing can be derived from the fact that nearly 10 million tons of coal per annum are used in this form in Great Britain.[9] The ability to use any low-grade fuel is a chief cause stimulating the advance in this method of firing. This method has been successfully applied to power stations, boilers, cement kilns and also in metallurgical furnaces. Recently in the United States, Gas Turbines[10], running on powdered coal have been built and their performance is being studied. Pulverised coal may also be used in Hot-Air engines. It may very well find a place in the field of gasification also, in combination with a secondary combustion.

3.2. *Fuels Suitable for Pulverisation*

The factors of importance in burning pulverised coal include (1) percentage of volatile matter, (2) ash content and (3) degree of fineness. Generally, for normal operation, the degree of fineness is limited to an optimum size. Still finer sizes will, of course, show increased combustion efficiency, but the extra costs needed to pulverise to such fineness may outweigh this advantage. The percentage of volatile matter is a measure of the ignitability of coal. Usually, coals having less than 20% or 25% are poor in ignition. This disability can be overcome by finer grinding.

In India, generally speaking, the volatile content of the coals is fairly high, excepting those belonging to the first ten seams of Jharia and Kashmiri. The Jharia coals may require finer grinding but since their ash content is also very high, it is doubtful whether finer grinding would be economical. High ash content, of course, increases the difficulties of pulverising and the wear of the mills, and decreases the calorific values. Coals from Jharia (I to X seams), Karanpura, West-Bokaro, Palamau, C.P., and Hyderabad usually contain more than 15% ash, and those from other fields less than 15%. These latter coals, it can be expected will not be difficult to pulverise and utilise, as more than 40% of the pulverised fuel fired installations in Britain have been using coals containing 14 to 18% ash.[9] Coals containing higher percentages of ash than this may require washing to reduce their ash content.

Indian coals containing 24% ash have been successfully washed down to 17%.[3] Apart from ash, moisture also requires consideration. Excess moisture causes clogging of pipe lines, and difficulty in pulverising. Indian coals contain usually a good percentage of moisture. The coals from Central India contain moisture as high as 12%, and those from other fields less than 5%. The moisture in Jharia coals is remarkably low. High moisture coals need drying before or during pulverising, which means additional cost. Whether the extra cost is worth its while, can be determined only under particular conditions and cannot be generalised. Central Indian coals which contain 15% ash may need only drying while coals of high ash content, for Jharia need only washing. The Punjab coals may require both drying and washing but are unsuitable as pulverised fuel, as their sulphur content is very high. Assam coals also come under this category.

3.3. *Types of Pulverisers*[7]

The pulverising of lump coals is done in mills called pulverisers, and there are three types, namely:

(1) Slow speed type	Ball mills.
(2) Medium speed type	Ring roll mills.
(3) High speed type	Impact and Pug mills.

These various types have their relative advantages and disadvantages, and selection in each case should be based on the full knowledge of all the local conditions, including the type and the composition of the fuel supplied. Table VI[2] will reveal the broad characteristics of the three classes of pulverisers.

TABLE VI

Characteristics of Pulverisers

	Relative Order of Merit		
	1	2	3
Consumption of power ..	High-speed impact	Ring-roll	Ball
Maintenance ..	Ball	High-speed impact	Ring-ro[l]
Ability to handle damp fuel ..	Ring-roll	High-speed impact	Ball
Noise ..	High-speed impact	Ring-roll	Ball
Uniformity of product ..	Ring-roll	Ball	High-speed impact
Fineness of pulverising ..	Ball	High-speed impact	Ring·roll

Usually coals containing more than 14% moisture are not fed to slow-speed mills. Those containing less than 6% are fed to both slow speed and medium speed mills. Ball mills and Ring-roll mills will suit Indian coals, since their moisture content is usually below 14%, and the mills are also easy to construct.

3.4. *Extent of Pulverisation*

The degree of fineness to which a fuel should be pulverised varies with the character of the fuel supplied and the pulverising equipment. The critical upper limit is imposed by satisfactory combustion conditions depending on fuel properties. Generally, 70 to 80% through 200 B.S. mesh, is the average product used in British Installations. Ball and Ring roll mills pulverise coals to a fineness of 85% through 200 B.S. Mesh. Output from these mills averages about 4 tons per hour with a power consumption of about 19 KW per ton.[11]

4. COMBUSTION

The problem which still dominates the combustion of pulverised fuel is how to obtain the correct rate of heat release in a combustion space from a coal of given ash content and of known physical characteristics. The efficiency of combustion equipment is dependent upon the combustion characteristics of pulverised coal such as changes in size, density, structure, etc. Ash affects combustion by way of its fusion point. The fusion point should be fairly high so that no clinkering trouble occurs; but this factor will not be a hindrance in the case of cement kilns.

A critical study of Indian coal ashes by R. K. Dutta Roy[4] revealed that the fusion point of ashes of Jharia coals (about 1,350° C.) is higher than those of Raniganj coals (about 1,150 to 1,250° C.). Ashes from Jharia coals contained more silica than those from Raniganj. It was also found that the ash content generally diminished with the increase in temperature—the maximum temperature being only 950° C.

Sulphur in coal is undesirable if present beyond a certain percentage, namely, 1%, since it attacks the metallic parts and gives off poisonous fumes. Generally, sulphur content in Indian coals is less than 1%, excepting those of the Punjab and Assam which contain more than 3%, and up to 8%[5]. Most of the sulphur in Indian Coals is in the organic form and hence cannot be reduced by washing[3]. It is unfortunate that no information regarding the combustion of Indian Coal particles, is available. The Fuel Research Institute, which has been recently established has just completed the task of obtaining the complete analysis of samples of coals from various fields in India. No work on the pulverisation of coals seems to have been done. Work on pulverised fuel is included in the long-term plan of the Fuel Research Institute. Burning characteristics of pulverised coal can best be studied on the lines of Dr. Orning's work.[6] Dr. Orning used an electric furnace, into which a stream of particles of known size and character was introduced. The furnace was kept at a steady temperature during the experiment and the residues of particles were collected and examined. By these experiments he was able to get very valuable information regarding combustion of pulverised coal. Dr. Orning's work can very well be repeated, for Indian coal particles.

5. NATURAL DUSTS

All raw coal won from seams contain nearly 5% of natural dusts. This dust is that fraction of the raw coal, which passes a 50-IMM series sieve.

The removal of the dust is advantageous at every stage of mining, preparation, handling and utilisation of coal. For example, removal of the dust at the mines ensures safety operation, while dust-free coal is easy to carbonize. Also value of lump coal, for boilers free from dust is enhanced. Moreover, this natural dust is itself useful, for it can be fired as pulverised fuel. That this can be burned, as pulverised fuel, is a fortunate compliment to the desirability of its extraction from the bulk. Natural dust requires less energy, to grind to the required fineness, than the " whole coal ", by reason of the friability of these dusts. These dusts are mostly non-caking and non-swelling too. Their volatile content is usually low and ash content high. But the dust can be ground to finer sizes without much expenditure on finer pulverisation. Mayer,[8] obtained, very satisfactory results while firing these dusts, in a boiler of 25,000 lb./hour capacity. The ash in these dusts is usually more homogeneous, in character, than pulverised " whole " coals and therefore has definite advantages like non-clinker formation, easy slag-tapping, etc. Being non-swelling, the ash will not form cenospheres, and hence will be absent from flue dust. Storing of the dust is not difficult, as the hazard of spontaneous ignition is smaller than that of pulverised 'whole' coal. These advantages definitely point towards the greater use of natural dust for pulverised firing. The cost of extraction of the dust from raw coal forms only a small part of the total cost of preparation of raw coal. Dust extraction can very well be done, by air-elutrition. The other methods, namely, screening and washing are either not feasible or inefficient. The quantity of natural dust that can be reasonably expected in India, may be of the order of 1 to 1½ million tons per annum, and this may be sufficient, in the first instance to feed cement industries in India.

6. Conclusions

The data so far available on Indian Coals, is limited only to their composition. The Fuel Research Institute has included the problem of pulverised fuel, in its long-term plan. No work so far seems to have been done on the pulverisation of fuels in India. The first step necessary in this connection is the determination of the grindability of various low-grade coals, on a laboratory basis. Coals from all other fields, excepting Raniganj (*b*), Jharia (*a*) and Jharia (*b*) (I to X seams), Bokaro, Punjab and Assam, should be tried for pulverisation. The characteristics regarding combustion of these pulverised fuels should be studied in laboratories. In this connection, work along the lines adopted by Dr. Orning will be very useful.

Natural dust offers the best possible opportunity to start work on pulverised fuel in this country. Efforts should therefore be directed towards recovering these dusts from raw coal in India.

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LIST OF REFERENCES

1. CSIR (1949). .. *Indian Coals*, Their Nature and Composition, published by Fuel Research Institute,
2. G. W. Himus .. *Elements of Fuel Technology*.
3. CSIR (1948). .. *Washability of Indian Coals*,
4. R. K. Dutta Roy (1940) .. "A Critical Study of Some Indian Coal Ashes," Paper presented to Symposium on Indian Coals, *Proc. of the National Institute of Sciences, India*, p. 538.
5. N. N. Chatterjee (1940) .. "Sulphur in Indian Coals," Symposium on Indian Coals, *Ibid.*, p. 523.
6. Dr. A. A. Orning (1947) .. "Mechanism of combustion of pulverised fuel," *Proc. of Pulverised Fuel Conference*, p. 45.
7. P. G. W. Hawkselay (1947) "Mechanics of present pulverising practice," *Ibid.*, p. 656.
8. R. Lessing (1947) .. "Natural Coal Dust," *Ibid.*, p. 588.
9. Ministry of Fuel and Power, U. K., 1947, .. "Statistics of consumption of pulverised fuel in Great Britain," *Ibid.*, p. 949.
10. T. I. Yellott and C. F. Kott Camp (1947) .. "The pulv. coal gas turbine Locomotive," *Ibid.*, p. 830.
11. W. F. Sparks (1947) .. "The Preparation and Distribution of Pulv. Fuel in Bulk," *ibid.*, p. 690.