EXPLORATION FOR COAL IN INDIA

By

Satyam Singh, M.Tech (Applied Geology), MGMI,
Asim Tripathi, M.Tech (Applied Geology), MGMI
KSK Energy Ventures Limited

1.0 INTRODUCTION:

1.1. The existence of coal as a fuel was known to the Chinese civilization about 3000 years back but the real importance of its value was realized only in 1750 AD for smelting of iron, supplemented by the invention of steam engine in 1769 AD by James Watt, In India, it has been recorded in ancient scriptures as **Angarpathar (Charcoal Stone), Bara-Kad (Barakar), Dam-O-Dar (fire in womb) and Kalipahari (Black hillock).** The first mining of coal dates back to 1774 (Sitarampur – West Bengal) and 1779 in Hutar Coalfield. The regular fair large scale mining , however, started with construction of Raniganj – Calcutta railway line in 1855. Till 1971 most of the production of coal came from private owned mines. The entire coal mining industry in India was nationalized in 1973. In fact, as a back as 1937, supplementary note to Burrows Committee Report by Dr. Nag and Mr. M. S. Krishnan emphasizes the need of state ownership of the entire Coal Industry with a view to end all the problems of the industry.

1.2. With increasing network of railways in the country in the middle of last century, the need for increased production of coal was felt and consequently a Geologist was appointed in “Survey of India”. Subsequently, the entire exploration work was entrusted in 1857 to a new organization “Geological Survey of India (GSI)” which is the oldest department of the country. Since then, G.S.I have been engaged in exploring coal in the country. The exploration of coal received impetus in 1956 with the formation of National Coal

Development Corporation (NCDC). At present coal exploration is being carried out mainly by the Geological Survey of India (Regional Exploration) and by Central Mine Planning & Design Institute Ltd. (CMPDI) and its contractual agencies (detailed exploration) like Mineral Exploration Corporation Ltd. (MECL) and Geology and Mining Departments (DGM) of the Govt. of Orissa, Madhya Pradesh and Maharastra.

2.0 DEFINITION OF COAL:

2.1 Coal is a stored fuel, occurring in layers in the Earth's Crust, which has been formed by partial decay of plant materials, in continuous anaerobic fermeutation under alkaline conditions, accumulated millions of years ago and further altered by action of heat and pressure. This definition excludes bituminous shales, which contain fuel material, and to an extent peat, which is, regarded as raw material of a stage in the formation of coal.

2.2 Chemically coal is made up of Carbon, Hydrogen, Oxygen, Nitrogen and impurities. The impurities are mainly mineral matter. When coal is burnt, completely, the residue obtained is called ash which is generally 90% of the mineral matter in Indian Coals.

3.0 TYPE OF COAL SPECIES:

3.1 It is generally agreed that various solid fuel substances derived from the plant material by the geological processes belong to the coal series. The various species of coal showing progressive maturity are:

1. Peat: (A parent substance for coal series).
2. Lignite: (Brown or Black)
3. Bituminous: (Including its sub-divisions)
4. Anthracite: (Including its sub-divisions)

5. Graphite: (The ultimate end member of the series).

Apart from the above, there are gradational species between the lignites and Bituminous and Anthracite.

3.2 Peat in India is found in Gangatic delta of Bengal and in the state of Mysore. The lignite is being mined at Nayveli (Tamilnadu), Palana (Rajasthan). Matano-mudh and other deposits of Gujarat and Karewa lignites (Kashmir) are other important deposits, former being deep seated (1000 meters and below). Most of Peninsular Coals and some Tertiary Coals of Meghalaya and Nagaland belong to bituminous variety. Semi-antharacitic coal occurs in the parts of Rajhara colliery, Daltonganj Coalfield, Jharkhand and now has exhausted. Anthracite coal occurrences are reported from Himalayan belt.

4.0 COAL CHEMISTRY:

4.1 CHEMICAL COMPOSITION OF COAL:

4.1.1 The simplest form of analysis of coal has been known as "*Proximate Analysis*" and consists determination of the moisture (M%), Ash (A%) and volatile matter (VM%). So this is often added determination of Sulphur (S%) and phosphorous pentaoxide (P_2O_3) and Calorific Value (CV). The solid residue left after determination of VM and after deducting the ash is termed as *"Fixed Carbon*". It is to some extent a confusing term since it bears no relation to true carbon content and contains small amount of S, N and O. The complete proximate analysis, thereafter, consists moisture (air dried coal), ash, volatile matter and fixed carbon all adding to 100% by weight.

4.2 BASIS OF ANALYSIS:

4.2.1 The basis of the proximate analysis can be grouped in following different categories:

A. *Based on dirt bands*:

i. Excluding all dirt bands (all combustible and non-combustible dirt bands.

ii. Including all dirt bands (ROM)

iii. Excluding only Non-Combustible dirt bands.

iv. Excluding dirt bands having thickness of 1m and above.

v. Dry Mineral Matter Free (DMMF) or unit coal basis.

Unless otherwise specified normal proximate analysis results are received for (i) and (ii) above.

B. *Based on moisture content*:

i. On as received basis.

ii. On as analyzed basis.

iii. On equilibrated (on 60% RH 40^0C).

iv. On 90% RH and 40^0C and

v. On dry basis.

C. *Type of Moisture*:

i. Surface moisture.

ii. Free moisture

iii. Inherent/Hygroscopic /equilibrated/ capacity moisture.

iv. Water bound to coal 'molecules' by chemisorptions or hydrogen bonding with reactive groups.

v. Water hydration of mineral matter or water of constitution of minerals.

Based on moisture content of coal (on equilibrated basis) the coals are divided into high moisture and low moisture coals and 2% value of moisture is taken a dividing line.

D. *Volatile Matter*:

The volatile products obtained during pyrolysis of specified amount of coal out of air, in a crucible of standard size at 925^0C + 15^0C for seven minutes in standard condition. Lumace is termed as 'Volatile Matter'. It is expressed in terms of percentage. The volatile matter mainly contains H_2, CH_4, CO_2, H_2S, N_2, NH_4 and other hydrocarbons, tar and moisture (given by matter as well as mineral matter).

4.2.2 Based on volatile matter and moisture content, the Indian coal have been classified as follows: (VM% on DMMF basis and moisture on equilibrated basis):

I. a. Anthracite : VM less than 8%

b. Semi Anthracite: VM less than 10%

II. Bituminous

a. Low volatile or low moisture coal: Moisture up to 2% VM up to 35% usually.

b. High volatile or high moisture coals : Moisture above 2%, VM above 35%, sulphur less than 1% in either cases.

III. Abnormal Coals

4.3 **Ultimate Analysis:**

4.3.1 The ultimate analysis in terms of percentage by weight of moisture, mineral matter, Carbon, Hydrogen, Sulphur, Nitrogen and Oxygen is termed as 'Ultimate Analysis'. The mineral matter is assumed as 1.1 times the ash, but it has to be determined for precision work. The carbon is corrected for carbonate, hydrogen for moisture and water of constitution of mineral matter. This analysis is expressed on equilibrated basis, dry basis and/or DMMF basis.

4.3.2 The ultimate analysis has wide range of application for scientific and industrial purposes. It is possible to predict caking propensities and to calculate calorific value of coal if the elemental analysis (Ultimate Analysis) is known. On turn, the industrial application or end use could be decided.

4.3.3 Useful Heat Value (UHV) is the quality parameter, which is referred to often in industrial use and is important because it specifies the amount of heat, which may be obtained, on burning the coal under different conditions. This parameter is calculated on the basis of Moisture and Ash content of coal, determined on the basis of Proximate Analysis with the help of following empirical formulae.

UHV (Kcal/kg) = 8900-138 (A% + M%)

4.3.4 Useful Heat Value which is a factor of ash and moisture is the basis of coal grading and its pricing. Heat value range under different grade of coal for commercial purpose is given in Annexure.

4.3.5 In view of the Globalization of Coal related activities under different climatic condition and use of coal in different industrial purposes, a standard parameter for heat value has been evolved and adopted globally which is termed as Gross Calorific Value

(GCV). The range of GCV in different grade of coal is also given in Annexure.

4.3.6 **Special Tests:** For different industrial uses of non-coking coal special tests are required to know the burning and characteristics of ash so generated. These are Deformation and Flow Temperature (ITD, HT, FT). The ash of coal is also analyzed for the composition of oxides of different elements and is called as Ash Analysis.

4.3.7 Hardness of coal plays an important role for selection of excavating and handling equipments and as such the parameter for this i.e. the Hardgrove Grindability Index (HGI) is determined.

5.0 SPECIAL PROPERTIES OF COKING COALS:

5.1.1 "*The coking coal is the coal which gives the metallurgical coke on pyrolysis, under appropriate conditions*". A group of coals of bituminous range, usually in carbon range of 83 to 91% on DMMF basis, develops plastic properties at about 350^0C, as a result of which, these coals, during carbonization, exhibit fluidity, swelling and agglutinating properties, expansion and contraction in volume and after carbonization produce coherent residue of varying strength.

5.1.2 Some of the important tests required to determine coking nature of coal are as under:-

i) Caking Index

ii) Roga Index

iii) Dilatometric test (variation in length of a column of coal during heating).

iv) Plasto-metric test: (The resistance offered by the plastic mass of coal after heating).

v) Sopazanikov test (measuring the thickness of plastic layers on unidirectional heating).

vi) Grey King Low Temperature carbonization and Assay (GKLTC).

vii) Swelling Index.

viii) Micum Index.

5.1.3 Apart from these tests, it is necessary to determine whether a coal can give the metallurgical coke, the coke made from the coal is subjected to the following tests:-

i. Shatter Index.

ii. Density-Bulk and apparent.

iii. Irisid test.

iv. ASTM Tumbler test.

v. Size analysis of coke.

vi. Reactivity of coke.

vii. Graf Index and Dyrtus Index.

viii. Havana Stability Index.

ix. Coking Index etc.

5.1.2 It would be seen from the above, that it is not necessary that a coal having 'caking properties alone would give metallurgical coke. Hence, ALL THE CAKING COAL MAY BE COKING BUT ALL COKING COALS ARE NECESSARILY NOT CAKING COALS.

6.0 GEOGRAPHIC DISTRIBUTION OF COAL IN INDIA:

6.1.1 The major coalfield in India is all located in three major alignment. The most important is called Damodar-Sone Valley Coalfields. The main coal basins in this alignment from east to

west are Raniganj (mainly in West Bengal and small part in Bihar), Jharia, Giridih, East and West Bokaro, Ramgarh.

North and South Karanpura, Auranga (Damodar Valley Coalfields), Hutar, Daltonganj, Ramkhola-Talpani, Singrauli (Sone Valley Coalfields.) The important alignment in Wardha-Godavari valley coalfields which include Wardha Valley Coalfields like Wardha Kamptee, Umrer and Bhander etc. and coalfields under Singreni Coal Company. These two alignments meet to the north of Nagpur where Pench-Kanhan, Tawa Valley and Mohpani Coalfields are situated. The third alignment is called Mahanadi Valley Coalfields, which include Hasdo-Arand, Korba, Ib and Talchir Coalfields, Where Mahanadi alignment meets Damodar alignment, and numerous coalfields like Bisrampur, Jhilmili, Sohagpur and Lalchanpur are seen. All the above coalfields are called Gondwana coalfields.

6.1.2 The tertiary coalfield, mainly located in NEFA, Nagaland and Meghalaya are Namchik, Makum, Dilli-Jeypore, Naziria, Lakhum, Langrin, Siju, Darrangiri and Cherapunji. Apart from these, the lignite fields of Matanomadh, Kala, Unrser of Gujarat, Palana of Rajasthan and Neyveli of Tamilnadu are important from economic point of view. The distribution of these coalfields is given on the cover page of this note.

7.0 PRINCIPLES OF COAL EXPLORATION:

7.1.1 The principles, which govern the exploration, are many. However, chief amongst them are as follows:

i. ***Principles of successive approximation:*** Which requires gradual building up of the knowledge of coal bearing area in stages by collection and synthesis of data. The exploration is usually pursued in four stages viz. geological mapping, Regional Exploration, Detailed Exploration and

Developmental Exploration. There is often overlapping and or devoting of these stages.

ii. ***Principle of geological interpretation and verification***: This is based on study of geological latitude where every additional point of observation is planned according to plausible geological interpretation, which is either confirmed or modified.

iii. ***Principle of Completeness of Exploration***:

This principle requires realization of main aims of exploration which is in case of coal are:

a. Lay

b. Disposition

c. Quality

d. Reserves of coal seams

e. Geo-mining characteristics

f. Technological utility of coal being explored.

iv. ***Principle of uniformity of observation points:***

Since the coal seams are 'generally tabular bodies, use of exploration grid is necessary. Since coal seam is usually an entity, whose properties must be evaluated by assuming it as 'Chance Quality' which requires study by random selection necessitating equal spacing of sampling points. This, however, has to be used with proper geological knowledge.

v. ***Principle of optimum outlay of time and expenditure***- This is essentially a basic principle of any commercial venture and is equally applicable in case of exploration. The main expenditure on exploration comprises:

a. Labour cost

b. Material cost

c. Laboratory cost

d. Documentation cost.

vi. ***Degree of reliability***: Though not a principle but is an important factor for further expenditure on mine construction. The degree of reliability is a function of number of observation points and under various stages of exploration (1st principle) are as under :-

Stages	Degree of Reliability
a) Preliminary geological Mapping	10% - 40%
b) Regional Exploration	40% - 70%
c) Detailed Exploration	70% - 80%
d) Developmental Exploration	80% - 99%

8.0 RESERVE OF COAL

8.1.0 The reserves of coal, in principle are calculated by determining volume of insitu coal and multiplying the same by gravity natural (or also specific gravity) to determine the tonnage of coal available. These figures are further refined, basing on various geo-mining considerations and are classified according to the degree of reliability.

8.1.1 **Classification of Reserves**: The classification used by CMPDIL (which is broadly based on Indian Standard Procedure (ISI) is as under:-

i. **Blocked out reserves**:

These coal seams (ore workings) whose all the three dimensions have been proved by the mine drivages and whose technological properties are fully established are timed as block out reserves (this is not included in ISP).

ii. **Proved Reserves***:*

a. The reserves estimated from dimensions revealed in outcrops, trenches, mines workings and boreholes and the extension of the same to a reasonable distance, not exceeding 200 m. on Geological Evidences.

b. Where little or no exploratory work is done and where outcrop exceeds one kilometer in length, another line, roughly 200 m. from outcrop will define a block of coal which may be regarded as proved on geological evidences.

   However, for (b) above CMPDI insists on calculations from (i) Incrop region and (ii) In case of reserves to be mined by the underground entries the coal upto 15 m. cover line must be excluded from proved reserves.

iii. **Indicated Reserves***:*

Incase of indicated, the point of observations are 1000 m. apart but may be 2000 m. for the beds of known geological continuity. CMPDI insists on preliminary technological parameters. Also, where geological structure and geo-mining conditions are not well known, the reserves are placed by CMPDI in Indicated Category. Further Proved Reserves as classified by GSI during regional exploration on the basis of 200 m. radius in widely scattered areas without

continuity for mining, are also placed in Indicated Category for mine planning.

iv. **Inferred Reserves***:*

This refers to coal for which qualitative knowledge estimates are based largely on broad knowledge of geological characteristics of the coal seam, but for which there are no measurements. The estimation of reserves is based on assumed continuity for which there is geological evidence upto 1000 m. from the outcrop.

8.1.2 **Gross and Net Insitu Reserves**:

To compensate towards unforeseen geological disturbances a deduction of 10% is made from the gross insitu reserves to obtain net insitu reserves. In case of heavily faulted areas and areas showing erratic burning, an additional deduction of 10% (Total 20%) is made in gross proved reserves to arrive at net reserves by CMPDI.

8.1.3 Due to various technical reasons barriers of total coal have to be left against rivers, railways, old abandoned workings, fire areas and others.

9.0 GEO-MINING CHARACTERISTICS OF COAL SEAM AND ASSOCIATED STRATA:

9.1.1 The geo-mining characteristics are divided into three main parts viz:

a. Physio-Mechanical properties of coal seams and rocks.

b. Geo-hydrological conditions.

c. Civil Engineering and Town Planning work related to Geology.

9.1.2 The main physio-mechanical properties require to be evaluated are:-

i. Compressive strength – Uni-axial/Tri-axial

ii. Shear strength – Single/Double.

iii. Tensile Strength & Split Tension.

iv. Elastic Constants

v. Particle specific gravity and gravity natural.

vi. Angle of internal friction (Calculated)

vii. Porosity (Calculated & Determined)

viii. Cohesiveness (Calculated)

ix. Permeability

x. Protodyaknov Strength Index

xi. RPP

xii. Rippability

xiii. Angle of repose of ROM and sized coal.

9.2 GEO-HYDROLOGICAL CONDITIONS:

9.1.1 This aspect of coal exploration was in infancy and has now been developed to cater the need for dewatering and studies for environmental aspect. The broad parameters being evaluated are as under:-

i. Meteorological data of rainfall

a. Daily rainfall

b. Monthly rainfall

c. Annual rainfall

d. Number of rainy days.

ii. Data of Surface Hydrology

a. HFLs of rivers and nalas.

b. Flow measurement

c. Estimation of volumes of ponds, faults etc.

d. Aquaduts and canals etc.

iii. Ground Water Regime

a. Water table maps.

b. Transmissibility

c. Specific yield etc.

d. Artesian water condition & head.

9.3 CIVIL ENGINEERING AND TOWN PLANNING WORK RELATED TO GEOLOGY:

i. Topographic contouring of block for industrial site.

ii. Foundation Engineering.

iii. Selection of dumping ground.

iv. Selection of alignments of roads, railways, pipe lines, power lines etc.

v. Alternative site for existing civil work if necessary.

9.4 ENVIRONMENTAL IMPACT ASSESSMENT (EIA):

9.4.1 This field of scientific study has now become essential in view of the imposition of the guidelines of MOEF related to all mining activities in the country and hence detail studies and management schemes are required to be formulated to get the required clearances of Govt. of India.

9.4.2 This aspect itself is a separate subject and beyond the scope of Geological Studies and hence not dealt here precisely. However, the geological data is collected and collated even during the

exploration stage, which are further supplemented and analysed for studies related to Environmental Impact Assessment.