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Coal Beneficiation Technology for Coking & Non-Coking Coal Meant For Steel and Thermal Power Plants

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Abstract: *There are 21 coking coal washeries in production both in private and public sectors. Production of clean coal in these washeries during 1989-90 was 12 million tonne and it is expected to go up to 37 million, tonne during 2015-16. Planning Commission has taken the decision that non-coking coal meant for Thermal Power Plants situated far away from feeding coalfield, should be beneficiated. Coal Washing is a process of separation mainly based on difference in Specific Gravity of Coal and associated impurities like Shale, Sand & Stones etc so that we get relatively pure marketable coal without changing its physical properties. The Washed Coking Coal is meant for Steel Plants. The Washed Power Coal/Washed Non-Coking Coal/Middling is dispatched to various Power Houses. The Coal Washery Rejects are the major environmental hazard during the process of Coal Washing. Considering the fact of requirement of millions of tones clean coal for the end-users, mainly power houses, this problem will have to be solved effectively. The benefits of low ash coal burning in boilers are realized but reimbursement of extra cost of beneficiation for washed non-coking coal needs to be considered*

Key Words: *Coking Coal, Middlings, Rejects, Deshaling, Coal Washing, Steel Plant, Power Houses*

I. INTRODUCTION

There are a number of washeries under construction now and these are expected to be completed by 2018. Present washeries face problems in optimum production more on quality aspects than on quantity and it appears that trend of using imported coking coal of low ash to blend with indigenous high ash coal for steel sector requirement, may continue for some time to come on considerations of optimized steel production. A coal preparation plant (CPP) is a facility, washes coal of soil and rock, crushes it into graded sized chunks (sorting), stockpiles grades preparing. A CPP may also be called a coal handling and preparation plant (CHPP), The more of this waste material that can be removed from coal, and lower its total ash content. The greater its market value and lower its transportation costs. Besides the above coking coal washeries, Bina deshaling and Piparwar beneficiation plants are in advance stages of construction in non-coking coal sector. Future prospects of washeries for non- coking coal beneficiation appear to be bright as, in view of sharp rise in demand for coal, there is increasing trend in mechanized mining of inferior seams resulting in deterioration in quality and consequent reluctance by consumers to accept the same.

Grading of Coal **Table-1**
A. Coking Coal

Grade	**Parameter**
Steel I	Ash > 15%
Steel II	Ash > 15% < 18 %
Washery I	Ash > 18% < 21 %
Washery II	Ash > 21% < 24 %
Washery III	Ash > 24% < 28 %
Washery IV	Ash > 28% < 35 %

B. SEMI COKING COAL	
Grade	**Parameter**
Semi Coking I	Ash + moisture < 19 %
Semi Coking II	Ash + moisture > 19 % < 24 %

C. NON-COKING COAL	
Grade	**Gross Calorific Value bands for Non-Coking Coals (In Kilo Calories/Kilogram)**
G1	Above 7000
G2	6701 to 7000
G3	6401 to 6700
G4	6101 to 6400
G5	5801 to 6100
G6	5501 to 5800
G7	5201 to 5500
G8	4901 to 5200
G9	4601 to 4900
G10	4301 to 4600
G11	4001 to 4300
G12	3701 to 4000
G13	3401 to 3700
G14	3101 to 3400
G15	2801 to 3100
G16	2501 to 2800
G17	2201 to 2500

D. HARD COKE	
Grade	**Ash %**
Beehive Ordinary	> 31 % < 36 %
Beehive Premium	< 27 %
Beehive Superior	> 27 % < 31 %
By Product Ordinary	> 25 % < 30 %
By Product Premium	< 25 %

SUITABILITY OF COAL

E. HARD COKE	
Industry	**Type of Coal Required**
Steel making, sponge iron industry	Non-coking coal of high Initial Deformation Temperature (IDT) (>1200 degrees Celcius)
Steel making	Coking and semi-coking coal, direct feed and washed; blendable coal; low ash % Assam and Ranigunj coal
Steel castings	Non-coking coal
Special Smokeless Fuel (SSF)	Semi-coking coal of Coking Index 8 10
Power sector	Non-coking coal; middlings of coking coal washeries; washed coal of non-coking coal washeries
Old boilers	Superior grades of non-coking coal
Halwais, domestic use, hotels, etc.	Non-coking coal; CIL Coke / LTC Coke
Glass and potteries	Long Flame non-coking coal
Cokeries / coke oven plants	Coking and semi-coking coal
Cement sector	Non-coking coal; middlings of coking coal washeries
Cast iron castings	Hard coke
Briquette making / domestic fuel making	Semi-coking and non-coking coal; middling & rejects of washeries
Bricks	Non-coking coal; middlings of coking coal washeries

II. COAL INDIA LIMITED (CIL)

Coal India Limited is an Indian state-controlled coal mining company headquartered in Kolkata, West Bengal, India. It is the largest coal producer company in the world, and contributes around 81% of the coal production in India. Union Government of India owns 79.65% of the shares in CIL and controls the operations of CIL through Ministry of Coal. In April 2011, CIL was conferred the Maharatna status by the Union Government of India. On 31 March 2013, its market capitalization was INR 1.952 trillion (US $35.9 billion) making it India's 5th most valuable company by market value.

CIL is the largest coal producing company in the world. It produced 462.422 MT (million tonne) coal during FY 2013–14. Coal India operates through 81 mining areas in eight states in India. It has 470 coal mines out of which 164 are open cast, 275 are underground and 31 are mixed mines. Production from open cast mines during 2012-13 was 91.65% of total production of 422-462 MT. Underground mines contributed to 8.35% of production. CIL further operates 17 coal washeries, out of which 12 are for coking coal and 5 are for non-coking coal.

Subsidiaries:

Coal India produces coal through seven of its wholly owned subsidiaries. It's another wholly owned subsidiary CMPDIL carries out the exploration activities for other subsidiaries. It provides technical and consulting services to it and to third party clients for coal exploration, mining, processing and related activities. CIL also has a wholly owned subsidiary in Mozambique, Coal India Africana Limitada.

Fig, 1 View of Bhojudih Coal Washery under (BCCL)

Employees:

Coal India had 457,926 employees as on 31 March 2013. Out of which 304,792 were workmen, 33,542 were supervisors and 19,592 were Executives. Coal India spent Rs.273.21 billion on Employee benefits which accounted for 52.47% of the total expenditure incurred during FY 2013–14.

The Details of Number of Employees, Revenue for FY 2012-13 and Production of Coal is Given in the Table-2

Subsidiary	Employees	Revenue INR billion (FY 2012-13)	Coking coal (MT)	Non-coking coal (MT)	Total Coal Production (MT)
Bharat Coking Coal Limited	61,698	89.37	26.970	4.243	31.213
Central Coalfields Limited	48,126	92.38	16.156	31.905	48.061
Central Mine, Planning & Design Institute Limited	3,142	6.05	-	-	-
Coal India Africana Limitada		-	-	-	-
Eastern Coalfields Limited	74,276	97.40	0.043	33.868	33.911
Mahanadi Coalfields Limited	22,065	120.93	-	107.894	107.894
Northern Coalfields Limited	16,073	99.86	-	70.021	70.021
South Eastern Coalfields Limited	73,718	176.48	0.157	118.062	118.219
Western Coalfields Limited	54,960	74.23	0.330	41.957	42.287
Sub-total	*354,058*	*756.72*	*43.656*	*407.950*	*451.606*
North Eastern Coalfields	2,376	-	-	0.605	0.605
Dankuni Coal Complex	551	-	-	-	-
CIL Headquarters	941	13.78	-	-	-
Total	**357,926**	**770.49**	**43.656**	**408.555**	**452.211**

Plants on different principles and in various sizes are conceived as follows for commercial exploitation:

Table .3 Various Sizes of Coal Treated

Technology	Size of Coal (mm)
Photometric Ore Sorter	125-50 50-20
In pit de-shales	1200-200 200-13/6
Electronically controlled moving pan jig	400-40 200-30
Dry Shale Extractor	200-100 100-50

Pilot plants for dewatering fines below 0.5mm obviating froth flotation are conceived as follows:

Table .4 Processes of Various Sizes of Coal Treated

Technology	Size of coal treated (mm)
AED/FC Dry Process	1-0.1
Column Flotation	0.5-0
Oil Agglomeration	0.5-0
Oleo Flotation	0.5-0
Slurry Jig	3-0.1
Spiral Concentrator	3-0.1

Coking coal

Also known as metallurgical coal is used to create coke, one of the key irreplaceable inputs for the production of steel. There are many varieties of coal in the world, ranging from brown coal or lignite to anthracite. The property that really sets coking coals apart from other coals is caking ability, which is the specific property required in order to make coke suitable for making steel. Coke quality is largely influenced by coal rank, composition, mineral content and the ability to soften when heated, become plastic, and re-solidify into a coherent mass. Bituminous class coals of high, medium, and low volatile rank that possess these properties are called “coking” coals. Coke is produced by heating coking coals in a coke oven in a reducing atmosphere. As the temperature of the coal increases, it becomes plastic, fusing together before re-solidifying into coke particles. This is known as the caking process. The quality of the resultant coke is determined by the qualities of the coking coals used, as well as the coke High quality coking coals are in great demand by steel producers, who need these coals to make high quality coke to maximize the productivity of their blast furnace operations.

Non-Coking Coal

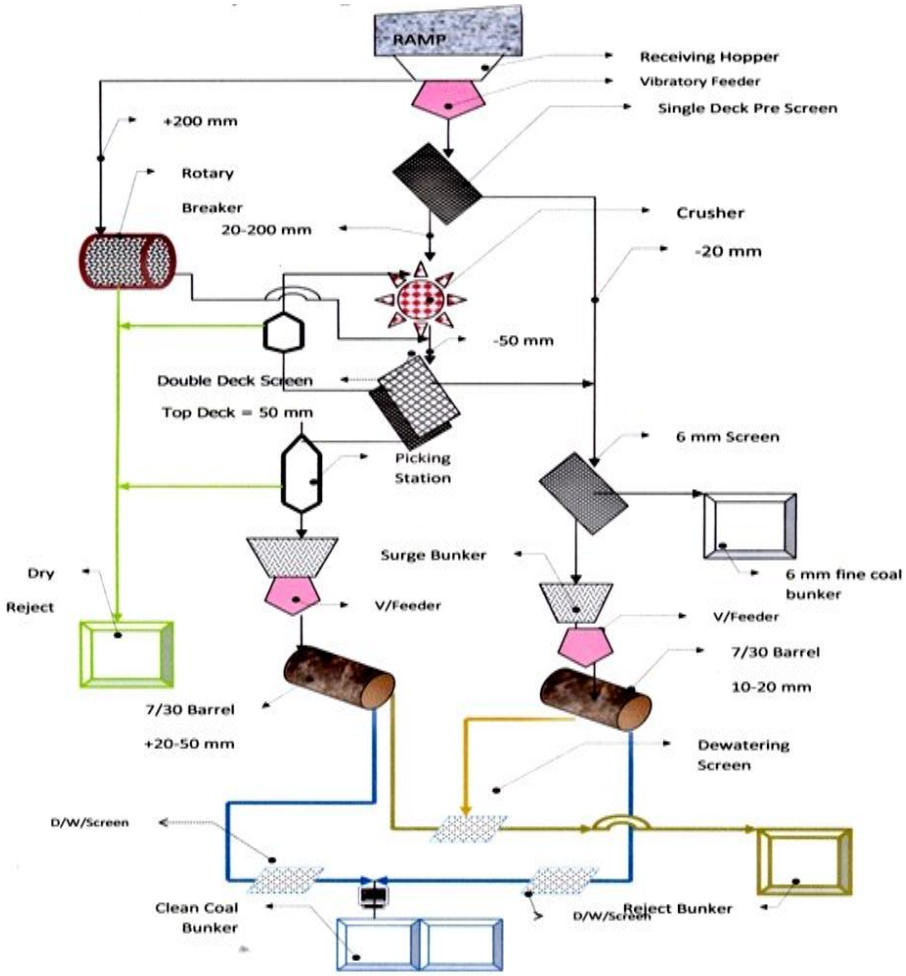
Used for cement, fertilizer, glass, ceramic, paper, chemical and brick manufacturing, and for other heating purposes. These are such type of coal which doesn’t have properties like Coking Coal.

III. COAL WASHERIES UNDER OPERATION IN INDIA

Table .5 Coal Washeries under operation in India

Sl. No.	Type of Type of Coal	Sector	No.	Capacity (Mty)
1	**Coking**	Coal India	11	19.68
		Other PSUs	3	4.85
		Private	4	6.42
		Sub -Total	**18**	**30.95**
2	**Non -coking**	Coal India	7	20.20
		Private	21	50.15
		Sub -Total	**28**	**70.35**
		Total	**46**	**101.30**

Fig.2 Flow Diagram for Coal Beneficiation Plant



Effect of High Ash

- Staging and fouling of water walls
- Reduced flame stability
- Reduced availability of coal mills
- Increased requirement for land for dumping
- Higher emissions
- High boiler erosion
- Damage to and high erosion of pulverizes
- Damage of conveyor belts, coal crusher
- Blockage of chutes and feeders

III. COAL WASHING TECHNOLOGY OPTIONS

Clean coal technology being practiced in coal washeries in India, as pre-combustion clean coal technology, mainly focus on cleaning of coal by removing ash from coal. Earlier only coking coal was being washed because steel making needs coking coal of ash of 17 to 18%. The raw coal ash in Indian coking coal varies from 25 to 30%. Now-a-days, Ministry of Environment & Forests has put restriction on the use of high ash coal in power sectors, which necessitated priority to wash non-coking coal also. The choice of process equipment involved in coal washing depends on factors such as the type of coal being treated; the market requirement and the economics. Continuous research and development efforts, including trial and adoption of latest equipment/ technology are being done Coal Washing Technologies under trial in India.

Washability:

The washability characteristics of a coal reserve are provided by obtaining liberation data on the raw coal sample. Liberation refers to the amount of physical breakage required to separate material of different material densities. Low density material is clean coal whereas high density material is reject (rock). The intermediate density material is called middling. Liberation data is commonly obtained by float and sink analysis. The procedures for this analysis are detailed in Australian Standard **AS 4156.1-1994 "Coal preparation - Higher rank coal - Float and sink testing".**

IV. METHODOLOGY

Coal Sampling:

Sampling of coal is an important part of the process control in the CPP. A grab sample is a one-off sample of the coal at a point in the process stream, and tends not to be very representative. A routine sample is taken at a set frequency, either over a period of time or per shipment. Coal sampling consists of several types of sampling devices.

Fig 3 Coal stacker

Fig. 4 Coal Stockpile

Fig.5 Coal Reclaimer

Fig.6 Coal Handling Plant

Crusher:

Crushing reduces the overall top size of the ROM coal so that it can be more easily handled and processed within the CPP.

Thickeners:

Thickeners are used for dewatering slurries of either tailings or product. A thickener is a large circular tank that is used to settle out the solid material from the water in the feed slurry. The separated water is clarified and reused as process water in the CPP.

Thickeners are sized according to the volume of feed slurry to be processed. Typical size ranges are from 13 to 40m in diameter and 3-4m high. The floor of the thickener is conical, sloping gently down toward the centre. The feed is pumped into the feed well, at the centre of the thickener, near the top.

Gravity Separation:

Gravity separation methods make use of the different relative densities of different grades of coal, and the reject material.

Jigs:

Jigs are a gravity separation method for coarse coal. Different types of jigs:

Dense Medium Process:

Dense medium gravity separation methods use a material such as magnetite to form a medium denser than water to assist in separation.

Cyclones:

A cyclone is a conical vessel in which coal along with finely ground magnetite (media) is pumped tangentially to a tapered inlet and short cylindrical section followed by a conical section where the separation takes place. The higher specific gravity fractions being subject to greater centrifugal forces pull away from the central core and descend downwards towards the apex along the wall of cyclone body and pass out as rejects/middling. The lighter particles are caught in an upward stream and pass out as clean coal through the cyclone overflow outlet via the vortex finder.

Dense Medium Baths (DMB):

Different types of DMB:

a) Wemco drums
b) Tromp shallow bath
c) Teska bath
d) Leebar bath
e) Drewboy bath
f) Daniels bath
g) Chance cone
h) Barvoys bath

Fine Coal Method:

Fine coal is cleaned using froth flotation methods. Denver cells and Jameson Cells are two flotation methods used. Spirals perform a simple, low cost and reasonably efficient separation of finer sized material, based on particle density and size.

Dewatering Product Coal:

Water is removed from the product to reduce the mass, and runoff on the stockpile. Different methods of dewatering exist, including:

- Coarse coal centrifuges
- Screen bowl centrifuges
- Slurry screens
- Dewatering cyclones
- Horizontal belt filters

Dewatering Tailings (Reject):

Water is removed from tailings to recycle water. Filters, centrifuges and thickeners are used in this part of the process. The black water which is produced as a by-product is typically placed in a coal slurry impoundment.

Screening:

Screens in screening plant are used to group process particles into ranges by size. These size ranges are also called grades. Dewatering screens are used to remove water from the product. Screens can be static, or mechanically vibrated. Screen decks can be made from different materials such as high tensile steel, stainless steel, or polyethylene.

Control and Instrumentation:

Control and instrumentation is a very important part of a CPP. Measurement of flow, density, levels, ash and moisture are inputs to the control system. PLCs are used extensively in plant design. SCADA systems are typically used to control the process.

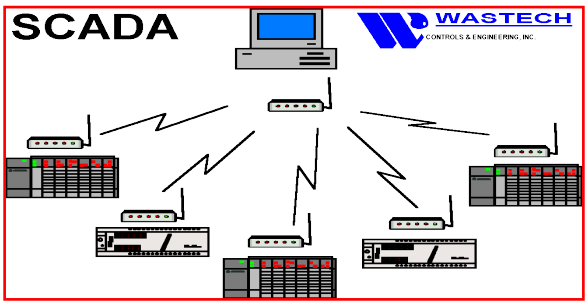


Fig.7 Scada System

V. OBJECTIVE OF STUDY

- Technical and Financial Feasibility of Producing Low Ash Coal for use in remote power station.
- Capturing heat content in washery rejects for generating Power using Fluidized Bed-Boiler based Power Plant at pit head.

VI. Data Obtained From Coal Washery Under BCCL, A Subsidiary of Coal India Limited

Table. 6 Washery and their Capacity

Washing Process:	
Washery	**System of Washing**
Sudamdih	2 Stage HM Cyclone (37-0.5mm), Flotation (-0.5mm)
Patherdih	Deshaling Jig(75-0mm), HM Bath(75-13mm),
Moonidih	2 Stage HM Cyclone (30-0.5mm),W/O Cyclone(-0.5mm)
Mohuda	HM Cyclone (25-0.5mm), Flotation (-0.5mm)
Madhuban	Batac Jig (13-0.5mm), Flotation(-0.5mm)
Dugda-II	HM Cyclone (13-0.5mm), Flotation (-0.5mm)
Bhojudih	Deshaling Jig (75-0mm), HM Bath (75-25mm),
	Batac Jig (25-0.5mm), Flotation (-0.5mm)
	HM Cyclone (13-0.5mm)

Details of Existing Washeries :			
S. No.	**Name of Washery**	**Year of Commissioning**	**Operable Capacity MTY**
A. Coking Coal			
1	**Dugda-II**	1968	2.00
2	**Bhojudih**	1962	1.70
3	**Patherdih**	1964	1.60
4	**Sudamdih**	1981	1.60
5	**Moonidih**	1983	1.60
6	**Mohuda**	1990	0.63
7	**Madhuban**	1998	2.50
TOTAL (Coking Coal)			11.63
B. Non-Coking Coal:			
	Dugda – I	1961/1998	1.00
TOTAL (Non-Coking Coal)			1.00

VIII. ENVIRONMENTAL AWARENESS

- Effluent treatment / Re-circulation arrangement
- Water Sprinkling in a radius of nearly 2 km of the Washery
- Tree Plantation around Washery premises and colonies done every year.
- Rain Water Harvesting.

IX OTHER KEY ACTIVITIES FOR EFFECTIVE POLLUTION CONTROL

- Systematic and scientific excavation of the slurry ponds to make the space available for settling of fines in the ponds / dyke area itself and recycle back the clear water through pumps for re-use in the plant as process water.
- The recycling pumps have been fully renovated and are operating under strict supervision to avoid any out flow of even clear water.
- Market has been found for sale of old stock of slurry of the Washery.

X. FUTURE SCOPE OF WORK

- Various recommendations made by earlier committees on washeries like strengthening of Coal Preparation Engineering Institute and cadre for operating personnel, start of a Central Training Institute.
- The production of better quality of coke from metallurgical coal either by using inferior quality coal with lower reactive content, or non-coking coal in blend. It should be decided after successful trial at the pilot plant stage.
- To build up strong indigenous base cost effectiveness, availability of spare parts and other considerations standardization of equipment is very desirable.
- Sufficient stress has to be given by the national laboratories and academic institutions in the country to interact with washeries and impart know-why.
- Regular interaction with consumers, particularly with steel plants and thermal power stations is essential.
- Necessary infrastructure by way of pilot plants should be built, to achieve the purposes.
- CPEI of CMPDI, conceived as Central Organization for coal washeries, should, initiate actions and monitor implementation of all issues connected with washeries with assistance, if necessary, from practicing professionals abroad, scientific and educational institutes in the country, washery administrators and equipment manufacturers.

XI. CONCLUSIONS

- Challenges in deterioration in quality of raw coal emphasis on increased mechanization/open cast mining.
- Coal preparation should be recognized as a technological necessity for the coal industry.
- coal washeries should be recognized as an industry with its own technology and skills entirely different from the mining industry
- Detailed geological investigations should be conducted. Linkages should be established for all the existing and future washeries, over a span of at least 15-20 years, so that effective operational planning in washeries is possible.

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