

COAL WASHING PILOT PLANTS AT  
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The plan, design and selection of industrial coal washers require the proper assessment of a number of factors which can be summarised as follows:

- (1) Methods of Mining, mode of transport and handling at the collieries as well as inside the washery and their resultant effect on the size of the coal fed to the washery.
- (2) Requirement of the consumers as regards size, quality and moisture content of the washed products.
- (3) Washability characteristics of the coals to be cleaned.
- (4) Limitations and efficiency of the different types of washing plants.
- (5) Capital and recurring expenses etc. etc.

Laboratory test results generally assist in the primary selection of washing schemes or flow-sheets. But for sound planning the final selection has to be based on plant trials. The main objects of installing a pilot plant are:

- i) To collect basic data for planning of commercial washeries.
- ii) To prepare and supply various washed products in bulk (which will be expected from commercial washeries) to other pilot plants or large-scale units to study their carbonization, combustion and gasification characteristics so that an integrated planning can be done for the ready utilisation of all washery products before the commercial washeries come into operation.

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iii) To study the economics of washing, utilising various schemes and techniques and to select the best one suited for the type of coals to be treated.

iv) To study special problems encountered in commercial washeries.

A description of the coal washing pilot plants at the Central Fuel Research Institute is given under.

A. 40 t.p.h. composite coarse coal washer

The erection of the 40 t.p.h. coal washing pilot plant at the Central Fuel Research Institute has already been completed. It comprises of two different types of washing units - a heavy Medium Separator and a Baum Jig each of 20 t.p.h. capacity and includes all essential and auxiliary units, required for the full scale operation of a commercial plant. These two units can be combined in a number of ways for the purpose of washing the coals to be tested. The raw coal may be crushed to below 3" (or 4") and screened at 1" (or  $\frac{1}{2}$ " ), if required, before despatch to the washing plant.

The most outstanding feature of the pilot plant is that it incorporates adequate flexibility for following up six to eight different types of washing schemes. Incidentally, this is the largest coal washing pilot plant in the world.

The principal schemes of washing which it is intended to follow may be summarised as below:

- (1) The entire crushed coal can be washed in either of the washing plants. For washing in the heavy medium plant there is a provision for removing the fines below  $\frac{3}{16}$ ". The different products can be sent to the respective bins. The Heavy Medium separator will produce two products, viz. cleans and sinks while the Baum Jig will produce three products, viz. cleans, middlings and rejects.
- (2) The entire raw coal feed can be deshaled in the Baum Jig at some high gravity of cut, and the resulting product can be rewashed in the Heavy Medium Separator maintained at some suitable lower gravity to yield clean coal and middlings.
- (3) The coal can first be washed in the Baum Jig. The separated middlings and/or rejects or both can be rewashed in the Heavy Medium Separator.

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The middlings and rejects can be crushed to 1" or  $\frac{1}{2}$ " prior to rewashing and can also be fed back to the Baum Jig along with the raw coal, if so desired.

- (4) The coal can be treated in the manner stated in scheme No.(3) using the Heavy Medium Separator and the Baum Jig as primary and secondary washer respectively.
- (5) The two products, 3" -1" (or  $\frac{1}{2}$ " ), and 1"(or  $\frac{1}{2}$ " )- 0 obtained after screening the crushed raw coal can be sent to either of the washing plants or separate washing.
- (6) The rewashing of the products obtained by treating the coal according to scheme No.(5) can be carried out in a number of ways as has been stated in the previous schemes.

Description of the plant:

The pilot washery is composed of the following principal Sections:

- (1) Run-of-mine coal storage bin
- (2) Central coal preparation plant, storage and distributing system
- (3) Heavy Medium washer
- (4) Baum Jig including slurry and effluent treatment
- (5) Provision for rewashing and disposal of washed products
- (6) Magnetite preparation, cleaning and thickening system
- (7) Centralised control
- (8) Buildings etc.

(1) Run-of-mine coal storage bin:

Raw coal is unloaded directly from railway wagons or trucks on to six raw coal bins manually. The bins have been installed under the ground and are of reinforced cement concrete. These bins can store 300 tons of 2" to 0 coal. Each bin has been provided with an adjustable grate which can be aligned with a portable chain feeder



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mounted on rails under the bins. It can unload coal from the bin at the rate of 20 to 70 per hour and deliver it to a trunk belt conveyor.

(2) Central preparation plant, storage and distributing system:

The unloaded coal is carried by means of a set of belt conveyors to an inclined fixed bar screen or grizzly via a drum type magnetic separator for removing tramp iron.

The undersize from the grizzly is received in the crushed coal bin placed underneath. The oversize from the grizzly rolls down to a grid having 8" apertures. The 8" coal retained on the grid is broken manually to make it pass through the 8" apertures. The 8" to 3" (or 8" to 4") product is led by means of a cross feeder to a single roll crusher adjustable for 3" and 4" products. The crushed product is conveyed back to the crushed coal by means of belt conveyors. The bin has been provided with a gate and chain feeder for drawing coal at controlled rates.

A belt conveyor carries the coal to the screening plant. A belt conveyor weigher has been provided to record the instantaneous and cumulative weights of coal being handled. A scraper and a bucket elevator have been provided midway between the crusher house and the screening plant to divert (if required) the crushed coal to a bin from which it can be distributed to other pilot plants of the Institute. A syntron type double deck vibrating screen has been provided underneath the bin to classify the crushed coal, if desired.

The screening plant for the washery is of the vibrating deck type and permits installation of deck with various screen apertures. The two separated products from the screen are conveyed by means of two reversible belt conveyors meant for feeding the Baum Jig and heavy medium separator respectively. The screening plant can be by-passed and the crushed coal conveyed to either of the said hoppers by means of a reversible belt conveyor. Four weighers have been provided on the belt conveyors to record the rate and the quantity of flow.

(3) Heavy Medium Washer:

The coal to be washed in the heavy medium washer is lifted by means of a bucket elevator and delivered on a desliming screen of 3/16" aperture. The screen is of horizontal vibrating deck type and is provided with water sprays, for efficient separation of the dust which would otherwise enter the heavy medium and effect its specific gravity and viscosity. The fines which pass through the screen are conveyed by the underflow water to a second horizontal vibrating screen provided with a 40 mesh net, which removes most of the water and -40 mesh particles from the -3/16" coal. The 3/16" -40 mesh coal is then collected inside a bin while the separated water containing -40 mesh particles flows to the settling pond.

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The 3/16" coal is fed to a drum type heavy medium separator with a washing capacity of 20 tons of coal per hour. Inside the drum there are four spiral conveyors at the rear end and a number of lifters in the front. The drum rotates at the rate of 3 to 4 revolutions per minute.

The heavy medium required for the separation of coal from its associated impurities is prepared with a suspension of finely ground magnetite (mostly under 300 mesh) in water. It is circulated continuously through the plant. By varying the proportion of magnetite particles and water the specific gravity of separation can be varied from 1.30 to 1.80.

The drum separates the coal into two fractions. The lighter fraction constituting the clean coal floats on the surface of the medium and is conveyed to the depulping-cum-rinsing screen by the circulating medium. The impurities being heavier than the separating medium sink to the bottom of the bath wherefrom they are conveyed to a horizontal, vibrating, depulping-cum-rinsing screen by the spirals and lifters provided inside the drum via a chute suitably placed to receive the sinks. The washed products are finally collected in the respective bins.

The depulping-cum-rinsing screens have been provided with two hoppers placed in series to receive the undiluted and diluted media respectively. The undiluted medium flows to a storage tank wherefrom it is continuously pumped back to the system. The diluted medium is stripped off the fine coal by means of a 40 mesh horizontal vibrating screen and then is led to a thickener-cum-storage tank for proper thickening.

#### (4) Baum Jig including Slurry and Effluent Treatment

The coal from a hopper is lifted by means of a bucket elevator and is discharged into a small inclined covered chute provided with a roll feeder. The roll feeder in combination with the covered chute maintains more or less a constant rate of feed to the Jig. The Jig is designed for a normal throughput of 20 tons per hour. It has six cells in two compartments. Each cell is provided with a reciprocating air valve which admits and exhausts air to and from the system according to the cycle of operation desired. The cycle and operation can be varied from 25 to 65 pulsations per minute by means of an adjustable gear.

A turbo blower together with a receiver has been provided to supply 700 cu.ft. of air per minute at about 2.5 lbs. per sq. inch. gauge pressure for providing the jiggling action. Water is pumped continuously through the jig at the rate of about 350 gallons per minute.

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The jig can be operated within the specific gravity range of 1.55 to 1.80. It has been provided with a fish float in each of the two compartments which control the separation of the rejects and the middlings at proper gravities by maintaining proper bed depth. Any variation in the proportion of rejects or middlings in the jig bed is instantaneously detected by the respective floats which in turn automatically changes the rate of pulsations and bring the bed height to the predetermined level. The two products (the middlings and the rejects) as discharged from the jig box are received by two bucket elevators. The buckets are perforated and this facilitates the dewatering of the products. They are then conveyed to their respective bins after they are weighed on the weighers provided. They can be crushed and rewashed, if so desired.

The pulsations of water make the lighter fractions, i.e. the clean coal, move to the surface of the jig bed which are then carried by the circulating water to a conical settling tank. The clean coal settles to the bottom and is taken out continuously by means of a bucket elevator. It can either be stored in the bin or can be sent for rewashing. The excess water overflows the launder of the settling tank and is then led to a reinforced cement concrete settling pond and is finally received in a second pond called 'suction back', which supplies the water for recirculation in the jig as well as for spraying the raw and washed products on vibrating screens of the heavy medium separator.

(5) Provision for rewashing and disposal of washed products:

This section has got a combination of conveyors, a double roll crusher and a vibrating screen. The products to be rewashed may be screened to remove the undersizes while the oversizes may be crushed down to 1" or  $\frac{1}{2}$ " prior to rewashing. The crushed products are ultimately delivered to the reversible belt conveyor meant for feeding it to either of the washing sections.

The washed products collected in respective bins are disposed off by trucks.

(6) Magnetite preparation, cleaning and thickening system:

A rugged jaw crusher has been provided to crush magnetite down to  $\frac{1}{2}$ " which can be lifted up by means of a electrically operated skip. It can feed crushed magnetite continuously to the ball mill. Water is circulated through the ball mill to carry the milled product over to a classifier. The classifier consists of an inclined channel provided with an adjustable spiral conveyor. The overflow from the classifier flows to a thickener cone. The oversize products which settle to the bottom of the classifier are conveyed back to the ball mill by the spiral conveyor for further grinding.



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The thickener-cum-storage tank consists of a large circular tank with a conical bottom. It has been provided with a raking mechanism which is rotated slowly by means of an electric motor. The particles settling at the bottom are collected in the conical section of the thickener which supplies the undiluted medium for the heavy medium separator.

When the heavy medium separator is in operation, a portion of the thickened medium is continuously sent to a magnetic separator for separating the non-magnetics including coal and clay slimes from the magnetite. The cleaned magnetite is demagnetised by means of a demagnetiser and is then sent to a densifier to separate out excess water from the cleaned medium. The overflowing water flows to the top of the thickener while the cleaned and thickened medium flows to bottom conical portion of the thickener.

#### (7) Centralised Control:

The power for operation of the washery is supplied through a main switch installed inside a control room at 440 volts, 3 phase, 50 cycle A.C. The control and signal circuits receive power at 220 volts, single phase, 50 cycles A.C. from a small transformer installed inside the washery.

There are 40 motors with a total installed horse power of 250. These have been divided into two groups for ease of operation and control:

- (i) Raw coal storage & preparation section, and
- (ii) Coal washing section.

These have been housed in two separate dustproof rooms. There are provisions for proper ventilation and lighting, both natural and artificial. The rooms have been provided with glass windows so that the operator gets a clear view of all the units under operation.

The control panel of each section has been designed to indicate with light diagrams the pattern the flow of the materials as well as the operating conditions of the different components. There are provisions for alarm signals which are operated before a machine is started or stopped.

#### (8) Building etc.

The washery has been housed inside two principal steel framed sheds covered on top and partly on the side with corrugated asbestos sheets. All outside conveyors and bins for different washed products have also been likewise covered.

The total cost for the supply and installation of the plant and putting it into operation is nearly 21 lakhs of rupees and the surface area covered by the entire plant is about 10,000 sq.ft.

B. Semi pilot Coal Washing Plants and Small Coal Washers at the Central Fuel Research Institute

Besides the 40 t.p.h. composite coal washing pilot plant at the Central Fuel Research Institute, a number of small scale washing units (semi pilot plants) have been installed from time to time during the last eight years. These units have mostly been designed, fabricated and installed by the staff of the Central Fuel Research Institute. The units are briefly described as follows:-

1) 20" Heavy Medium Cone-Separator: This was the first unit to be set up at the Central Fuel Research Institute. This test unit was installed with a view to finding out the possibilities of recovering coking fractions from Indian coals by washing and for studying coking properties of the washed fractions. It has been used for the bulk supply of washed coal to the 400 lb. Swoboda test coke oven for coking tests.

The plant is essentially an inverted cone having 20" base diameter and 40° cone angle provided with a stirrer rotating at a speed of about 13 r.p.m. The cone is filled up with the heavy medium made up of a suspension of either baryte or magnetite in water which is recirculated inside the cone by means of airlift arrangement to prevent settling. 1" to 1/8" coal is fed to the cone from a hopper provided with an oscillating feeder. The floats are carried over a weir in the cone by the circulating medium on to a divided vibrating screen. The impurities sink to the bottom of the cone wherefrom they are filled up by means of an air lift on to the other side of the divided screen. The floats and sinks are retained on the screen while the heavy medium passes through the screen and is collected in a hopper. From the hopper the heavy medium is delivered back to the cone by means of airlift for re-use. The products are finally rinsed in the latter part of the screen with spray water to remove all traces of the heavy medium. The diluted medium is thickened to proper consistency and re-used. The capacity of the plant is 400 lb/hr. A magnetic separator is incorporated in the circuit to clean the heavy medium when it gets highly contaminated with coal dust or clay slime.

2) Cyclone Washer: In view of the inferior cleaning characteristics of a major portion of future reserves of our coking coals ( particularly the lower seam coals of Jharia field and Bermo seam coal of Bokaro field), it will be necessary to crush these coals at least 1/4" or 1/8" for recovering reasonable yields of clean coal. In this size range, conventional washers fail to affect any efficient separation. Special attention has therefore to be paid to cyclone washing techniques, developed recently at the Dutch State mines as it holds much promise for the efficient cleaning of fine coal.



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A 6" dia. cyclone washer of 2 tons per hour capacity has been designed, fabricated and installed. Small coal ( $\frac{1}{2}$ " -36 mesh or  $\frac{1}{8}$ " -36 mesh) and the heavy medium suspensions are mixed in a pulp tank in the ratio of 1:6 by weight and delivered into the cyclone tangentially at a pressure of about 10 p.s.i.g. ( $0.7 \text{ Kg/cm}^2$ ) by means of a rubber lined pump. The underflow and the overflow from the cyclone containing the sinks and the cleans are delivered on to a partitioned vibrating screen. In the first part of the screen the coal is demediumised and in the later part the coal is rinsed with water to remove the adhering medium. The undiluted medium is returned to the feed tank while the diluted medium is thickened, cleaned and then returned to the feed tank after adjusting the consistency. In another set up the circulating pump has been replaced by an overhead tank and the cyclone is operated, inclined at  $20^\circ$  to the vertical. Results have shown that in this way good results can be obtained.

3) Drum Washer: A drum washer of 2 tons/hr. capacity has been designed, fabricated and installed to test coals of size  $2'' - \frac{1}{4}''$ . Its principles and operations are the same as those of the drum washer incorporated in the coarse coal washing pilot plant. It is provided with an automatic density controller which controls the specific gravity of the bath. Over the above the routine tests the drum washer is utilised to produce washed coal samples in bulk for carbonisation tests in the H.T.C. Plant at the Central Fuel Research Institute and to prepare low ash clean coal required for carbide manufacture etc.

4) Flotation Cells: In addition to the laboratory flotation cell of the Denver Sub 'A' type (2000 gm. capacity) installed at the Central Fuel Research Institute, to study the recovery of coking fractions from fine coals ( x 36 mesh) and slurries by flotation technique, a flotation cell of bigger capacity has been recently installed. This has been supplied by the Automatic Coal Cleaning Co.Ltd., Carlisle. In this cell there is no vertical shaft and hence collection of froth from the entire surface is possible. The cell is essentially a rectangular tank provided with two opposed propellers fitted in a submerged horizontal shaft to produce adequate agitation and aeration. At the top of the tank there is a rotating scraper to remove the froth. The cell is of a continuous type and is provided with automatic arrangement for removal of concentrates and tailings. The capacity of the unit is about 200 cwt. of dry coal per hour.

Besides the above coal washing pilot and semi pilot plants installed at the Central Fuel Research Institute tenders have been invited for a composite fine coal washing pilot plant incorporating a heavy medium small coal washer, a small coal jig washer and flotation cells and it is expected that the plant will go into operation within the next two years.

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The plant will be located by the side of the existing coarse coal washing pilot plant and will have an average capacity of 7 tons per hour. It will be necessary to use some sections of the coarse coal washing pilot plant for the operation of the fine coal washer. Receiving of r.o.m. coal and subsequent crushing it to below 3" size, will be transferred to the ground storage bunker of the fine coal plant. Various products and fractions from coarse coal plant will also be taken to the fine coal plant for necessary treatment.

The fine coal plant will be a test unit and it will separately treat coal of widely varying characteristics. Therefore, the plant has to possess adequate operational flexibility. There will be simultaneous operation of the heavy medium washer or the fine coal jig with the flotation unit if necessary.

Coals required to be treated in the fine coal washing plant will be of the following sizes:

- i) R.O.M. coals crushed to below  $\frac{1}{2}$ ",  $\frac{1}{4}$ " or  $\frac{1}{8}$ ".
- ii) Screened fines (below  $\frac{1}{2}$ ") of R.O.M. coal crushed to below 3".
- iii) Middlings and rejects from the coarse coal washing plant and other outside commercial plants crushed to  $\frac{1}{2}$ ",  $\frac{1}{4}$ " or  $\frac{1}{8}$ ".
- iv) Slurries and effluents (normally below 36 mesh) from the coarse coal plant or other washeries.

The heavy medium washer will treat coal of sizes  $\frac{1}{2}$ " -36 mesh,  $\frac{1}{4}$ " -36 mesh or  $\frac{1}{8}$ " -36 mesh. At times it may be required to extend the bottom size to 52 mesh. There will be provisions for incorporating in future a cyclone washer in the heavy medium circuit. For this purpose depulping and rinsing screen provided for the heavy medium washer, will also be used for the cyclone washer, when installed.

The fine coal jig will usually treat coal of size  $\frac{1}{2}$ " -0. It may be required to remove the slimes from the feed to the Jig Washery by prior Screening. The washer will have 6 cells and 2 compartments and will be provided with rotary air valves of adjustable frequency and fitted with automatic reflux discharge mechanism. The flotation unit will have 10 cells, with provisions for retreatment of concentrates and tailings in series. The concentrates and the tailings will be dewatered by a single drum filter in turn. In addition, this unit will also dewater untreated slimes below 36 mesh.

The crusher (intended to crush 3"-0 coal to smaller sizes) will be so adjustable that any product below  $\frac{1}{2}$ ",  $\frac{1}{4}$ " or  $\frac{1}{8}$ " size can be obtained.

A centrifuge will dewater cleans from the heavy medium washer and the jig washer. The feed to the centrifuge will be of  $\frac{1}{2}$ "-0,  $\frac{1}{4}$ "-0 or  $\frac{1}{8}$ "-0 size.

The cost of the plant is estimated to be about 11 lakhs of rupees.