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Slurry Transportation in a Coal Preparation Plant

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ABSTRACT

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INTRODUCTION TO COAL PREPARATION

Coal preparation is both a science and an art, it deals with taking raw coal and producing a salable product that meets contract specifications by removing the impurities. Coal preparation, as commonly practiced today, is carried out in water based processes, and makes heavy use of slurry transport principles and procedures.

Coal preparation is regarded as the processing of raw coal to yield marketable products and waste (refuse) by means that do not destroy the physical and chemical identity of the coal. Coal is a very heterogeneous material made up of different coal types and varying amounts of mineral matter. As mined it normally contains all the layers of coal and impurities found in the seam, plus portions of the strata above and below the coal seam. The preparation plant sizes, crushes and removes impurities so that the coal may be shipped as a saleable product.

There are four basic types of operations used in cleaning the coal, to these may be added a number of auxiliary operations which are not directly involved in the coal cleaning. The four basic operations are comminution, sizing, concentration, and dewatering.

Comminution means reduction to a smaller size. Depending on the sizes involved, the coal is either crushed, broken, or ground. Breaking is commonly used on the largest sizes, crushing on the mid-range sizes, and grinding is used on the very finest sizes. Grinding or pulverizing is normally done just prior to utilization. There are no hard and fast rules as to what these size ranges are, adjacent coal preparation facilities may have different size ranges for similar coals.

Sizing is the separation of coal into products characterized by difference in size. This can be accomplished by screening or by classifying, the latter being a sizing method dependent upon the relationship existing between the size of coal particles and their settling velocity in a fluid medium, generally water.

Concentration is the separation of coal into products characterized by some physical difference such as specific gravity. Concentration is the heart of coal preparation where the actual cleaning occurs and the refuse is separated from the coal. It is normally accomplished in jigs, heavy media vessels, on tables, in heavy media cyclones, water-only cyclones, flotation cells, or other specific concentrating devices. It also can be accomplished during other unit operations, such as sulfur removal by crushing to liberate the sulfur particles (commonly pyrite) and then screening or classifying to achieve separation (pyrite being normally smaller and heavier than coal).

Dewatering is the removal of surface moisture that clings to the coal's surface area. The finer the coal, the greater the surface area and surface moisture. Dewatering by mechanical means is generally conducted only to the extent of producing a damp cake. If further de-

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produce a large amount of dust that must be scrubbed from the air and then disposed. A common by-product of dewatering is the removal of super fine coal which is inherently high in ash, sulfur, and surface moisture; this is referred to as desliming.

Auxiliary operations are by nature quite diverse. They involve storing (in bins, silos, or open piles), material transport (by conveyors, feeders, elevators, or pumps), sampling, weighing, chemical reagent feeding, feed distribution and such other operations needed to move or control the coal from one cleaning operation to another.

In this presentation, a certain amount of technical jargon is unavoidable. A brief definition of some of the terms employed is listed below.

The terms preparation or cleaning are used interchangeably in referring to the processing of the raw or "run-of-mine" (ROM) coal. The "feed" to a cleaning plant or equipment is the material received for processing. The products are the concentrate and the tails (a final tailings is called "refuse" if dry, and "slurry" if wet and pumpable). If more than two products are made, the other is called a "middlings". To process the coal in a piece of equipment it is necessary to have the coal moving through the machine. The depth of the coal moving is referred to as the thickness of the "bed". In some processes (notably breaking or screening), the process efficiency can be increased by removing the material which is smaller ("minus") the product size. This is called "scalping" and on large sizes, is done with a large opening screen ("grizzly"). The clean product is referred to as "clean coal" or "washed coal" interchangeably. Material going over or out the top of a machine is called the "overflow". Similar material coming out the bottom of a machine is called the "underflow".

PHYSICAL COAL CHARACTERISTICS AND THEIR RELATION TO PREPARATION

The major characteristics of the raw coal that are important in coal preparation are surface moisture, specific gravity, structure and breakage, size composition, hardness, friability, abrasiveness, and corrosiveness.

Fresh coal at a dry place in a mine is normally saturated with moisture even though it appears dry and dusty when crushed. The percentage of moisture present, commonly called 'bed moisture', is more or less constant throughout a given mine and is a characteristic of rank. Such moisture ranges from one, two or three percent in bituminous coal to 45 percent in lignite.

All of the coal cleaning methods in general use are methods of gravity concentration with the exception of froth flotation. Consequently, the specific gravities of the impurities associated with coal have primary importance. Other factors being equal, the dense impurities can be removed in the cleaning operation more easily than the lighter impurities, which approach in density the coal from which they are to be separated.

Coal tends to be very regular in shape, generally being cubical. This shape holds for the largest block that is mined, down to the microscopic particles. To a considerable extent, the sizes and shapes into which the coal naturally breaks are determined by the major system of vertical cleavage planes and by a more or less uniform network of planes of weakness.

The physical structure and strength and the methods of mining and handling during processing define the size composition of the run-of-mine coal. This size composition relates directly to processing, in that certain operations are more or less efficient on various size ranges.

Friability or size stability, hardness, and grindability of the coal are all measures of the ease with which coal may be reduced in size, either intentionally or unintentionally. Compared to other minerals, coal is relatively soft and can be easily reduced in size. This ease of size reduction is an important factor, in that while the particles are reduced in size, they generally do not round off but rather form fresh surfaces and edges. This form of fresh edges in size reduction causes coal to be highly abrasive and is a major cause of maintenance problems.

Due to the inclusions of many different minerals in the coal, especially sulfur, coal in contact with water generally causes a significant corrosion problem.

These characteristics are all interrelated when selecting the coal preparation process for any specific coal.

The selection of the processing flowsheet is probably the single most important step in the plant design process. Design of physical structure, placement of equipment, etc., will stem from the flowsheet and be influenced by the flow selected. The question "What are we trying to accomplish?" must be continually asked, and each answer scrutinized to make sure that basic purposes are not being lost in the enthusiasm of the designing.

Prior to selecting the flowsheet, the following questions must be asked in determining the basic purpose of the plant:

(1) What characteristics of the raw coal make it necessary to install preparation facilities? Why?
(2) What sizes of raw coal must be upgraded?
(3) To what degree must the percentage of ash and sulfur be reduced to insure a saleable product?
(4) Will further reduction of ash and/or sulfur improve saleability? Realization?
(5) What limit must be placed on preparation cost per clean ton due to reject losses, operations, maintenance and depreciation?

Coal preparation processes fall into two general types: (1) those conducted in water-only medium, and (2) those conducted in a mixture of water and a high gravity material such as magnetite (heavy media systems). The general guidelines for selecting the applicable process is based on the sink-float data for coal under question. Heavy media is normally used when the separating gravity is 1.50 or below, or if there is more than 10% near gravity material. Water only processes are normally used when the separating gravity is above 1.60 and there is less than 10% near gravity material. The best way to illustrate this is with an example. Table 1 is the sink-float analysis for a fairly typical eastern bituminous coal. From this data the flowsheet shown in figure 1 was developed.

Table 1: Typical Float-Sink Analysis for Plant Design

Specific Gravity	Direct			Cumulative Float			Cumulative Sink		
	Wt %	Ash %	S %	Wt %	Ash %	S %	Wt %	Ash %	S %
Float 1.3	41.74	5.56	4.10	41.74	5.56	4.10	100.00	21.03	4.85
1.3 x 1.6	37.28	15.03	4.95	79.02	10.03	4.50	58.26	32.12	5.38
1.6 x 1.9	2.98	46.44	6.58	82.00	11.35	4.58	20.98	62.48	6.15
1.9 Sink	18.00	65.13	6.08	100.00	21.03	4.85	18.00	65.13	6.08

The basis of design for this flowsheet was to process 400 short tons per hour of 1-1/2" x 0 raw coal as shown in table 1.

Process Description

Raw Coal. Four hundred TPH of 1-1/2" x 0 raw coal from the preparation plant feed conveyor will be directed by the discharge chute to the desliming sieve bends and screens.

Heavy Media Cyclone Cleaning. Desliming sieve bends and screens will separate at 28 mesh. The oversize fraction will flow by gravity to the heavy media sump, to be combined with the media and then pumped to the heavy media cyclones where separation of clean coal and refuse products will take place. The major quantity of media used in the process will be drained by sieve bends and screens for both clean coal and refuse, and will return directly to the heavy media sump. The remaining media adhering to the coal and refuse products will be rinsed on the rinse section of the screens and will be treated as dilute media. The product from the clean coal drain and rinse screen will be dewatered in mechanical centrifuges. Refuse material will only be screened and conveyed to a refuse bin.

Media Recovery System. The dilute media will be treated in double-drum magnetic separators. The magnetite concentrate from the separators will be returned to the heavy media circuit. The tailings from the magnetic separators will go to the desliming sieve bends.

Magnetite makeup will be fed on demand from the magnetite storage bin into the heavy media sump.

Water-Only Cyclone Cleaning. The desliming underproduct, consisting of minus 28 mesh material, will be pumped to the water-only cyclones. The overflow of the water-only cyclones will be fed to rapped sieve bends, which will deslime the clean coal products. The plus 100 mesh coal product will be fed to the Bird screen bowl centrifuges. The effluent of the rapped sieve bend, which will consist of the minus 100 mesh fraction of the coal will be fed to the froth flotation circuit. Water-only cyclone underflow will flow by gravity to the flotation circuit to recover any misplaced coal.

Flotation Cells Product Dewatering. The flotation circuit will process the undersize of the rapped sieve bend, which consists of the minus 100 mesh size fraction and the water-only cyclone underflow.

The float product, together with the 28 mesh x 100 mesh water-only cyclone product from the rapped sieve bend, will be fed to the Bird screen bowl centrifuges. The Bird centrifuge screen effluent will be returned to the water-only cyclone feed. The bowl effluent will be combined with the flotation cell tails and flow to the refuse thickener.

Refuse Thickener. A refuse thickener will be provided to remove most of the fine solids in the process water. Sources of water to the refuse thickener are:

- o tailings from the flotation cells, and
- o effluent from the solid bowl centrifuges

Thickener overflow will be pumped back into the plant as spray water and makeup water. A thickener underflow pump will be provided to pump the slurry to settling ponds.

SLURRY TRANSPORT IN A COAL PREPARATION PLANT

Like any process industry, coal preparation is a group of unit operations interconnected by a materials handling system. The materials handling system involves those dry process steps, such as the conveyor system and the slurry process steps which include the pumping system and the launderers. There are also process steps that are neither dry nor slurry; this last area is normally classed with the slurry handling system as it usually runs to wet rather than to dry. In a typical coal preparation plant most of material streams are slurry flow, except for the initial feed and the last three products (two clean coal and one dry refuse) which are dry flow.

Slurry is either piped (motivating force by pump or gravity) or flumed and laundered. Even in those areas, such as sieve bend discharge, which are commonly chutes, the material is a very thick slurry. Principles of slurry transportation are very important to the coal plant operator, even if he is unacquainted with the proper terminology or the underlying theory.

Coal plant operators' problems with slurry transport system fall into five basic and interrelated categories: accessability, maintainability, availability, corrosion, and abrasion. The first three categories are related to plant design and the problems normally can be resolved through the use of good engineering practices. The last two categories (corrosion and abrasion) relate to the characteristics of the coal and how they effect the plant operation.

While coal is relatively soft as minerals go ($\sim$ 50 on the Hardgrove grindability scale), it still can give operators problems in their slurry systems. Problems arise from several factors, one being that while coal is soft, it is also very friable and tends to break into fresh surfaces instead of becoming rounded.

Because the coal particles break and do not round, this means that the final processing steps are as subject to wear or abrasion as the first steps. Actually they are subject to higher wear due to the increase in the number of particles handled. An example of this would be that the fine coal discharge chutes need the same amount of wear protection as the fine coal underflow pans at the raw coal screens. The fine coal discharge chute from the basket centrifuge is usually lined with polished stainless steel because the product is relatively dry (18% by weight surface moisture), while the raw coal screen underflow pan is lined with cementitious liner because the product is in a true slurry form (10% by weight solids).

Abrasion appears in the preparation plants as equipment, chute and pipe wear. Depending on flow conditions, some items have been known to wear out in less than 500 hours. A coal preparation plant in Illinois was changing baskets on a fine coal centrifuge processing 28 mesh x 0 coal every 80 to 100 hours. The same plant was getting 1500 - 2000 hours on pumps before having to replace the casing and the impeller. Chute liners and pipe, in high wear areas, were lasting about 1000 hours.

There was no way to minimize the wear on the centrifuge basket, but through the proper design of the installation, the downtime required to change the basket was minimized. This was accomplished by allowing plenty of work area around the centrifuge and placing a lift beam over the centrifuge. Feed chutes to the centrifuge were thereby easily removed.

The high wear pumps were operating at 1170 RPM. By replacing these pumps with low speed (800 RPM) hard iron pumps, the operating life was tripled to 6000 + hours.

The chute and pipe wear problem was lessened by using ultra high molecular weight polyethylene where ever possible, i.e., in non-impact areas. Areas subject to impact were fixed with easily removable or bolt-on liners. A side note of interest was that A.R. special alloy plate was only lasting about 100 hours longer than mild steel plate. The large cost difference strongly favored replaceable mild steel.

Another factor is the mineral content of the coal which can be leached into the water used for processing and eventually cause corrosion problems.

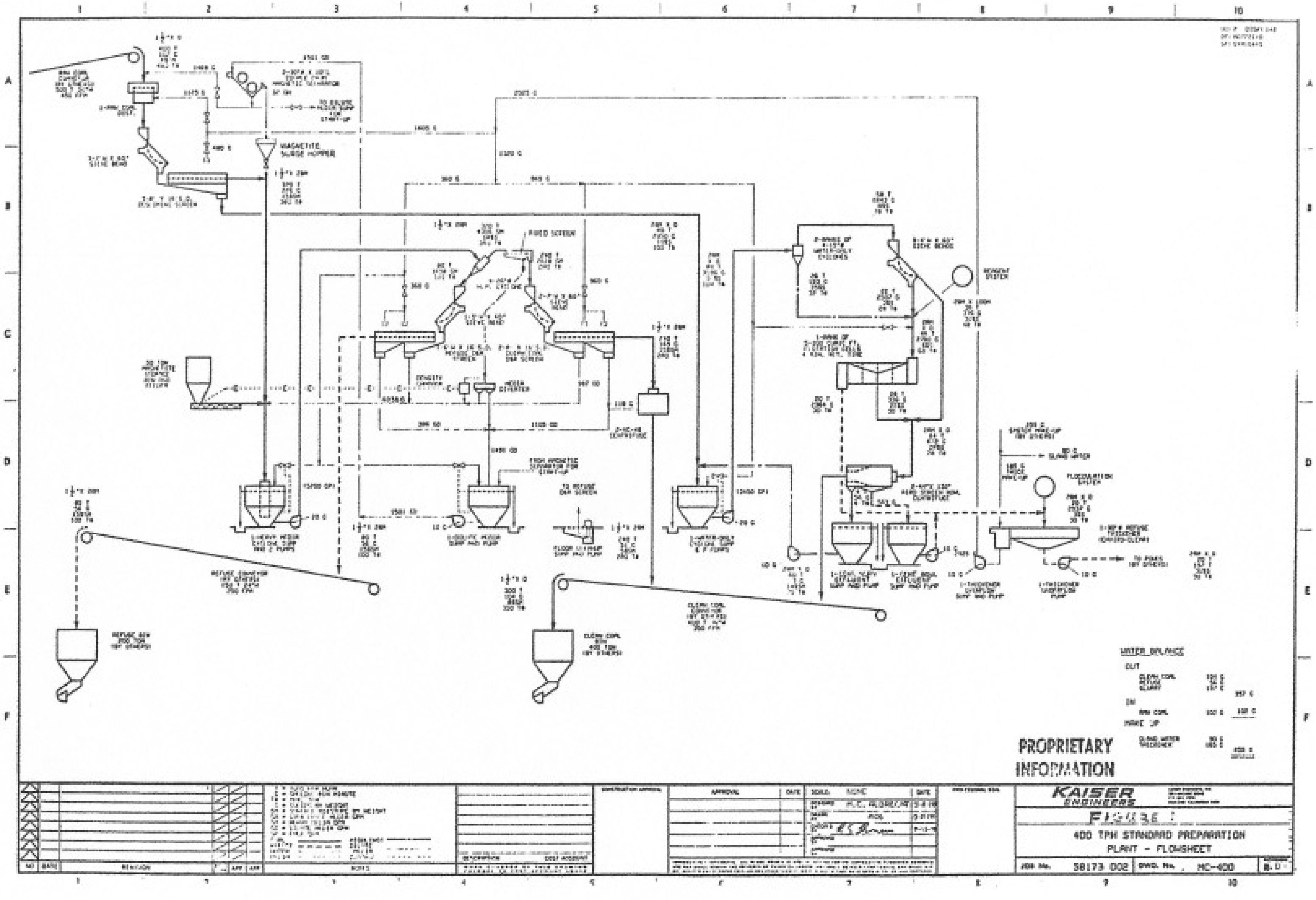
Corrosion in a preparation plant occurs only on the nonwearing surfaces, as the wearing surfaces do not last very long. Historically, the primary source of corrosion has been from the leaching of sulfur to form sulfuric acid, or "Coal Mine Drainage" water; the typical reddish runoff from old coal wash piles.

The best cure for corrosion is a good paint job. This is more difficult than it sounds, as most equipment manufacturers and plant erectors do not follow steel structure painting council specifications. Strict adherence to SSPC standards, would solve a lot of problems. A fairly new corrosion related problem had begun to appear in the coal industry and this is a buildup of ions in the processing water. This buildup has been occurring as more plants are closing their water circuits and only adding sufficient water for makeup product losses. Some very exotic, to the coal industry, solutions to this problem have been suggested. Inasmuch as this problem is fairly new, the best method of handling the problem is probably not developed yet.

Some slurry transport problems faced by the coal preparation plant operator are directly related to the plant design. These problems include pumps located in out-of-the-way parts of the plant, pipe runs that look like a plate of spaghetti, and angled elbows and joints. Coal preparation plants have tended to be the type of operation, where the maximum amount of equipment is shoe horned into the minimum space and then all the pipe is "field fit". The operator is usually using the cheapest capital cost equipment, without any thought as to how much the equipment will cost to maintain.

As the cost of coal is rapidly increasing, coal operators are now beginning to look at the overall cost of operating the plant. This change is the opening needed to push for the best possible slurry transport system inside the plant. It can truly be said that the coal operator is coming out of the dark ages when the engineering of his slurry system is considered. The coal operator is highly resistive to change, and a strong argument must be used to sell him any new idea.

This resistance to change, commonly referred to as the "Gran-daddy" approach (e.g., "that's the way my gran-daddy did it, that's the way my daddy did it, and that's the way I'm going to do it"), makes it tough going for the man with a new idea to sell the idea to the coal industry. Add this to the fact that the coal industry has traditionally been a low dollar per unit volume industry, the people in the decision making position of most coal companies are still unwilling to spend money for maintenance improvement item.


MAGNETITE SURGE HOPPER
FIXED SCREEN
MEDIA DIVERTER
WATER BALANCE
OUT
IN
MAKE UP
PROPRIETARY INFORMATION
KAISER ENGINEERS
FIGURE 1
400 TPH STANDARD PREPARATION PLANT - FLOWSHEET
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MC-400