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Research and Development

An Engineering/ Economic Analysis of Coal Preparation Plant Operation and Cost

Interagency Energy/Environment R&D Program Report

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EPA-600/7-78-124
July 1978

AN ENGINEERING/ECONOMIC ANALYSIS OF COAL PREPARATION PLANT OPERATION AND COST

UNITED STATES DEPARTMENT OF ENERGY
SOLID FUELS MINING AND PREPARATION DIVISION
WASHINGTON, D.C. 20241

Contract Number ET-75-C-01-9025

OFFICE OF ENERGY, MINERALS, AND INDUSTRY
OFFICE OF RESEARCH AND DEVELOPMENT
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

PREFACE

The following report presents the results of a study conducted by the Hoffman-Muntner Corporation of Silver Spring, Maryland, for the United States Department of Energy under Contract Number ET-75-C-01-9025. This effort, funded through the Federal Interagency Energy/Environment Research and Development Program, was performed under the technical direction of Mr. W. E. Warnke of the U. S. Department of Energy, Solid Fuels Mining and Preparation Divison. The purpose of this study was to identify the costs associated with the various types and levels of physical coal preparation processes currently available. Although data of this type have been previously generated in fragmented form, it was the objective of this study to give a comprehensive presentation having a uniform time base. A methodology was developed that permits meaningful comparison of the relative costs of coal cleaning. This technique was applied to current technology and economics, but can also be utilized in the future with appropriate index adjustment.

To accomplish this objective, eight existing coal preparation plants were selected for anaylsis. These plants range in complexity from a relatively simple jig plant to a rather sophisticated preparation circuit utilizing heavy media, froth flotation, and thermal drying. Each of these plants is discussed separately with an analysis of the individual process and the level of cleaning achieved as supported by the specific washability data. Additionally, the major cost components such as capital, labor, and materials are summarized to arrive at the total cost of cleaning for each plant. These analyses are presented from the perspective of the preparation plant operator and do not assess the many user oriented benefits resulting from coal cleaning. In addition to increased heat content, these benefits include lower emission control, transportation, boiler maintenance, and ash disposal costs.

For background, general discussions are provided covering the various types of coal cleaning processes. These discussions include brief descriptions of the processes and associated equipment with cost data detailing their impacts on the total cost of preparation.

ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to those many dedicated individuals in the coal industry who took the time out from their busy schedules to make available the current preparation plant operating data, a portion of which is summarized in Section 5.0. Without their patience and understanding, this study could never have been accomplished. Further, the author wishes to extend many thanks to those knowledgeable members of the preparation equipment manufacturing community who were so very cooperative in providing the price and technical data included throughout this report. Finally, the author wishes to convey a special expression of appreciation to Messrs. W. E. Warnke, A. W. Deurbrouck, and R. E. Hucko of the Department of Energy, Solid Fuels Mining and Preparation Divison, for their valuable counsel and constructive suggestions during the course of the program. It was indeed an honor and privilege to work on an important study of this type with so many capable personnel, too numerous to mention.

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SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

Unlike the manufacture of certain chemicals and metals where a specific process will give reasonably constant results, there is no universal approach to the production of clean coal by physical preparation techniques. This occurs due to the substantial variability in the physical and chemical composition of coal from seam to seam and even within the seam itself. Therefore, a given preparation process that is effective with a coal from one seam may be inappropriate with a coal from another seam in achieving a comparable level of cleaning. For this reason, the particular approach taken to coal cleaning must be designed around the specific coal and the desired end results within the economic constraints of the situation.

Although there is a myriad of approaches to coal cleaning, the technology is founded on relatively few basic physical principles. Nearly all physical cleaning techniques being applied today rely either upon specific gravity or surface characteristics to effect a separation of the coal from the undesirable constituents such as ash and pyritic sulfur. Most of the specific gravity processes and all of those relying upon surface characteristics are wet in nature. For those wet processes based upon specific gravity, the medium of separation is water either by itself or mixed with a substance such as magnetite to give the mixture a density slightly greater than that of coal. These processes are performed in a variety of vessels and other devices described in Section 2.0 of this study. The major process based upon surface characteristics (or surface chemistry) is froth flotation. As covered in more detail by Section 2.2.7, this process creates a condition which encourages the coal to adhere to air bubbles and float and the refuse to sink. In a coal preparation plant, these physical separation techniques are applied by themselves or in combination to most economically achieve a desirable end product given the physical and chemical composition of the raw coal.

To determine the physical and chemical properties of the raw coal around which the preparation process is designed, it is necessary to obtain a representative sample. The importance of this sample cannot be overemphasized since it constitutes the root of flow sheet (process) design and thus equipment selection. A screen analysis is normally made of this sample showing the size consist of the future plant feed. This has particular significance by showing the amount of finer material in the feed which is a critical factor in selecting the cleaning approach and sizing the equipment. Further, a washability study (float and sink analysis) is made of these size fractions to show the separation of coal from the undesirable constituents (ash and sulfur) at various specific gravities. The combination of this data permits the preparation plant designer to focus on the critical points of separation and thereby determine the approach best suited to achieve the desired results. In many situations, the process objective is to maximize the reduction of ash forming constituents. However, in light of today's increasing environmental restrictions, the optimization of sulfur removal as well as ash is of prime importance.

Many times the material on which this detailed analysis is performed is obtained from core samples which are seldom representative of the raw coal as mined. This occurs because an insufficient number of samples are collected and the mining method directly influences the amount of refuse and fines in the mined product. Unfortunately, this situation can be very costly and necessitate substantial plant redesign in order to approximate the projected plant performance. For this reason, more extensive sampling should be conducted and performed in a manner which closely simulates the effects of the particular recovery (mining) technique.

Since there is by necessity such a variety of approaches to the physical preparation of coal, there is no single figure for the "cost of coal cleaning." Our studies have shown there is a range of costs from less than \$2.00 to over \$4.00 per ton of raw plant feed depending upon the capacity and make-up of the preparation circuit. Each cost within this range is a composite of the capital and operating and maintenance costs associated with a specific plant during a given time frame. Time is a factor due to the inherent variability within any given coal seam as previously mentioned. Although two preparation plants may have an identical input capacity and essentially the same equipment, their individual "cost of cleaning" will more than likely be different for a variety of reasons. Assuming consistent accounting methods, these reasons include differences in: 1) raw coal feed; 2) operating procedures; 3) clean coal specification; and 4) local cost of labor, material, and services. Many times these differences can be significant due to more or less advantageous conditions for refuse disposal. In spite of the specificity of coal cleaning costs, meaningful generalizations can be made concerning the cost of various processes. At the lower end of the above range (\$2.00 to \$4.00 per ton input), would be an intermediate size plant screening out the finer material and cleaning only the coarser size fractions with inexpensive equipment such as the Baum jig. The upper end of the range, approaching $4.00 per ton input, would be representative of a plant cleaning all size fractions with thorough treatment of the finer material by such equipment as heavy media cyclones and froth flotation in addition to fairly extensive thermal drying.

It should be noted that this range of cleaning costs is that experienced by the coal preparation plant operators. However, this is only a portion of the economic equation for coal cleaning. In order to determine the true (net) cost of preparation from an overall economic perspective one must also account for the benefits accruing to the user of clean coal. These benefits which should appropriately be set off against the operator's cost include:

1. Increased Heat Content of Cleaned Coal
   (Greater Btu content per unit weight)
2. Transportation Savings
   (Less weight to ship for same Btu content)
3. Pulverizing Cost Savings
   (Less cleaned coal needs to be pulverized for same Btu content required to meet output)
4. Boiler and Related Equipment Maintenance Savings
   (Clean coal is less corrosive)
5. Ash Disposal Cost Saving
   (Clean coal leaves less bottom and fly ash)

6. Lower Emission Control Costs

(Less particulate and SO_2 from clean coal)

This being the case, the complete equation for coal preparation is:

Net Cost of Cleaning = Operator's Cost - User Benefits

Since these user benefits can only be accurately quantified on a site specific basis, they are not considered by this study. Only the range of operator's cost will be addressed.

It is the primary purpose of this study to give better definition to this wide range of costs. This is accomplished by looking at a spectrum of actual preparation plants and examining the major elements in their particular cost of cleaning. These eight plants presented in Section 5.0 range from a relatively simple jig plant to a variety of fairly complex preparation circuits utilizing a number of heavy media techniques, froth flotation, and thermal drying. In each case, a discussion is given of the plant performance and cost which identifies for the reader those factors in the design of the plant and/or the manner in which it is being operated which are most influential on cost. Using the cost relationships from these actual preparation plant examples as a base and one's own washability data, the capital and operating and maintenance (O&M) cost of almost any contemporary cleaning process can be estimated with reasonable accuracy. Understandably, the cost developed in this manner for any given process handling a particular coal would only be an approximation of what might be experienced. However, it should be a useful planning tool for the would-be preparation plant operator to anticipate capital requirements and O&M costs. Such information permits an assessment of market conditions in relationship to the minimum price for which the clean coal could be sold to yield a certain rate of return or otherwise satisfy one's economic criteria for investment.

In the following section, a brief discussion is presented of each major element within the preparation plant complex and, as appropriate, how it generally impacts the capital requirements and O&M cost. This discussion is also intended to give the reader some broad exposure to the technical aspects of coal preparation which should aid in understanding the sensitivity of cleaning cost to approach and operational variances.

SECTION 2.0

PREPARATION PLANT COMPLEX

2.0 PREPARATION PLANT COMPLEX

As addressed by this study, the coal preparation complex consists of the cleaning plant and any outside facilities and equipment associated with the cleaning process. These additional items include the raw and clean coal storage areas, water clarification facilities (ponds or thickeners), conveyors, coal and refuse vehicles, sampling system, load-out facility, and thermal drying if applicable. A typical preparation complex is arranged as shown in Figure 2-1 below.

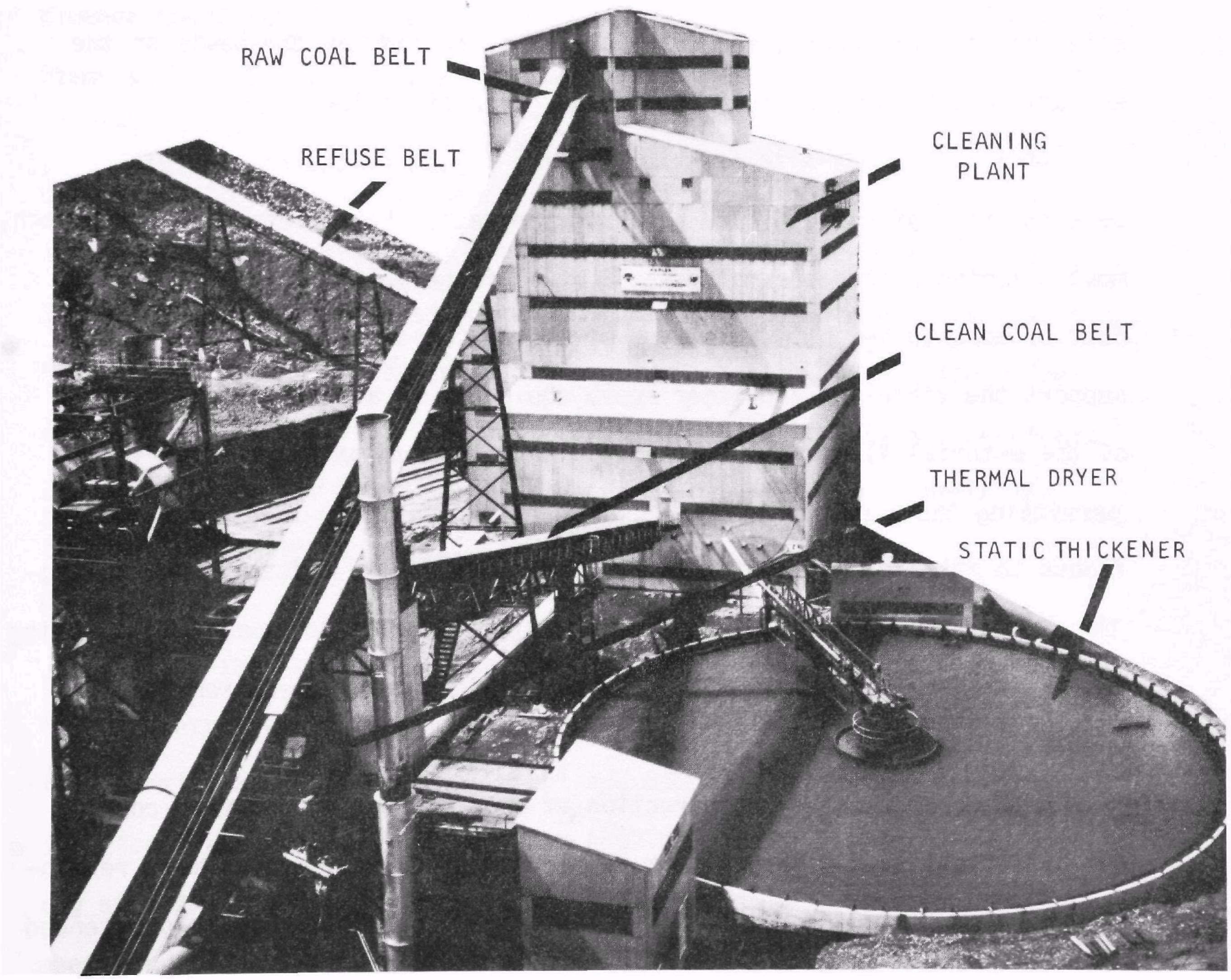


FIGURE 2-1

TYPICAL COAL PREPARATION COMPLEX

Layout -

Normally, it is desirable to locate the preparation complex as close as possible to both the mining activity and transportation. This eliminates much of the initial expense and long term maintenance of long distance conveying, trucking, or other means of getting the coal to the plant and then to a suitable location for final transport to market. However, this is not always possible due to the unavailability of sufficient land area, required services, or unsuitable topography. Therefore, the final selection of the preparation plant site must be made on the basis of the economic and practical realities of the given situation.

Once a suitable site is selected, the layout of the complex will be a function of capacity and cleaning approach. Regardless of the approach, most cleaning plants are multi-level steel frame buildings reaching 100 feet or more in height. This type of sturdy construction is necessary to support the vibrating and other heavy equipment in addition to the weight of the material flow. Some cleaning plants have as many as twelve levels permitting the preparation equipment to be sequentially located on various floors to make the most efficient use of gravity. In addition to reducing the initial cost of the plant, this arrangement helps to lower the operating and maintenance cost by limiting the pumping and piping requirements.

Construction -

Although the actual construction of even a large preparation complex can be accomplished within a year, a minimum of three years is more reasonable in view of today's conditions. The major contributor to this extended period is the governmental requirement that an environmental impact statement (EIS) be filed and approved before a preparation plant can be built. Assuming there are no problems with filing the EIS, a minimum of 18 months is required for compliance. This period further assumes there are no law suits filed and all paperwork is processed by EPA in a timely fashion. Unfortunately, this situation presents a real problem to the organization behind the future plant in terms of arranging financing and making other commitments. While this lengthy process goes on, costs rise and previous plans need to be reevaluated. Another factor to be considered which can influence the construction period is the equipment lead-time. Many essential items such as belting have a delivery of one year or more.

It is not uncommon to arrange for construction of the entire coal preparation complex under one contract. Although the prime contractor is responsible for "delivering" the complex on a turn-key basis, many subcontractors are involved due to the diversity of specialities required. Prior to 1970 such contracts were almost always firm fixed price. However, since the early 1970's, most construction agreements are carefully worded to allow for cost escalation as a result of material price increases and sometimes labor.

Operation -

All of the larger cleaning plants being built today are operated from a central control room with the aid of sophisticated electronics. This permits a single cleaning plant operator to monitor the functioning of a facility handling 1500 tons per hour or more of raw coal. By looking at a single control panel of the type shown in Figure 2-2, the operator can tell whether or not each major piece of equipment within the plant is operating. Should a serious problem develop within the plant, all affected equipment is automatically shut down to avoid damage.

In addition to the plant operator, there are a number of other personnel required to operate and maintain a preparation complex. For more detail on the numbers and types of such personnel, the reader is referred to the specific plant examples presented in Section 5.0.

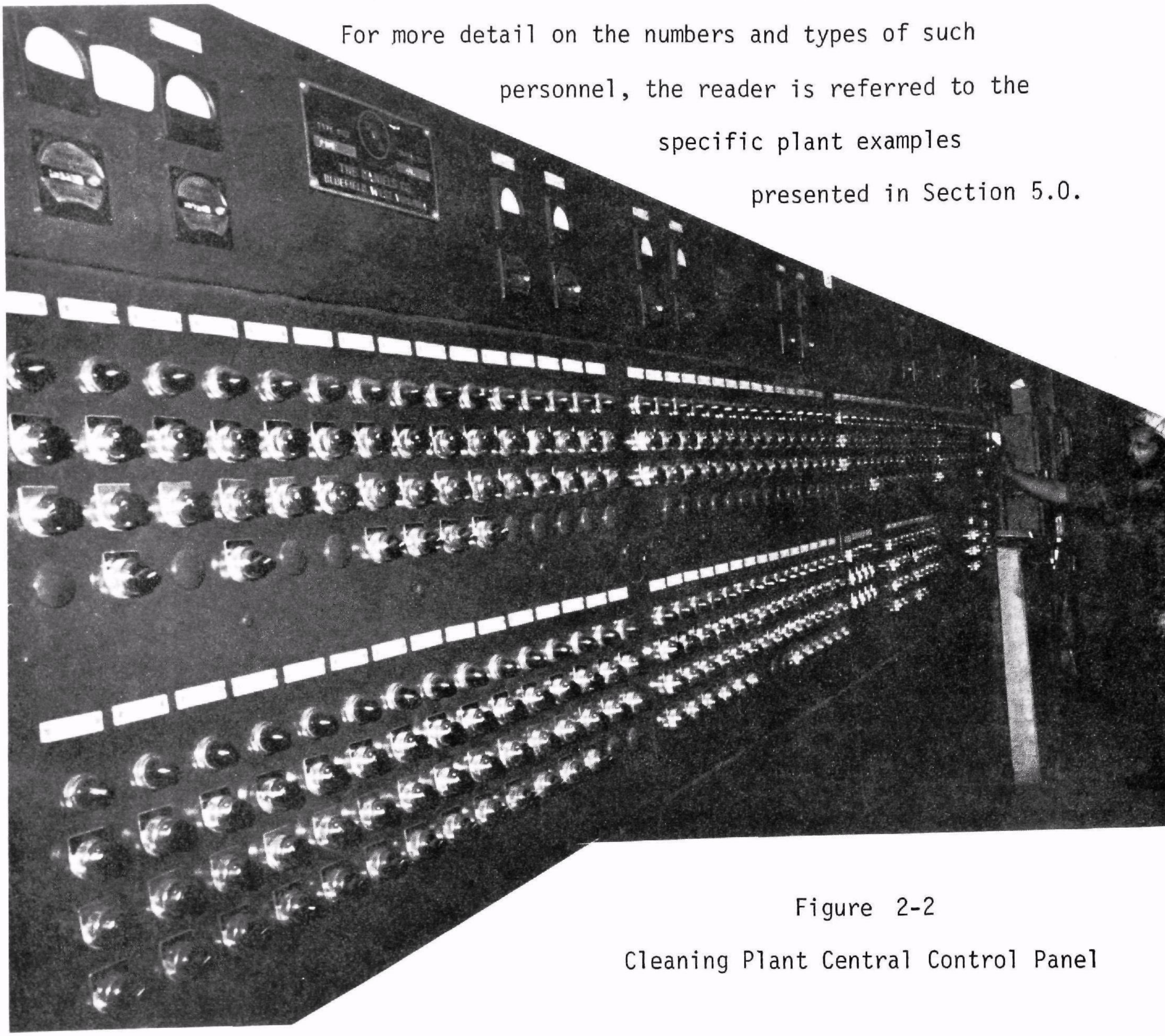


Figure 2-2
Cleaning Plant Central Control Panel

Cost -

As of mid-1977, the total capital cost for the larger coal preparation complexes examined by this study was in a range from around $7,000 to $23,000 per ton hour input. These eight plants had design input capacities from as much as 1600 tons per hour (tph) down to 600 tph. Although capital costs for plants in this range are somewhat sensitive to capacity, they are influenced most by the sophistication of the cleaning plant itself and the outside facilities such as thermal dryers. In this regard, some plants will have complete or partial redundancy of critical pieces of higher maintenance equipment. Such an arrangement permits servicing of these items without shutting down the entire plant. The additional capital cost of this arrangement can many times be justified on the basis of increased operating efficiency and output. An expansion of this theory is the implementation of complete parallel cleaning circuits which theoretically makes the plant capable of continuous operation at varying levels of production. Another factor which can have a significant impact upon the initial cost of a complex is the amount of site preparation required. The capital cost for each of the preparation plants examined by the study is presented in detail by Section 5.0 along with a discussion of which elements have the greatest cost impacts.

The balance of this section is devoted to a brief description of the major elements comprising the preparation plant complex. For ease of understanding, these have been separated into three categories, 1) Coal Handling and Storage; 2) Cleaning Equipment; and 3) Other Facilities. As appropriate, the influence of each major element upon the total cost of the preparation complex is given.

2.1 Coal Handling and Storage

Depending upon the layout of the particular preparation plant a significant portion of the total capital investment will be tied up in coal handling and storage equipment and facilities. As addressed by this study, this category of items includes:

1) Raw and Clean Coal Storage;
2) Conveyors Handling Coal & Refuse;
3) Removal of Tramp Iron; and
4) Clean Coal Loading Facilities.

Certainly, the cost of all of these items will vary with the magnitude of the plant. However, additionally their cost will be quite sensitive to geographic, environmental, and other factors based upon the site specific conditions. In the case of coal storage, closed or silo storage will cost about five times as much as an open pile of comparable capacity. Even though this is a severe cost penalty to pay for the advantages of closed storage, it might possibly be justified on economic grounds and/or necessary to meet local environmental restrictions. Conveyors are another major expense which vary mostly with the plant layout. However, other factors such as the need for secure enclosures or special foundations and supports can radically affect their costs. Loading facilities also vary significantly from plant to plant depending upon their level of sophistication. The following subsections describe these coal handling and storage facilities items in greater detail and some of the principal factors influencing their cost.

2.1.1 Coal Storage

The storage of the raw coal prior to entering the preparation plant as well as the clean product itself is a significant factor in the overall plant layout. At the raw coal end, adequate storage must be available to allow for fluctuations in the mining activities while maintaining a sufficient backlog of material to be efficiently fed to the preparation plant. Likewise, at the clean coal end, adequate storage arrangements must be made consistent with the operation of the plant and shipping commitments/schedules. Whether the clean coal is transported to the user via barge, unit train, or truck, the storage arrangement must provide for the efficient withdrawal of the material to minimize loading time.

The options for storage are either open or closed. In this country the trend is toward closed storage in the form of large cast-in-place concrete silos holding as much as 15,000 tons. However, in some situations, the classic open storage consisting of a stacking tube and reciprocating feeders is still determined to be appropriate. The shift toward silos is evidenced by the fact that one large organization engaged in the construction of both forms of storage, indicates it is booking orders for silos at the rate of better than 10 to 1 over open style arrangements.

Factors influencing the use of silos rather than open storage include:

1. Helps insure consistency of feed to preparation plant. Typically, a more uniform material in size and moisture content is withdrawn from a silo.

2. Environmental. Due to the dust and run-off from open coal storage, many situations dictate the use of closed storage. In areas near urban centers, regulatory bodies demand such arrangements.
3. Space Considerations. Since a silo requires less land for the same volume of storage, the price and availability of such additional space can sometimes be a determining factor.
4. Protection from Freezing. Frozen coal piles can be not only an inconvenience but a costly problem. Although silos provide greater protection from moisture and thus freezing, freeze-up can occur during extended severe cold periods such as the winter of 76-77. When this does occur, it requires the top layer to be broken-up with jack-hammers or other methods.
5. Aesthetics. Either for internal reasons or external pressures, appearance can influence the selection of closed storage.

Although the cost of maintaining a concrete silo is limited, some periodic maintenance is required. Patching or replacement of portions of the lining must be performed from time to time. If coal is permitted to directly impact the side of the silo at the intake, it will eventually wear through the wall. To avoid or mitigate this situation, baffle plates are being installed on many existing silos and most new ones to deflect the material. These plates must be replaced periodically to avoid costly damage to the silo.

Today, it is not uncommon to have single coal silos in the range of 10,000 to 15,000 tons. When greater storage capacity is required, multiple-silo configurations are applied. The cost of silos in this tonnage class will range from $50 to $125 per ton of storage. This wide variance relates to local geologic conditions and the cost and availability of labor and materials. As an example, in parts of Illinois, concrete can be purchased for as little as $30 per cubic yard, whereas in certain West Virginia locations the same volume of mix will cost as much as $75. These enormous differences in material cost relate to local competitive conditions and the distance from source to construction site of not only the mixed concrete but the components of the mix.

For the purpose of approximating the current (mid-1977) capital cost of the various preparation plants examined under Section 5.0, a cost of $110 per ton of storage was used for larger cast-in-place concrete silos. Although in the upper part of the above range, this figure is felt to be a reasonable estimate of the total cost of such facilities which can be adjusted by the readers to reflect exceptional conditions in their particular area. The capital cost determined in this manner is the fully constructed price of the silo alone and does not include any of the necessary conveyors to and from the structure. As shown below in Figure 2-3, such conveying requirements can be extensive.

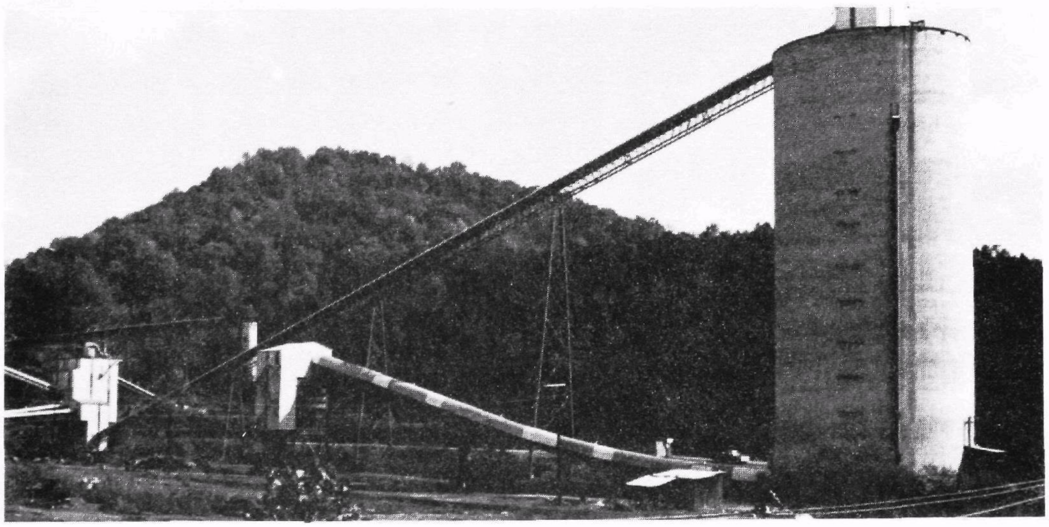


FIGURE 2-3
COAL STORAGE SILO

2.1.2 Conveyors

Another element common to all coal preparation plants, regardless of how simple, is a variety of conveying requirements. These requirements can be quite extensive depending upon the plant size and layout. For even medium size operations, it is not uncommon to move material several hundred feet from raw coal storage into the plant and then a comparable distance from the plant to the load-out area. Additionally, conveyors are required to handle the refuse from the plant and if thermal drying is included a further conveying requirement must be met.

Although vibrating conveyors have some application for moving coal short distances in and around a preparation plant, their use is limited. The major conveying requirements are met with belt conveyors which come in a wide range of sizes and configurations. As applied to a preparation plant, belt conveyors are selected on the basis of their ability to deliver given dry and wet tonnages between two points at a specified rate. Such factors influence the belt width and material, idlers, drive motors, structural requirements, etc.

Belt Conveyor Costs -

Depending upon the width and type of belt, distance traveled, elevation, and structural and foundation requirements, the price of belt conveyors will vary significantly. Therefore, based upon a sampling of mid-1977 prices for actual installations, we have established general installed pricing guidelines for various belt widths on a per linear foot basis. These estimated prices have been observed in determining the capital requirements for the coal preparation plants examined under Section 5.0 of this study. They are as follows on the next page:

36 Inch Width - $480 Per Foot

42 Inch Width - $520 Per Foot

48 Inch Width - $560 Per Foot

54 Inch Width - $600 Per Foot

Although there may be special applications for belt conveyors of smaller or larger widths than those given above, our experience indicates their use is limited. These prices are indicative of quality installations requiring some "normal" foundation work and include all labor, materials, and electrical hook-up necessary for construction of a fully tested conveyor. We feel they are valid for estimating the cost of lengths between 100 to 500 feet which do not have exceptional elevation requirements. When this occurs, the price can increase by as much as a factor of two or more. Conversely, when ground level conveyors can be installed without extensive foundation work, a significant savings over these estimated prices will be realized.

Our purpose in identifying the estimating procedure observed is to give users of the study the opportunity to make their own adjustments for significant variances brought on by unique site specific conditions. Since certain conveying requirements would exist whether there was a coal preparation plant or not, only those belts considered unique to the plant have been included in the capital costs presented in Section 5.0. For example, transporting of the material from the mining area to raw coal storage has not been included.

2.1.3 Tramp Iron Removal

During the mining process, stray ferrous material is loaded out with the raw coal and can find its way into the preparation plant. This material comes from broken tools, continuous mining bits, and other miner induced sources. Although the amount of such material, known as tramp iron, is relatively small, it can cause significant damage to the coal preparation equipment if not removed at an early stage in the process. Some of this debris is removed by rough screening (scalping) or by the rotary breaker if such steps are in the pre-preparation coal handling equipment. However, even if these types of equipment are present, it is common to place an electromagnet over the conveyor belt feeding the plant to insure the removal of the tramp iron.

Typically the magnet is suspended by threaded rods and turnbuckles over the trajectory of the material being discharged from the belt conveyor as shown in Figure 2-4.

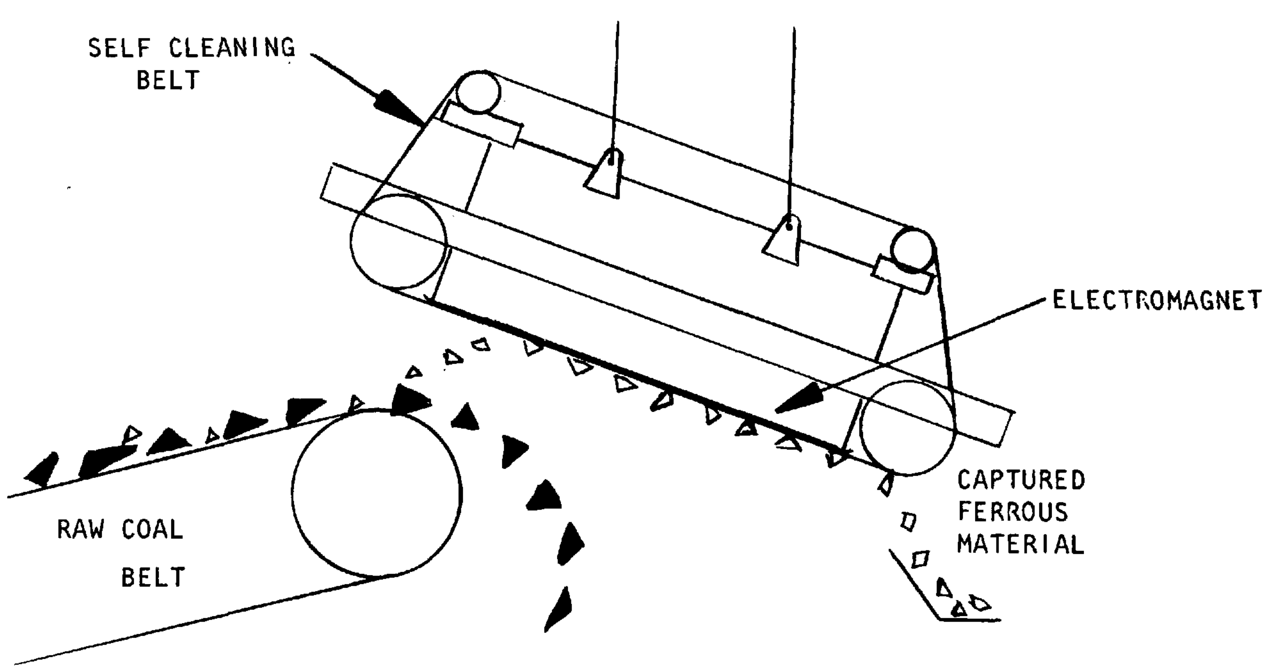


FIGURE 2-4

TRAMP IRON REMOVAL FROM RAW COAL

When the conveyor speed is 350 feet per minute (FPM) or more, this arrangement promotes maximum removal efficiency since influence of the magnetic field is most effective when the material is "opened-up" in flight. Additionally, the material is moving directly toward the face of the magnet and the momentum of any tramp iron assists in its capture by the magnet. Such magnets are available in both manual and self-cleaning types as well as explosion proof designs.

From a design standpoint, the magnet should normally be at least as wide as the width of the belt. Other factors influencing the selection of an appropriate tramp iron magnet are:

1. Depth of Feed
2. Suspension Position
3. Tramp Iron Size (minimum & maximum)
4. Size Consist of Feed
5. Belt Speed
6. Feed Rate
7. Operating Temperature Range
8. Head Pulley Material
9. Head Pulley Diameter
10. Available Current (AC or DC)
11. Degree of Troughing Idlers (if magnet is not placed over head pulley)

2.1.4 Loading Facilities

Following the preparation process, the clean coal is normally conveyed to an open or closed storage area to await transportation to the user via any number of methods. In some cases, this may be as simple as a conveyor belt direct to the power plant. Where short distances are involved, trucks also fill an important role. However, most prepared coal is transported via railroad or barge. When available, transportation via water is the least expensive of the two major methods. Barge loading facilities normally consist of a docking area capable of handling six to eight barges each having a capacity of 1000 to 1500 tons. Coal is fed into the barges via a telescoping tube at the rate of 1000 to 1500 tons per hour (tph). The cost of such facilities varies significantly depending upon the difficulty of placing pilings and other structural members necessary to secure the docking area. However, based upon the cost of recently completed facilities of this type, $1.5 million dollars is a good approximation for a river location capable of loading at the rate of 1000-1500 tph.

The most common method of coal shipment is the railroad. For obvious reasons, rate preference is given to train-load shipments. Therefore, it is advantageous to the plant operator, if delivery commitments allow, to accumulate the clean product until there is a sufficient amount of coal to fill a complete train of 80 to 100 cars, each holding up to 100 tons. For larger coal preparation plants making numerous train-load shipments annually, it is usually of economic benefit to negotiate a unit-train arrangement. Although there is a variety of unit-train agreements unique to the given situation, the normal arrangement is to dedicate the particular train to hauling coal between two specific points over an extended term.

When appropriate to the particular situation, unit train can provide a substantial savings over regular railroad shipment. In order to maximize the savings associated with this method of transportation, a fast efficient loading system must be available. There are currently in existence many unit train load-out facilities which have the capability of loading a 100-car train in less than four hours. For example, at the Leahy Plant of Amax Coal, cars are automatically flood loaded at the rate of 5500 tph from a 200-ton over the track loading bin. The bin receives 5500 tph via a 296 foot long 7 foot wide belt from a 15,000 ton concrete silo with eight 750 tph reciprocating feeders. This rapid car loading rate is possible with the installation of a special bin with pneumatic gates which are controlled by an electronic system actuated by beams of light directed across the railroad tracks. As the cars pass through the beams of light, the position of the empty hopper is known and the loading bin gates opened or closed accordingly. With this system, the average 100-car unit train loading time is broken down as follows:

Train Loading		110 Minutes
Train Switching		100 Minutes
Delays		20 Minutes
	Total	230 Minutes or 3 Hours and 50 Minutes

Similar success has been achieved with over the track silos where the train passes through a tunnel at the base and is flood loaded.

Although the costs associated with these facilities are justified by the resultant savings, they add significantly to the initial capital requirements. Depending upon the sophistication of the arrangement, unit-train loading facilities will add from $400,000 to a million dollars or more to the total cost of the complex. Since there is such a wide cost range, a figure of $500,000 was applied to those preparation plants covered by Section 5.0 where unit-train facilities were appropriate. This figure was selected as being representative of an adequate facility which readers may amend to fit their particular circumstance. Further, the reader may wish to delete such cost entirely on the grounds that it is not attributable to coal preparation since even without cleaning some type of loading facility would be required.

2.2 Cleaning Equipment

Although the entire preparation plant complex must be considered as an integrated functioning unit, we have, later in this section, separated the major items of equipment directly involved in the coal cleaning process for individual discussion. The majority of these pieces of equipment are found inside the cleaning plant. However, certain pieces such as rotary breakers and scalping screens do perform an important cleaning function outside the plant proper. Each major category of equipment provides a particular function which takes on varying degrees of importance depending upon the raw coal and the preparation process or processes being applied. Before discussing these individual categories of equipment, a few general comments on the major coal cleaning processes are in order.

As mentioned in the Introduction, most physical cleaning methods are wet in nature. The most common of these methods uses water as the separation medium. Prior to 1940, nearly all wet cleaning was accomplished by some method based upon water only. Since that time, heavy media processes have been gaining in popularity, but, as indicated by Table 2-1 , are not as widely used as water only cleaning. Some of the more common equipment utilizing this medium include jigs, concentrating tables, and hydrocyclones. The water separation technique employed by the first two pieces of equipment is based upon the phenomenon of hindered settling. Briefly stated, when a mixture of water and solids is agitated it responds as a single fluid of high specific gravity, with each solid particle tending to behave independently of all other particles.

Therefore, as any given particle begins to settle, it is settling in a medium which effectively has a higher specific gravity than water. The objective of physical coal cleaning methods employing this technique is to simulate a specific gravity close to that necessary to effect the desired separation of the coal from the accompanying heavy impurities (refuse).

As with all approaches to coal cleaning, there are relative strengths and weaknesses which make one process more or less advantageous under various conditions. The advantages of water only cleaning processes include:

1. Lower capital and operating cost than heavy media processes of comparable capacity.
2. When the amount of near-gravity material is 10% or less, - The efficiency of separation can approach that achieved with heavy media processes.
3. Can be cost-effective as a primary rough washer prior to heavy media thus reducing the more expensive heavy media cleaning capacity.

As would be expected from the above description of hindered settling, the major limitation of water only processes is their inability to make a sharp separation between coal and refuse. When there is a significant amount of near gravity material present care must be exercised in applying this technique so as to not discard too much coal which could be economically recovered by another process.

As commonly applied today, separation of coal and refuse by heavy media processes is accomplished in a suspension of magnetite and water. By varying the amount of magnetite, a medium can be created which has a specific gravity close to the desired gravity of separation as determined by float-sink analysis. Although expensive (approximately $70.00 per ton), magnetite has superior properties to any additive developed for this purpose thus far. In addition to being non-toxic, magnetite can be effectively recovered by magnetic separators. Further, because of its high density, the volume concentration of magnetite is kept low. As an example, when only ten pounds of magnetite is added to one gallon of water the specific gravity of the mixture is increased to approximately 1.8 grams per cubic centimeter.

Equipments based upon this separation process include heavy media vessels and cyclones. As discussed later, these equipments take on various configurations based upon the size and composition of the material they are handling. Generally, these equipments are more costly to install and operate than those using water only as the separation medium. The higher capital cost is mainly attributed to the additional equipment and facilities associated with pumping, monitoring, and recovery of the magnetite. Operating costs are higher because of the greater equipment capacity to maintain and the loss of magnetite which can be over a pound per ton of clean coal product. Further, careful sizing of the feed to heavy media processes is necessary to minimize undersized material. Such material is separated less effeciently and tends to increase magnetite consumption by contaminating the circulating medium. In spite of these higher costs and performance limitations, equipment based upon the heavy media separation process can provide a more economic solution to cleaning certain coals. Since the sharpness of the separation can be controlled more closely than water-only processes, such equipments can still work well in the presence of larger amounts (25% or more) of near-gravity material. This means that when applied to a closely sized feed, they will be able to approach the theoretical separation limits of the float-sink analysis.

The final major cleaning process to be covered, before discussing the individual equipment, is froth flotation. This process relies upon the surface chemistry of coal to effect a separation of coal and its accompanying refuse. Its major advantage is the ability of this process to clean very fine size coal (approaching zero). To effect a separation, a slurry of coal and water is conditioned with frothing and collecting reagents. Then, as air is bubbled through the slurry, the coal particles attach themselves to the bubbles and report to the surface as a froth where they can be collected. The clay and shale impurities stay in the slurry and are drawn off separately as refuse. When applied to higher rank coals (bituminous and anthracite), flotation can be very effective in reducing the ash content although it is not as effective in removing pyrites as some other processes such as concentrating tables and hydrocyclones. Besides the difficulty of controlling the accuracy of the separation, one of the major limitations of this process is that it is presently only effective when treating non-oxidized bituminous coals and anthracites. Further, since the response time is slow, the slurry must be retained for an extended period creating the need for excessive handling capacity. This weakness is being somewhat overcome through more efficient mechanical designs.

As currently applied, most preparation plant design centers around either a water only or heavy media process. In both cases, froth flotation may be used on the finer size (28 mesh X 0 and 100 X 0) fractions depending upon the economics of the particular cleaning application. However, this is not to say that water-only and heavy media processes cannot be effectively applied in the same coal preparation circuit. As an example, water-only cyclones are commonly used as roughing cleaners which produce a low gravity overflow product that reports to clean coal. The underflow product is then retreated in heavy media cyclones at a somewhat higher specific gravity of separation. Then, finer size fractions can be handled by additional water-only cyclones, concentrating tables, and/or froth flotation as appropriate to most economically achieve the desired end product. By combining these processes, some of the more expensive heavy media capacity can be eliminated thereby making for a more cost-effective preparation circuit. In Section 5.0 there are some examples of combined processes. Specifically, Examples 6 and 7 use heavy media and froth flotation while Example 8 uses heavy media and concentration tables.

This very brief exposure to the major cleaning processes should aid in the reader's understanding of the following sub sections which describe the equipment used to implement these processes. Where appropriate, an indication is given as to the sensitivity of cost to capacity or other measurable factors.

2.2.1 Size Reduction Equipment

Almost without exception, coal being handled by a preparation plant will at some point from the mine to load-out be reduced in size. Typically, in many larger preparation plants cleaning both the coarse and finer size fractions there will be a sequence of size reductions. The first or primary reduction will normally take place prior to the coal entering the cleaning plant. One widely used approach is to feed the raw coal from storage to a rotary breaker which, as described below, not only performs a size reduction function but also removes some debris. This arrangement is as shown in Figure 2-5.

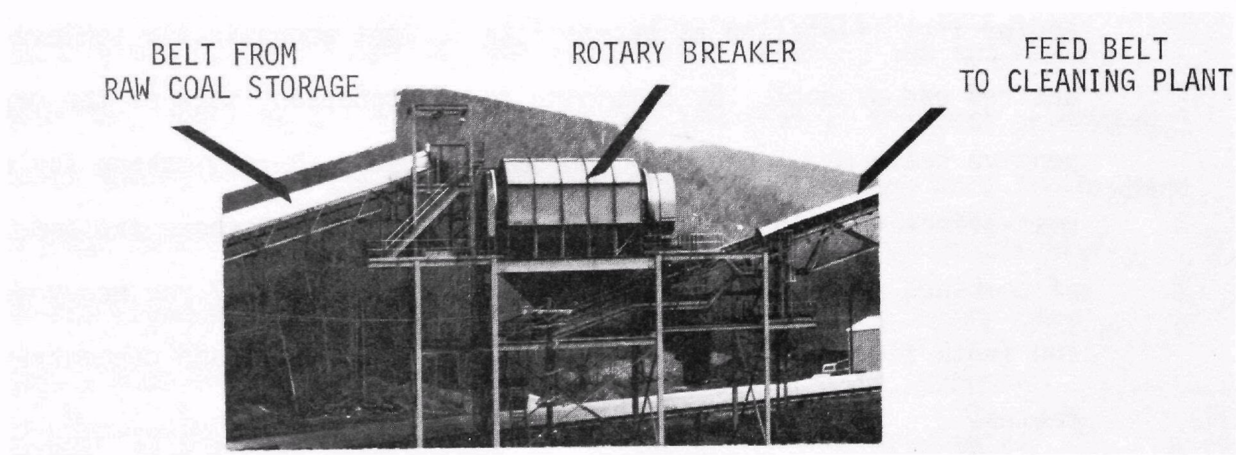


FIGURE 2-5

ROTARY BREAKER INSTALLATION

The rotary breaker is not a positive crushing device, but instead accomplishes its size reduction function through the gravity impact of the coal dropping from a height to break it to the desired size. A more complete understanding of this action can be had by looking at Figure 2-6 which is a cutaway view of a breaker manufactured by the McLanahan Corporation.

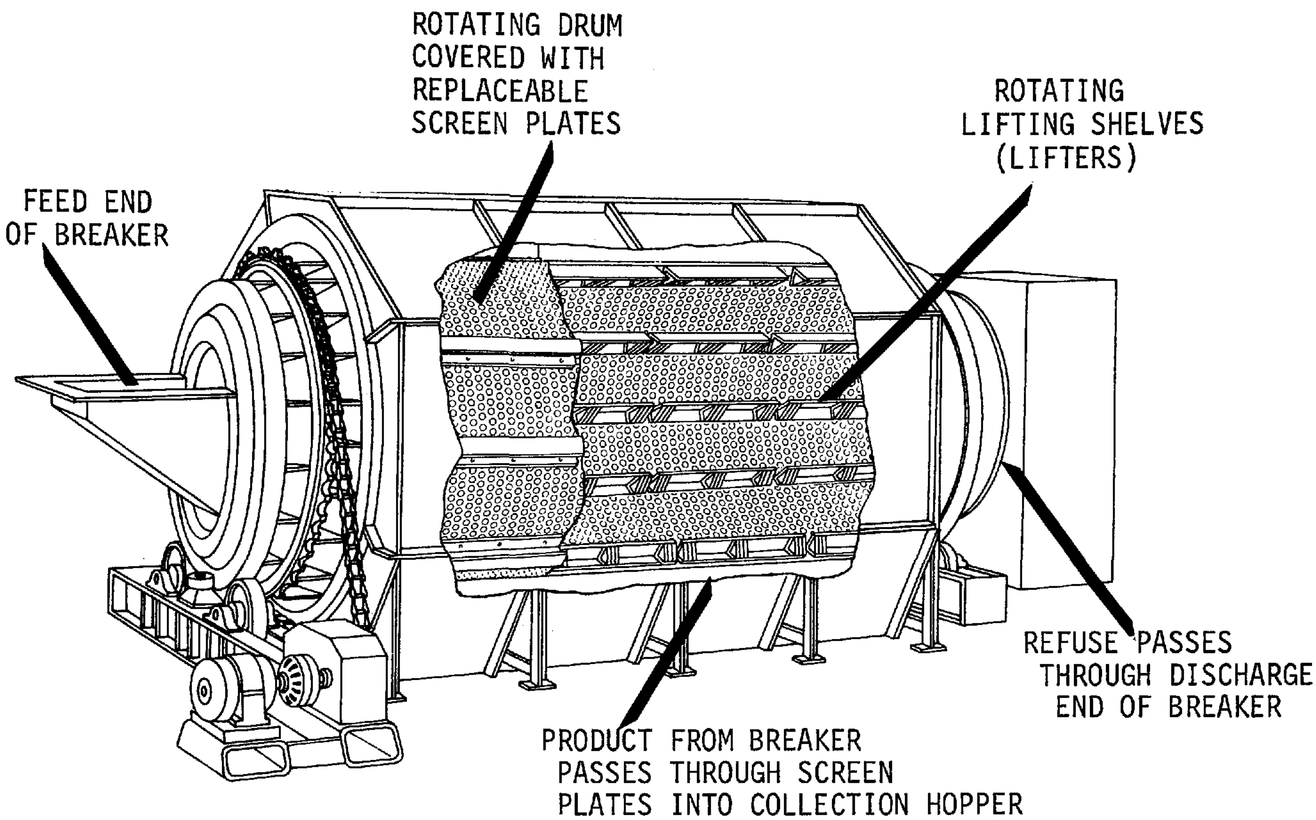


FIGURE 2-6

CUTAWAY VIEW OF ROTARY BREAKER

Essentially, the breaker consists of a rotating drum lined with screen plates having openings equivalent to the desired product size. As the raw feed enters the breaker, it is picked up on lifters attached to the inside of the rotating drum and then fractures as it drops on other coal or the screen plates. That material which breaks to within the size of the screen plate openings passes through and is fed to the cleaning plant. Rock and other material which do not fracture to the size of the screen plate openings move along the length of the drum until they are discharged through the refuse end of the breaker. If properly matched to the particular raw feed, this piece of equipment can perform a valuable and efficient initial cleaning function. Advantages of breakers include: minimum fines, high capacity-to-horsepower ratios, and ability to reject coarse refuse. The disadvantages included: operation influenced by moisture content of feed, not appropriate for finer sizing, and difficult to adjust product size.

The rotary breaker is the one type of physical cleaning equipment which performs its function by relying upon the difference in hardness between coal and rock. Coals which are too hard will not completely fracture over the length of the drum with the result being a significant portion of coal will be lost through the refuse end of the breaker. The hardness of a coal is normally expressed as a Hardgrove Grindability Index number. The higher the number, the softer the coal. For example, a Hardgrove number of 80 to 100 indicates a softer coal, whereas a number of 40 to 60 relates to a harder coal. As a general rule, rotary breakers are not applicable for coals having a Hardgrove Index much below 50. In these cases, a positive action crusher would be used for reducing the raw coal to the proper size consistent with the cleaning process or processes selected.

Depending upon the manufacturer and application, rotary breakers come in a range of diameters from 7 to 12 feet and lengths up to 20 feet. Maximum feed size is based upon the feed opening of the breaker. In the case of breakers manufactured by the McLanahan Corporation, the following relationships exist:

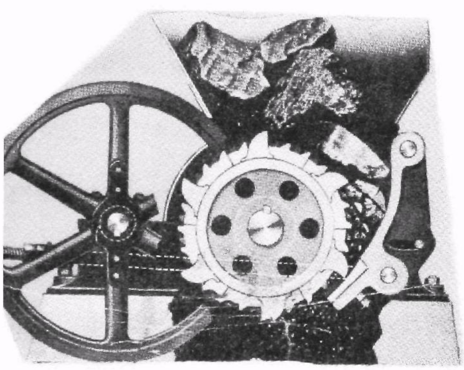
Breaker Diameter:	7 Ft.	9 Ft.	11 Ft.	12 Ft.
Maximum Feed Size:	12 In.	18 In.	24 In.	30 In.

Although the feed opening can be modified to meet a specific application, the McLanahan Corporation does not recommend deviating far from these relationships.

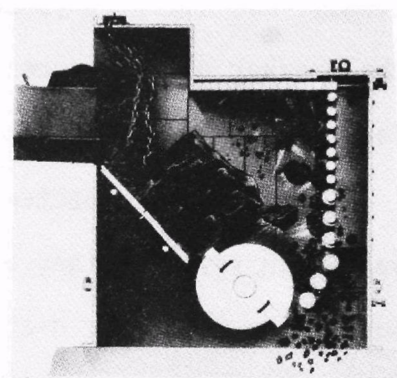
In addition to feed size, moisture content, and hardness, the selection of a rotary breaker is based upon the required capacity. The capacity is influenced by the amount of refuse in the feed and the allowable limits of oversize and undersize product. As stated above, the product size is determined by the openings in the screen plates. If oversize is permitted in the product, the capacity of the breaker may be increased by making the openings 1/4 to 1/2 inch larger than the desired product.

As would be expected, the F.O.B. factory prices of rotary breakers vary with size, design, and manufacturer. For example, one manufacturer has a line of 10 ft. diameter breakers which cost from $100,000 to $130,000 in 12 and 16 ft. lengths, respectively. These units have nominal capacities of 500 to 1400 tons per hour depending upon the specifics of the coal and product requirements as noted above. Another manufacturer has a 9 ft. diameter, 15 ft. long unit which sells for $80,000, and an 11 ft. diameter, 18 ft. long breaker at $95,000. Although all of these units perform the same basic functions, they do have different design configurations which may show advantages under varying applications. Another factor to consider is the extent to which the unit is assembled when it arrives on site. Some breakers come from the manufacturer nearly fully assembled thus reducing installation time and cost. However, for the purpose of approximating the installed cost of outside equipment of this type, including the necessary structural work as shown in Figure 2-5, an amount equal to two times the F.O.B. factory price is representative for mid-1977.

In addition to the rotary breaker, there is a variety of large scale crushers for making a primary size reduction of run-of-mine coal. These units are available from a number of manufacturers in various configurations capable of handling feed sizes up to 60 inches cube at rates as high as 3,000 tons per hour (tph). Two of the more popular crusher configurations of this type are the single roll crusher and the single rotor impact crusher shown in Figure 2-7.



SINGLE ROLL CRUSHER



SINGLE ROTOR
IMPACT CRUSHER

FIGURE 2-7

PRIMARY SIZE REDUCTION EQUIPMENT

Units of this type are designed to operate at slow speeds so as to produce a fairly uniform product and limit the generation of fines which can be detrimental to the efficient functioning of the plant. Of these two configurations, the single roll crusher has been the standard primary reduction piece in the coal industry. This popularity relates to its ability to rapidly reduce slabby feeds of almost any hardness to cubical products with a limited amount of fines. Roll crushers are further characterized by low headroom and power consumption as well as the ability to handle wet, sticky feeds with a high percentage of clay. The only major operational weakness of a single roll crusher is relatively low reduction ratios of about 6 to 1. Other configurations such as the double roll crusher have even lower ratios (4 to 1). This limitation is overcome by the impact type crushers which have reduction ratios of as high as 30 to 1.

However, the final selection of a crusher is based upon the nature of raw coal, the feed size, the desired product size, and the required capacity. With regard to the nature of the raw coal, the following characteristics are important: 1) hardness (Hardgrove index); 2) moisture content; and 3) percent and type of refuse. The feed size is important to determine the dimensions of the crusher, particularly the roll diameter in the case of that type crusher. Capacity is a function of all of the factors thus far considered. For single and double roll crushers, most manufacturers determine the capacity by first calculating the theoretical ribbon. The theoretical ribbon is the solid ribbon of coal and/or rock which would pass through the crusher without taking into account the crushability of the particular material. This theoretical ribbon which considers the bulk density of the feed and the space occupied by the roll elements or teeth is calculated as follows:

$$\text{THEORETICAL RIBBON CAPACITY (tph)} = \frac{\text{Roll Diameter X Roll Width X Roll Speed X Crusher Setting X Bulk Density X Time}}{\text{Conversion Factors (1728 X 2000)}}$$

Where: Roll Diameter & Width is in inches
Roll Speed (RPM X π) = Peripheral Speed
Crusher Setting = Desired Product Size X 2/3
Bulk Density is in Pounds/ Cubic Feet

Conversion Factors: Time = 60 Minutes/Hour
1728 Cubic Inches = 1 Cubic Foot
2000 Pounds = 1 Ton

Once the theoretical ribbon capacity is known, the actual or practical capacity is merely a function of the crushability (hardness factor) of the material. This relationship is as follows:

ACTUAL RIBBON CAPACITY (tph) = THEORETICAL RIBBON X HARDNESS FACTOR

For most coal the actual capacity is approximately 2/3 the theoretical and 1/3 for rock. However, the capacity for coal or rock is the same in most situations because rock is twice as heavy as the coal but has twice the hardness. From the above relationships, it is observed that an adjustment of the roll speed and/or increase or decrease of the product size will result in a direct change in capacity. Another rule-of-thumb exercised by the crusher industry is that as the capacity of the crusher is exceeded by 10-15%, the amount of oversize material increases radically.

As would be expected, the F.O.B. factory price of crushers is related to feed size and rate (capacity), type of design, and manufacturer. Further, the price is sensitive to the duty cycle. Manufacturers offer a range of machine strengths varying from heavy duty crushers applicable for use on harder coals with abrasive refuse to lighter duty machines handling clean coal from which the majority of the refuse has been removed. For estimating the cost of heavier duty primary size reduction equipment as a function of feed size and capacity, the F.O.B. factory prices of the "Coalbuster" line of single rotor impact crushers gives a good approximation. A picture of this type of crusher produced by the Jeffrey Manufacturing Division of Dresser Industries was presented in Figure 2-7. This piece of equipment sells for from $36,500 to $161,000 depending upon feed capacity. These machines are externally adjustable to permit product sizes of from 6 to 2 inches. Although the final selection and thus price will vary with the particular application, the following specific pricing may be used as a guide:

Nominal Feed Size	Nominal Capacity Based Upon a 5-6" Product	Price
30"	300 tph	$36,500
40"	600 tph	$65,360
50"	900 tph	$73,800
60"	1750 tph	$113,700
60"	2600 tph	$161,000

The above nominal feed sizes are rarely encountered due to the mechanized mining methods employed today. However, the crusher feed openings are kept wide to allow for variations in the raw coal as well as handle greater volume.

Smaller scale reduction equipment capable of reducing coal to a size of 2 inches or less is also available from a wide variety of sources. This category of equipment is typically referred to as secondary, since its normal function is to crush coal which has already been reduced from its ROM state. A typical application is to further reduce the larger clean coal product from a coarser cleaning process such as a Baum jig or heavy media vessel prior to load-out or additional cleaning. However, depending upon the mining method and other factors, crushers of this type can be applied in a primary role treating ROM coal.

As stated above, secondary size reduction may take place several times within the cleaning plant depending upon the sophistication of the process. Double and multiple roll type crushers are commonly used for this secondary reduction of coal to smaller sizes. However, there are configurations which combine the compression crushing concept of the traditional roll crusher with the inherent high capacity capability of the impact type crusher. One such unit is the "Flextooth" crusher produced by Jeffrey Manufacturing. The trade name of this line of crushers is derived from the design of the crushing elements which permits them to "flex" back away from the crushing area when experiencing tramp iron or other uncrushables. This unit, as with the roll type crushers, is characterized by a slower operating speed to promote uniformity of product and limit the creation of fines.

As would be expected, the cost of secondary crushing equipment is most sensitive to feed size and capacity. Capacity is greatly influenced by the desired product size and moisture content. This latter factor can be extremely significant when crushing clean coal following wet processes such as a heavy media vessel or Baum jig. When the moisture content of the crusher feed is high, the smaller particles will tend to stick to the rollers, thereby degrading performance. To cope with this problem, wipers are installed to scrape the sticking material from between the crusher teeth. In the case of some double roll crushers, each roll may be operated at a different speed to help alleviate this problem.

Normally, these secondary units are not as large as the primary cursher since they are only handling a portion of the plant feed. Further, they are lighter duty because much of the hard, abrasive refuse has been separated from the softer coal. As with primary crushers, the final selection and thus price of secondary size reduction units will vary with the specifics of the situation. However, for the purpose of estimating the cost of secondary crushers on the basis of capacity the following F.O.B. factory prices give a reasonable approximation as of mid-1977:

Nominal Feed Size	Nominal Capacity Based Upon a 2 Inch or Less Product Size	Price
14"	165	$8,800
14"	245	$12,100
20"	500	$20,400
24"	635	$33,100
24"	1065	$48,300
28"	1540	$59,000
30"	2500	$94,100

Although the feed to this equipment would rarely reach the nominal sizes noted above, the feed openings are kept large to accommodate the volume and variation in feed consistency. The capacities above are based upon a 2 inch product; as the product size is cut in half, the capacity is likewise affected. Since this equipment is normally used inside the cleaning plant, its fully installed cost is between 2 and 3 times the above prices.

2.2.2 Screens

There is not a coal preparation plant in existence that does not utilize a stationary or vibrating screen in some portion of the circuit. Screens perform a variety of sizing and collection functions critical to the overall success of the preparation process. These functions include:

1. Coarse Scalping of Smaller Material Prior To Initial Size Reduction.
2. Separation of Various Sizes of Material Throughout The Process.
3. Collection of fluids combined with the coal or refuse. This may take the form of simple dewatering or the draining and rinsing of the material to remove and collect the expensive heavy media (eg. magnetite).

As noted elsewhere, the proper selection and maintenance of screens is essential to the realization of the predicted performance and life expectancy of the screens themselves as well as other pieces of equipment within the circuit. For example, if a screen is passing a coarser material ahead of cyclones, the predicted classification will not be achieved and wear will be accelerated. Situations of this type are rapidly reflected in increased operating and maintenance costs brought on by greater amounts of downtime for repair and replacement with the associated materials and labor. It is for these reasons that a rigidly enforced screen maintenance procedure should be followed in all preparation plants. In addition to lubrication and alignment, this procedure should include a provision for periodically checking the tension on the screen decks as well as the surface for holes. When the wire cloth is loose, it results in excessive stress which leads to broken wires, the major cause of premature cloth failure.

Initially the selection of screens is merely a function of plant size and cleaning method. Influencing this selection are such factors as: 1) feed rate to screening station; 2) maximum size anticipated; 3) size analysis of feed; 4) required separation and efficiency; and 5) percent solids in feed. However, there are other important considerations which will influence the initial cost as well as the longer term operating and maintenance expense. These additional considerations involve such things as existing regulations regarding safety as well as noise and dust emission. For this reason, explosion proof motors may be required at dry screening stations in addition to rubber or polyurethane decking to reduce noise. Special noise reduction mountings and dust enclosures may also be necessary on vibrating screens. Since there is such a large set of variables affecting screen selection and thus cost, we have not as yet developed a simple formula for determining capital cost without knowing details of the screening application. Therefore, for the purpose of approximating the capital cost of the preparation plants examined under Section 5.0, actual price quotations as of mid-1977 were obtained from various screen manufacturers and applied accordingly.

SCALPING FUNCTION -

This activity which normally takes place outside of the actual preparation plant is often applied ahead of the primary size reduction equipment such as a rotary breaker or coal crusher. One such application is shown below in Figure 2-8.

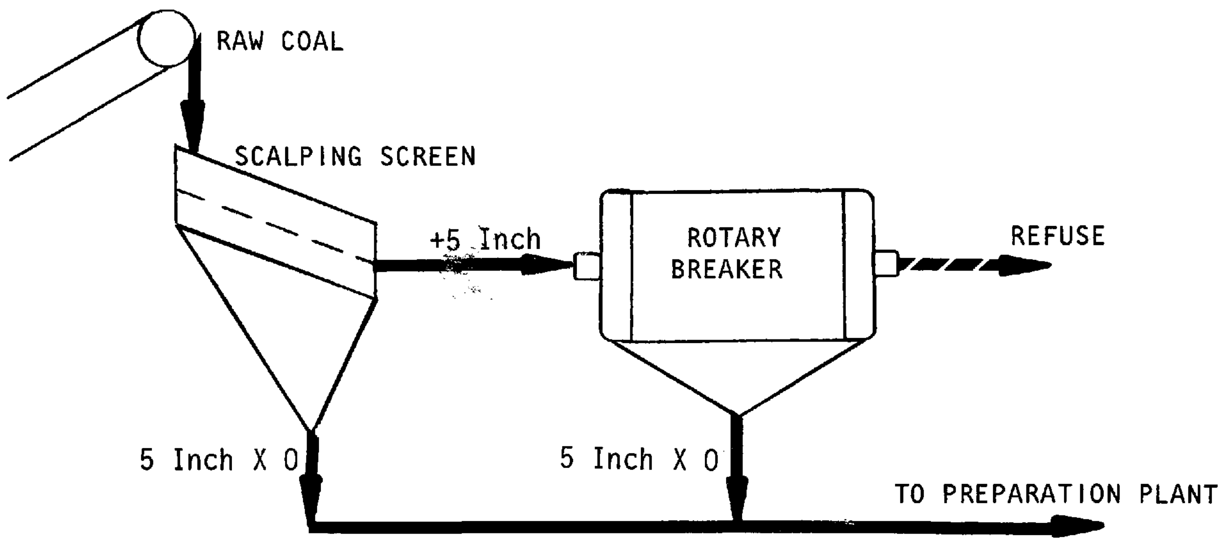


Figure 2-8
APPLICATION OF SCALPING SCREEN

The raw coal is conveyed to a feed box located above the scalping screen. In addition to absorbing the initial impact of the coal dropping off the conveyor belt, the feed box spreads the material over the screen for more efficient operations. Normally, the scalper is a rugged single deck vibrating screen mounted at a 20^{o} angle to promote material flow and separation. In a typical installation as shown above, the screen will pass 5 inch or less material with the oversize going to the breaker for further reduction. This is a cost-effective arrangement by reducing the amount of breaker capacity needed and also permitting the breaker to function more efficiently.

The material which fractures to the size of the breaker screen plate openings passes through and joins that which was scalped off by the scalping screen. Rock and other debris which did not break down to 5 inches or less passes out the refuse end of the breaker and is disposed of accordingly.

SIZE SEPARATION FUNCTION -

Following the scalping operation as described above, the coal must be separated into sizes suitable for load-out as is or further treatment within the preparation plant. Typically, the coal enters a feed box ahead of the sizing screen. As with the scalping screen, this feed box reduces the impact of the coal onto the screening surface and promotes a more even materials flow. Commonly, the sizing screen is a double deck vibrating type mounted on an angle of approximately 20 degrees in the manner shown below in Figure 2-9.

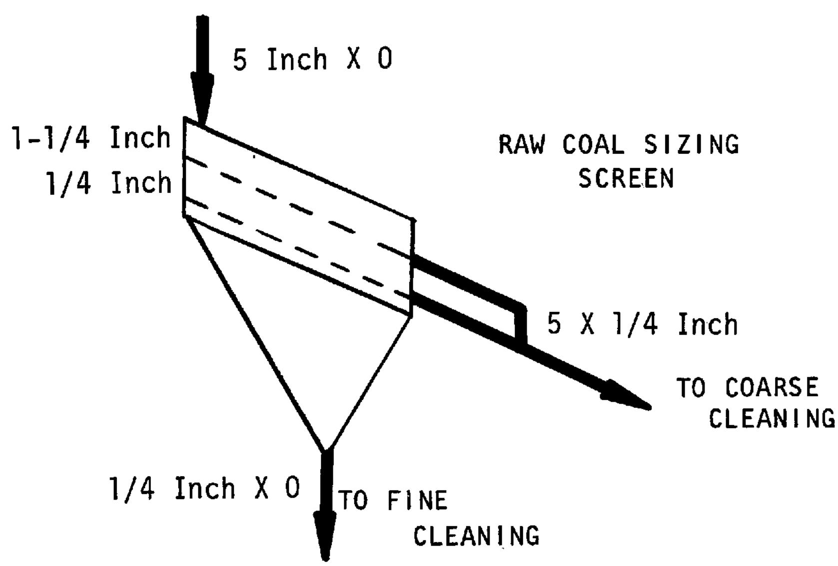


FIGURE 2-9
APPLICATION OF RAW COAL SIZING SCREEN

Depending upon the nature of the coal, the top deck will have openings in the range of 1 to 1 ½ inches. Bottom deck openings are determined by the manner in which the finer material will be handled, but are normally

½ inch or less. The inclined vibrating double deck arrangement is conducive to good separation of the material and thus promotes removal of the finer particles. This removal is important in that the effectiveness of such coarser cleaning methods as the jig and heavy media vessel is improved when less fine material is present. Based upon the level of preparation, the material passing through the sizing screen may go either to load-out or into the fine coal cleaning circuit of the plant. The larger material passing over the screen will move onto an optional pre-wet screen prior to coarse cleaning.

Pre-Wet Screening Function -

A further extension of the separation process occurs at the pre-wet screen. This function is described above as optional in that it may be combined with the sizing operation or omitted entirely depending upon the make-up of the material to be subjected to additional cleaning. When there is a significant amount of finer particles still trailing along with the coarse material, a low pressure spray of water can encourage their removal prior to entering the cleaning vessel. Typically, the pre-wet screen is a horizontally mounted double deck type which vibrates to encourage the distribution and separation of the material over the two screening surfaces. This reduces the depth of material on each deck and thus exposes greater surface area to the washing action of the water spray as shown Figure 2-10, which is a photograph of a pre-wet screen in operation.

Typically, the top deck of the pre-wet screen has openings of approximately one inch with the bottom deck passing material of 1mm or less. All material passing over these screens is fed to the course

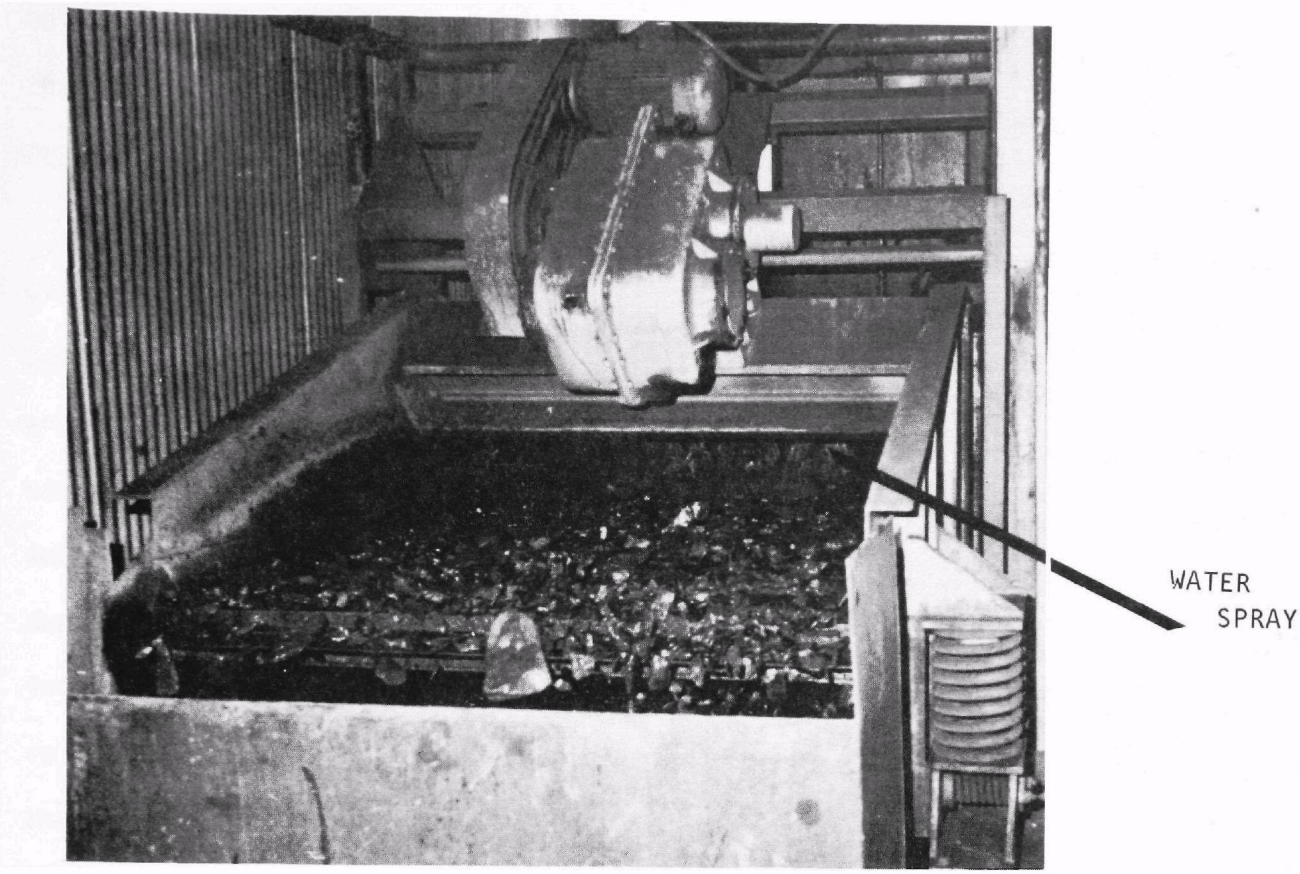


FIGURE 2-10
PRE-WET SCREEN IN OPERATION

washing vessel (jig or heavy media). The fines passing through are handled by a number of other methods depending upon the nature of the material itself and the sophistication of the fine cleaning portion of the preparation plant. In some cases the material may be dewatered in a centrifugal dryer and considered clean or refuse based upon its composition relative to the clean coal specification. Where it has been determined economic, this fine material may undergo additional cleaning. If a fine coal cleaning circuit is included in the plant, this and the less than 1/2 inch material will be further sized on what is referred to as a desliming screen.

Desliming Screen Function -

As mentioned above, the function of the desliming screen is to perform a further sizing of the finer material making for more efficient cleaning in the fine coal portion of the plant. This screen is normally a horizontally mounted single deck type which vibrates while receiving a spray of water to encourage the separation of the extremely fine materials; i.e. less than 1/2 mm (28 mesh). The name desliming comes from the function it performs since it removes very fine material. Depending upon the nature of the sulfur content in the coal, this very fine material may contain a high percentage of pyritic sulfur which was released during mining or earlier in the preparation process by crushing. To improve efficiency and reduce the size of the desliming screen, the material normally first passes over a sieve bend as shown Figure 2-11.

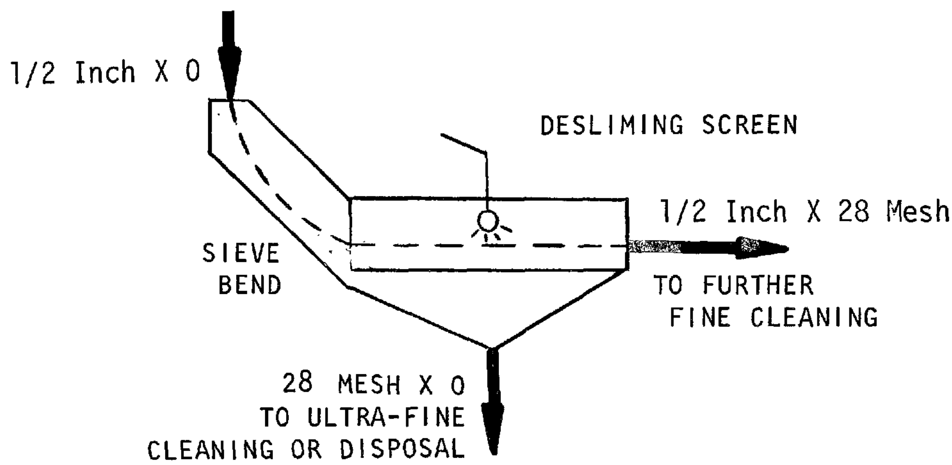


FIGURE 2-11
APPLICATION OF DESLIMING SCREEN

To promote better separation, the depth of material on the deck should be kept to a minimum. The 1/2 mm or greater material passing over this screen proceeds to the next portion of the fine cleaning circuit which may include Deister tables and/or cyclones. The less than 1/2 mm material which was washed through the screen may be either directed to froth flotation cells or cyclones for further recovery of clean coal or to a static thickener for eventual disposal. Obviously, the option elected must be based upon the economics specific to the situation. However, current technology and environmental considerations along with the price of coal are increasing the economic applicability of such finer recovery techniques.

FLUIDS COLLECTION FUNCTION -

Of the functions performed by screens, those involving the collection of fluids are most influential on plant capital and operating costs. One such cost saving function occurs in the recovery of dense media by drain and rinse screens. These screens promote a higher recovery of expensive heavy media such as magnetite which helps to keep operating costs down. Another cost saving function is performed by dewatering screens. By reducing most of the free water mixed with the coal, these screens not only improve the handling properties of the solid material, but also help to reduce the capacity of other dewatering equipment in the preparation plant.

Heavy Media Recovery Function -

Drain and rinse screens are positioned in the preparation circuit to handle the clean product as well as the reject from any prior equipment in which a dense media such as a magnetite/water slurry was the vehicle of separation. Since the fluid accompanying the material from heavy media vessels and cyclones contains a high concentration of an expensive material such as magnetite, these screens are used to collect as much of this fluid as possible so that it may be reused. This process is normally accomplished by a horizontally mounted double or single deck vibrating screen over which a low pressure spray of water is applied to rinse off the heavy media clinging to the coal and refuse. To aid the process and reduce the screen size, the material normally passes first over a sieve bend or cross-flow screen as shown in Figure 2-12. The vibrating motion promotes better separation of the material over the screen decks giving greater effectiveness to the rinsing action of the water spray. For this reason, one of the

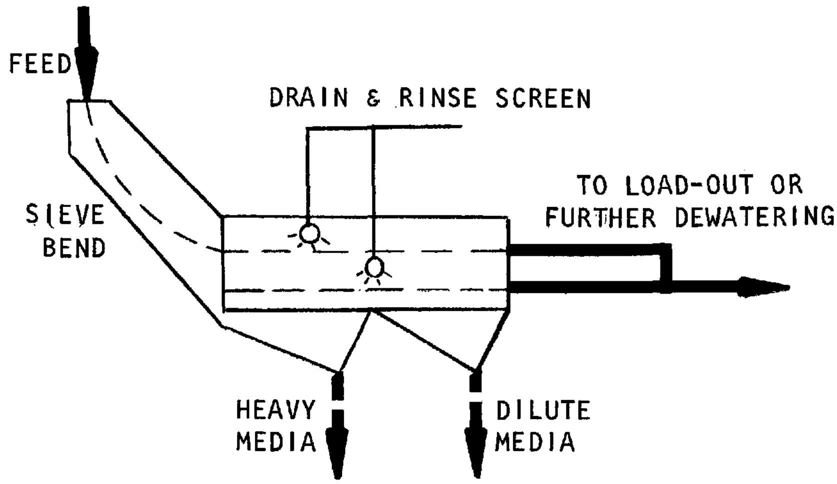


FIGURE 2-12

DRAIN & RINSE SCREEN FOR HEAVY MEDIA RECOVERY

key design criteria is to size the screen properly so the bed depth is kept to a minimum. As noted in the figure above, those fluids collected over the first half of the screen are referred to as heavy media and those from the second half as dilute media. Under normal operation, most plants route the heavy media directly back to the vessel or cyclone media feed circuit and the dilute media to magnetic separators which recover the magnetite for reuse. Typically, the screen openings of the bottom deck are kept small, thereby passing the fluid containing the magnetite but only negligible solids. When a double deck arrangement is used, this screen can also serve in a sizing capacity.

Dewatering Function -

As the name implies, the primary purpose of dewatering screens is to remove as much of the free moisture as possible in the material they handle. The need to perform this function is universal to preparation processes involving both heavy media and water only. In the case of heavy media processes, the dewatering screen may be applied immediately following the drain and rinse process where heavy media was recovered from the clean product and the refuse. For water only processes, like the Baum jig, dewatering screens are normally the first piece of equipment treating the "float" from the jig as well as the refuse.

Typically, the dewatering function is performed by a horizontally mounted single deck vibrating screen. In many installations, a sieve bend is placed ahead of the screen. Unlike the drain and rinse screens used for heavy media recovery, dewatering screens have dams at intervals along the screening surface. These dams develop greater bed depth by restricting the flow of material and thus give the vibrating action of the screen a better chance to beat out the water. Depending upon the particular situation, these screens may eliminate the necessity for further dewatering before load out or disposal. However, in all cases, they improve the handling characteristics of the material and reduce the load on subsequent dewatering equipment such as centrifuges.

Sieve Bend Functions -

In several of the foregoing screening applications, a sieve bend played an option role ahead of the screen as shown in Figure 2-13. When mounted in this way, it not only serves as a feed box to help distribute the material over the width of the screen but also aids the sizing and dewatering functions by reducing the load on the screen. A sieve bend can also be applied in the preparation circuit by itself to accomplish these latter two functions. To explain this action, the reader is referred to Figure 2-14 which is a cutaway view of a sieve bend manufactured by Heyl & Patterson, Inc. As the material enters the feed inlet, a series of baffles in the sieve bend feed box spread the material so that the slurry

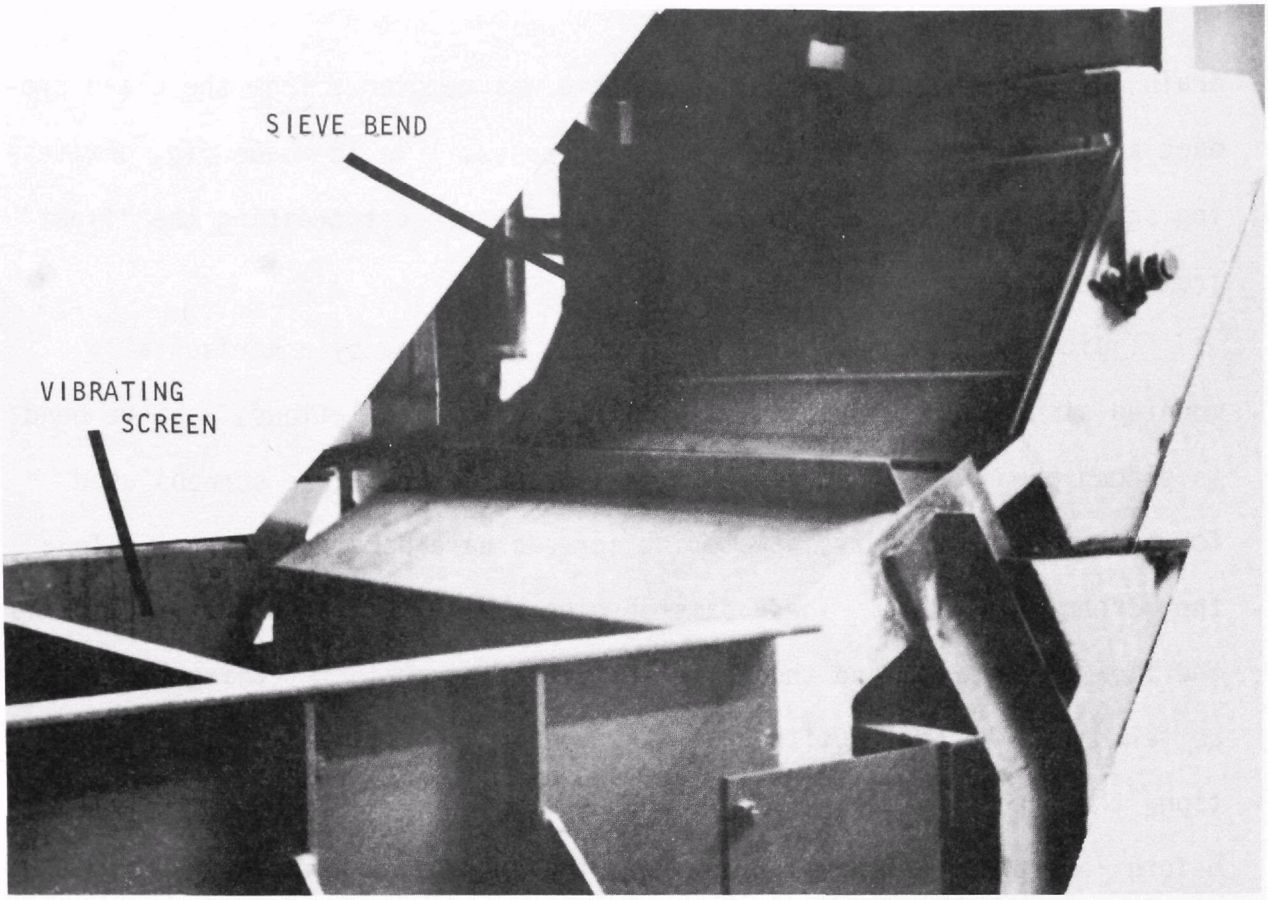


FIGURE 2-13

SIEVE BEND MOUNTED AHEAD OF VIBRATING SCREEN

is fed evenly over the width of the curved screen deck. By the arrangement of the feed spout, the slurry actually drops tangentially onto the screening surface. As the layer of slurry flows down the curved screen, the thickness is reduced as it passes over the horizontal screen wires. In practice, the depth of the slurry decreases by increments of about one-quarter the slot width each time it passes a slot. As an example, for a screen opening (slot width) of 1 mm, the thickness of the slurry layer being shaved off by each wire is about 1/4 mm. This 1/4 mm thick cut can only transport particles of up to 1/2 mm in size. Therefore, plus 1/2 mm solids pass over the sieve bend. The result is a

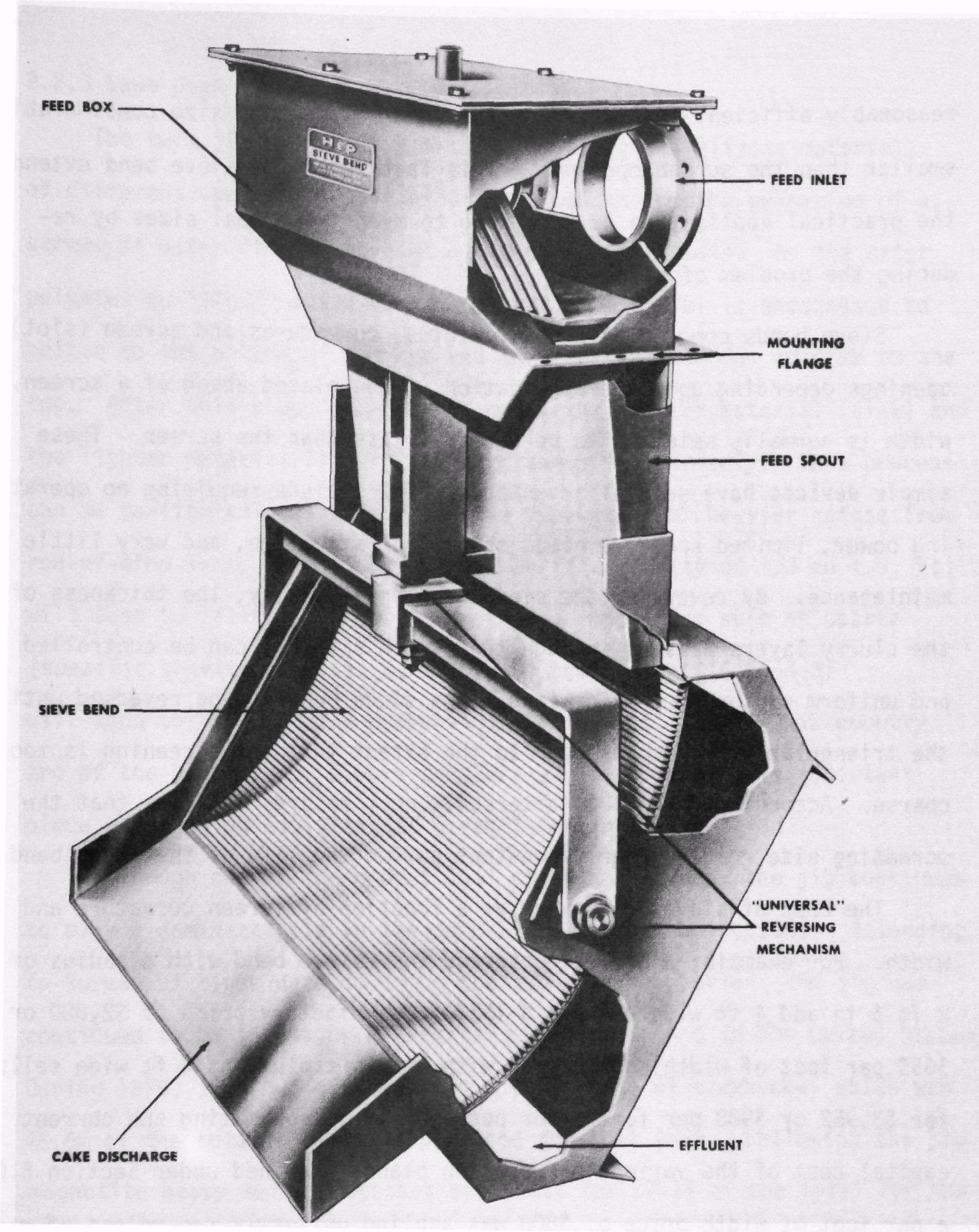


FIGURE 2-14

CUTAWAY VIEW OF SIEVE BEND
MANUFACTURED BY HEYL & PATTERSON, INC.

reasonably efficient separation of the feed solids at a size considerably smaller than the screen openings. This feature of the sieve bend extends the practical application of screening to much finer coal sizes by reducing the problem of blinding.

Sieve bends come in a range of widths, curvatures, and screen (slot) openings depending upon the application. When placed ahead of a screen, the width is normally selected to be one foot less than the screen. These simple devices have several advantages which include requiring no operating power, limited space, minimum supporting structure, and very little maintenance. By reversing the sieve bend periodically, the thickness of the slurry layers passing through the screen openings can be controlled and uniform performance maintained. The sieve bend can be reversed until the triangular wire becomes worn to the extent that the screening is too coarse. According to Heyl & Patterson, Inc., records indicate that the screening size remains nearly constant during the life of the sieve bend.

The cost of sieve bends vary as a function of screen curvature and width. For example, a Heyl & Patterson Inc. sieve bend with a radius of 2 ft 6 in and 4 ft wide has a mid-1977 F.O.B. factory price of $2,600 or $650 per foot of width whereas one with a 5 ft radius and 4 ft wide sells for $3,952 or $988 per foot. For purposes of approximating the current capital cost of the various preparation plants examined under Section 5.0, a per foot of width price of $800 was applied uniformly regardless of radius.

2.2.3 Baum Jig

The term jig describes a machine used for classifying materials of different specific gravities or unit weights by the pulsation of a stream of water flowing through a bed of the materials. As the water pulsates or "jigs" up and down, the heavier material is encouraged to settle to the bottom of the bed and the lighter material to rise to the top. After this classification is made, the heavier material (sink) and the lighter material (float) may be drawn off separately. This process can be particularly effective for the separating of heavier refuse from run-of-mine coal. Since coal has a specific gravity of 1.3 to 1.5, it will tend to "float" and the accompanying impurities such as quartz (specific gravity of 2.6), pyrite (5.0), and slate (2.6 to 3.3) will tend to "sink." The overwhelming number of jigs in this country are of the Baum type. A more complete explanation of this important piece of cleaning equipment is given later in this section.

Although one of the oldest coal cleaning methods, the jig continues to play a dominant role in the domestic preparation industry. According to Bureau of Mines data covering the 1964 to 1975 period, the jig has continued to be the major mechanical cleaning method in the United States. During 1975, jigs put out over 124 million tons of clean coal which was 46.6% of the total clean coal produced for that year. Following the jig, magnetite heavy media processes accounted for 27.1% of the total for that year. The third most utilized method is concentrating tables which contributed 10.7% of the clean coal in 1975. The relative roles these methods have played in prior years is summarized in Table 2-1.

TABLE 2-1

CLEAN COAL PRODUCED ANNUALLY BY
MAJOR MECHANICAL CLEANING METHODS
(Thousand Short Tons)

Year	Total Clean Coal Produced	Percent Produced By - Jigs	Magnetite Heavy Media	Concentrating Tables
1975	266,993	46.6%	27.1%	10.7%
1974	265,150	48.8	25.9	10.9
1973	288,918	45.9	25.8	12.1
1972	292,829	44.5	25.3	13.1
1971	271,401	42.5	25.9	13.1
1970	323,452	43.4	23.7	13.6
1969	334,761	46.3	21.4	13.5
1968	340,923	46.6	20.7	13.9
1967	349,402	46.2	18.9	14.2
1966	340,626	46.0	*	13.3
1965	332,256	45.6	*	13.0
1964	310,203	47.0	*	13.2

*Magnetite Heavy Media Not Reported Separately from other Heavy Media processes.

Source: Based Upon U.S. Bureau of Mines, Mineral Industry Surveys, Coal-Bituminous and Lignite Annual, 1964-75, Prepared in Division of Fuels Data and Division of Coal.

Jigs are applicable to a wide range of coal sizes. In the past, they have even been applied to raw feeds having chunks as big as 10 inches. However, they are most practically used on top sizes of 3 to 6 inches. The major limitations of the jig are that the amount of near gravity material should not exceed 10% and they are most efficient at high separating gravities of 1.5 or more. As a general rule, jigs can effect reasonably good separations on sizes down to ¼ inch and produce limited results on coal sizes as small as 48 mesh.

In the foregoing text and for the balance of this section, reference is made to the ability of a jig to effect a separation at a certain specific gravity. Although technically incorrect, one common simplification of this subject is to think of the jig producing a clean coal ("float") having the same ash and sulfur content as that part of the feed to the jig which would float on a solution having that particular specific gravity. In other words, if the specific gravity analysis (float-sink test) of the feed to the jig shows that the ash and sulfur contents of the float at 1.6 specific gravity are 10% and 1%, respectively, then the jig is said to be effecting a separation at 1.6 if its product has similar ash and sulfur contents. This approach gives a very rough approximation of the actual specific gravity of separation, since it does not consider the amount of float 1.6 (misplaced product) in the sink 1.6 and vice versa.

As stated above, jigging is a process to stratify a bed of particles according to their density. This is accomplished by alternate expansion and compaction of the bed of particles in a pulsating fluid flow which encourages the higher density particles to migrate toward the bottom of the bed and the lower density particles to move toward the upper portion of the bed . This density stratification is accomplished in spite of the great differences in size and shape of the particles. To better understand the mechanics of this process, the reader is referred to the cutaway views of a Baum jig presented in Figure 2-15.

This particular jig is a five cell, two compartment model, produced by the Jeffrey Manufacturing Division of Dresser Industries. In the front view, the inside of the first compartment is shown which consists of two cells. Although not visible in the drawing, the second compartment has three cells which perform the same functions. As the slurry of raw

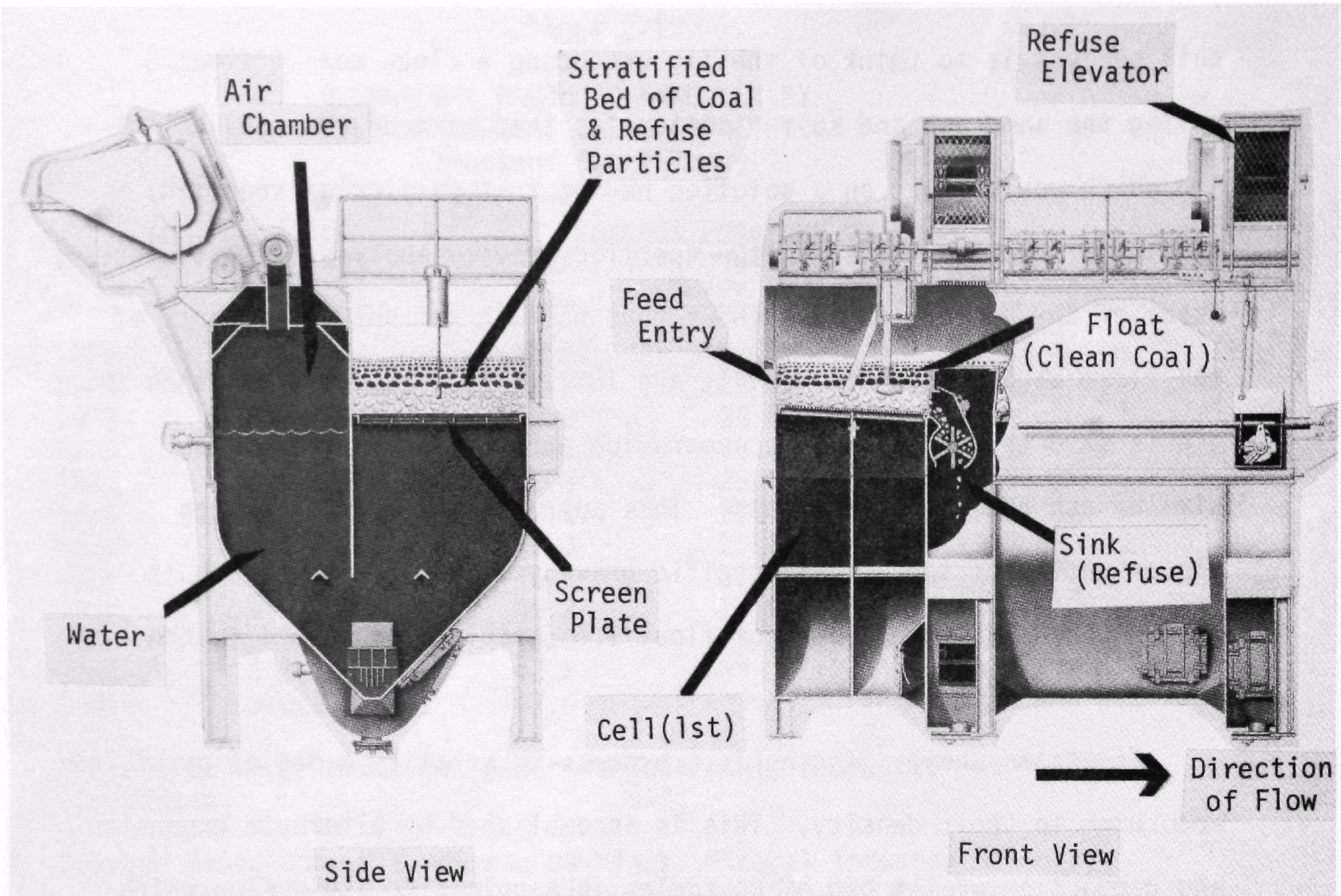


FIGURE 2-15
CUTAWAY VIEWS OF BAUM JIG

feed enters the jig, water is forced up through the bed of coal and accompanying refuse. This force is sufficient to lift the bed and "open it up" in suspension in the water. Then, the external force pushing the water up through the bed is quickly removed and gravity creates the force to pull the water back through the bed to encourage the stratification of the particles in the bed according to their density as discussed earlier. Looking at the side view of Figure 2-15 which is a cross-section of any of the five cells, one can get a feel for how these upward and downward currents of water are created. A blast of air in the air chamber forces water up through the screen plate in that cell. This action is referred to as the pulsion stroke of the jig. As this air pressure is quickly released, the water is permitted to return to its natural level just below the screen plate. This action is referred to as the suction stroke since as the pressure in the air chamber is released, the water is somewhat pulled back through the bed comparable to the action of a suction pump. The completion of the pulsion and suction strokes is considered a cycle. In a Baum jig, the speed may be adjusted to the particular requirement but nominally each cell operates around 22 cycles per minute. Although the cells in each compartment operate together, they are sequenced with the cells in the other compartments to permit the build-up of adequate pressure before opening the valve into the air chamber.

As the bed of particles moves along the screen plate in each compartment, the heavier material will sink to the bottom of the bed. At the end of each compartment, this bottom layer is drawn off as reject through a gate and then picked up in a bucket elevator having perforated baskets for partial dewatering. The material in the upper layer of the bed passes over ("floats") to the next compartment where a further separation is effected. That material which "floats" through all jig compartments is the product from the jig. Depending upon the sophistication of the particular cleaning process, the reject from the last compartment, sometimes referred to as middlings, may be reclaimed for further treatment.

Jigs are sized to the particular coal cleaning requirement on the basis of tons of feed per hour per square foot of effective jigging area. Specifically, this is the area of the screen plates over which the bed moves. This capacity is influenced by three factors relative to the make-up of the feed. In the following order, these are:

1. Percent of Near Gravity Material
2. Percent of Fine Material (¼ in. X 0)
3. Refuse Volume

The first two factors are especially critical to the performance of the jig. When the near gravity material is 10% or less, a relatively "black and white" separation exists. However, over 10% near-gravity material presents a more difficult washing situation. A very close second to the percent of near-gravity material is the amount of fine material in the feed as determined by screen analysis. When the jig is fed more than one ton per hour per square foot of jigging area of 1/4 inch X 0 material there is not as sharp a separation. If this guideline on fines is observed and the percent of near gravity material is not over 10%, up to 5 tons per hour per square foot of jigging area may be fed to a typical Baum jig. How these factors affect capacity can be observed in the following example:

Given:

Raw Coal Feed: 400 tph of 5 in. x 0
Near Gravity Material at Washing Gravity: 5 - 10%
Percentage of ¼ in. x 0: 25%
Refuse Volume: Not sufficient to be a limiting factor

Solution:

Based upon near gravity material percentage of 10% or less, jig should be able to handle 5 tons per hour per square foot of jigging area or 80 square feet would be sufficient. However, since 25% of the feed is 1/4 inch X 0, or 100 tph, 100 square feet of jigging area should be available to meet the 1 ton per hour per square foot test.

Therefore, a jig having a minimum of 100 square feet of jigging area is sufficient to handle the 400 tph.

Baum jigs are produced by a few major companies in this country and come in a variety of standard sizes. Some indication of the larger sizes available and their cost is given by the following list of F.O.B. factory prices of Jeffrey Manufacturing's Baum jigs:

Width of Screen Plate	Number of Compartments	Number of Cells	Jigging Area	Nominal Capacity	Price*
6	2	4	72 ft^2	350 tph	$107-118,000
7	2	5	105 ft^2	500 tph	$125-140,000
7	3	6	168 ft^2	800 tph	$168-185,000

*Based upon mid-1977 price quotations.

For the purpose of estimating the installed price of a piece of equipment of this type, a number of between 2.5 and 3 times the F.O.B. factory price gives a reasonable approximation. In those coal preparation circuits considered under Section 5.0 of this study, the above pricing/capacity relationships were observed.

Batac Jig -

A modified form of the Baum type jig is the Batac jig which is manufactured in this country by the Roberts and Schaefer Company under exclusive license from Humboldt Wedag in Germany. Normally, the Batac jig is intended for use in cleaning finer size coal having a top size of around 3/4 inch. These jigs come in various configurations depending upon the feed rate, washability, density, and grading of the raw coal. The length of the jig bed and its subdivision depends on the percentage of heavy product or the number of separation cuts, whereas the feed rate generally determines the bed width.

The Batac jig is considered a hydropneumatic device which differs in several ways from the conventional Baum jig. A few of these differences are:

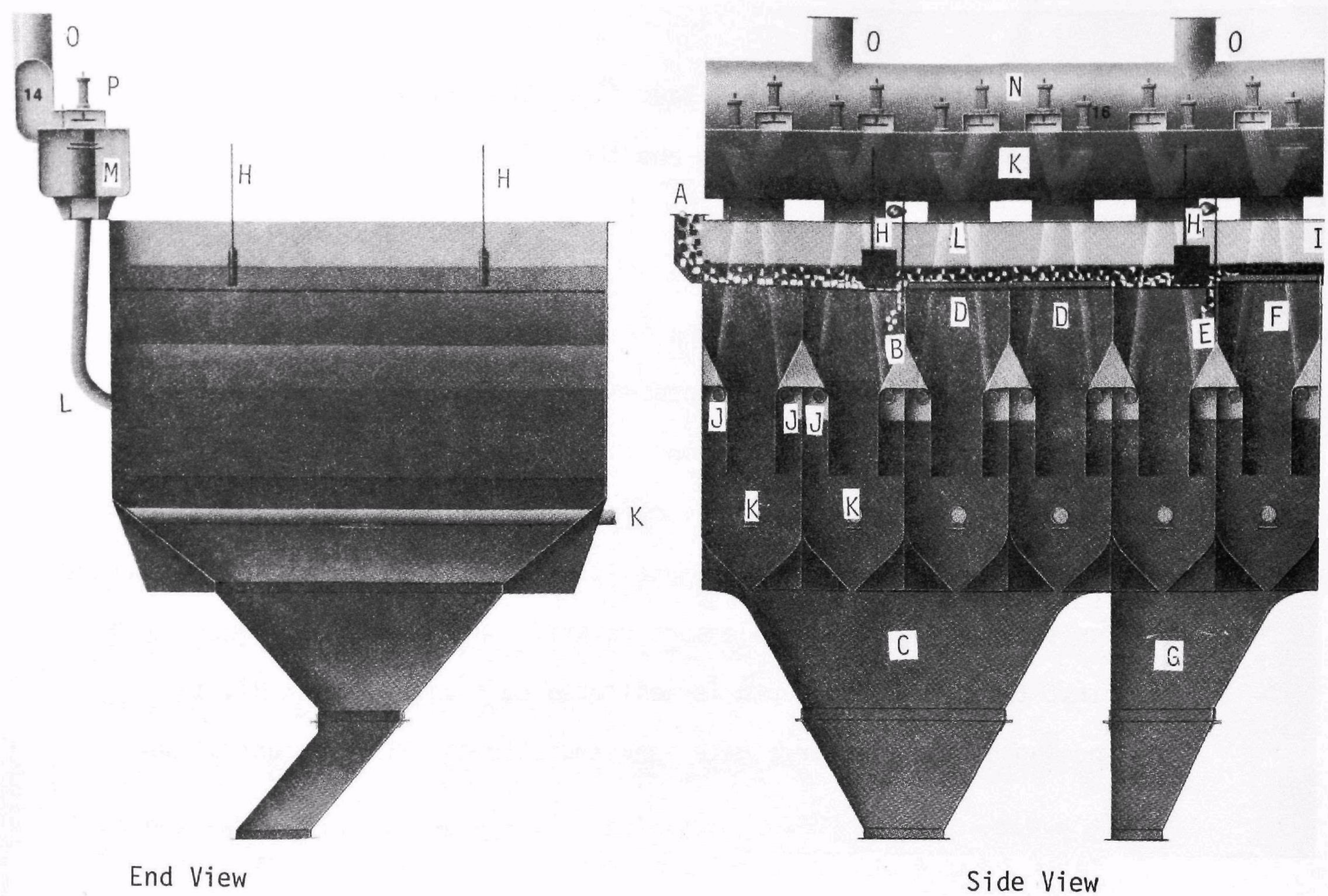
1. Pulsations are produced directly beneath the bed screen (instead of in an adjacent chamber), in multiple chambers distributed uniformly throughout the jig. Air pulses in each chamber are controlled independently.
2. Instead of moving a large volume of water, with its attendant slow-surge characteristics, the multiple chambers in the Batac jig each move a small volume of water, allowing rapid initial surge, and precisely controlled frequency and shape of the jig stroke.

According to the manufacturer, the Batac jig can be designed with wider beds thus providing significantly higher throughput in the same space required by a conventional Baum jig. This is possible because of its improved operating efficiency and the elimination of the adjacent air chamber.

The general configuration of a Batac jig is presented in Figure 2-16 along with an identification of the major components. Using this Figure as a reference, the raw coal is introduced over the full width of the jig bed as shown by point A. Pulsations in the first two cells separate the coal and middlings from the coarse refuse, forming separate layers of these materials. The layer of heavy refuse is discharged at the end of the second cell as shown by point B. To ensure relative purity of the product leaving the first two cells, bed depth is monitored constantly (point H), and the opening of the discharge gate adjusted automatically to control bed depth.

Cells 3 and 4 utilize a feldspar bed to carry the coal, middlings and fine refuse which pass over the bridge plate from cell 2. Because the jig bed screen in these two cells is large (16 mm), as the feldspar bed lifts and separates in response to water surges, the fine refuse sifts down through the bed and screen (point D). By the time the incoming product reaches the end of cell 4, only coal and middlings remain, and these pass over a bridge into cell 5.

Cell 5 operates much the same as cell 2, with the coarser middlings serving as the jig bed, and being discharged through a controlled-size gate at the end of the cell (point E). Finer middlings, together with coarse and fine clean coal pass over another bridge into cell 6. In cell 6, with its feldspar bed, fine middlings are discharged through the bed and screen (point F), leaving clean coal to flow out of the jig (point I) onto dewatering equipment.



Major Components -

A. Raw coal inlet
B. Coarse refuse discharge
C. Refuse Collecting hopper
D. Fine refuse discharge
E. Coarse middling product discharge
F. Fine middling product discharge
G. Middling product collecting hopper
H. Bed depth sensors
I. Clean, washed coal outlet
J. Air chambers
K. Water inlets
L. Air distributing pipes
M. Air distribution chamber
N. Exhaust air collecting chamber
O. Exhaust air pipes
P. Valve control

Figure 2-16

CUTAWAY VIEWS OF BATAC JIG

The air inlet and outlet valves for the surge chambers (point J) under the Batac jig are operated by air cylinders and quick air releases to get the necessary rapid actuation. Air cylinders, in turn, are actuated by solenoid-controlled air valves (point P). Sequencing of these valves, and the air releases is controlled by solid-state electronic circuitry mounted on removable panels in the master control panel. Panels are "programmed" for the particular material being handled, so that only a substitution of these panels is ordinarily required to modify operation of the jig for differing materials.

Based upon a high volatile 3/4 X 0 raw coal having 15% to 20% 28 mesh X 0 material, the following capacities, requirements, and costs are presented as a function of the three standard Batac jig widths.

Bed Width in Meters	Maximum Feed Rate TPH	Jigging Area Sq Meters	Water Supply GPM 1]	Jigging Air CFM 2]	Approximate Total Horsepower	Approximate F.O.B. Factory Price 3] 1st Qtr. 1977
3	360	18	3,600	2,800	275	$560,000
4	480	24	4,800	3,800	330	$585,000
5	600	30	6,000	4,800	340	$610,000

1] At 11.4 psig pressure measured at the inlet header for raw coal feeds containing not more than 35% refuse material.

2] At 6.4 psig measured at the jigging air distribution chamber.

3] Includes the Batac, Jigging Air Supply Blower, Control Air Compressor, and Refuse and Middlings disposal elevators.

The maximum feed rates will be less as the top size is reduced and/or the percentage of minus 28 mesh material in the feed increases.

Under Section 5.0 of this report, a preparation plant (Example 4) is considered which includes two Batac jigs in its fine cleaning circuit.

2.2.4 Heavy Media Vessels

As the name implies, heavy media vessels effect a separation of coal from the accompanying refuse by creating a medium having a specific gravity equivalent to the desired specific gravity of separation. This establishes an environment which encourages the coal to float and the heavier refuse to sink in a manner which closely simulates that predicted by specific gravity (float-sink) analysis. As mentioned earlier, heavy media vessels can perform a relatively sharp separation by accurately controlling the amount of magnetite in the solution. Normally, vessels of this type are used on coarser size fractions down to ¼ inch. Although more expensive to install and maintain than a Baum jig of comparable capacity, heavy media vessels can show economic advantage with coals having a large percentage of near gravity material necessitating a sharper degree of separation. The initial cost of this category of equipment is higher since in addition to the vessel itself, it is necessary to have adequate circuitry to recover for reuse the expensive heavy media (magnetite). This not only includes magnetic separators and the associated pumping, piping, etc., but also the equipment used to monitor and maintain the proper density of magnetite in the vessel's circulating medium. Operating costs are also higher than comparable capacity Baum jig cleaning circuits due to the cost of the magnetite lost in the washing process in addition to the greater amount of equipment requiring power and periodic maintenance.

Heavy media vessels are manufactured by several companies in this country and come in a variety of sizes and configurations. The major differences in these equipments relate to the methods used for introducing the raw feed into the washer as well as recovering and discharging the float and sink products. Large scale washers can handle raw feeds approaching 800 tons per hour. One such larger unit is the Daniels Precision Washer. This has a trough type design utilizing a transverse flow where the feed to the vessel and the discharge of the product are transverse to the direction of the flight conveyor which collects and rejects the refuse. Another unique feature of this equipment is the submergence baffle which immediately forces the feed to the vessel under the surface of the medium (water and magnetite) where the actual separation occurs. As the float material rises to the surface it overflows the side of the tank. Figure 2-17 is a top view of this equipment clearly showing the rectangular conveyor which collects the refuse off the bottom of the tank and discharges it at the far end of the vessel.

As would be expected, the cost of heavy media vessels varies with capacity. However, the price is most sensitive to the particular style. For example, a drum type separator manufactured by the WEMCO Division of Envirotech Corporation which is capable of handling a feed of 500 tons per hour (tph) costs $125,000. A 500 tph capacity Barvoy heavy media vessel manufactured by the Roberts and Schaefer Company costs less than $50,000 as of mid-1977. Obviously, each of these units has its own unique features which make it more or less advantageous under varying coal preparation requirements and conditions. The point to be made here is that there is no single price per ton of capacity appropriate for estimating the cost of this particular category of cleaning equipment. This being the case, the prices used for approximating the capital cost of the heavy media vessels appearing in the preparation plants considered under Section 5.0 of this study were based on specific quotes.

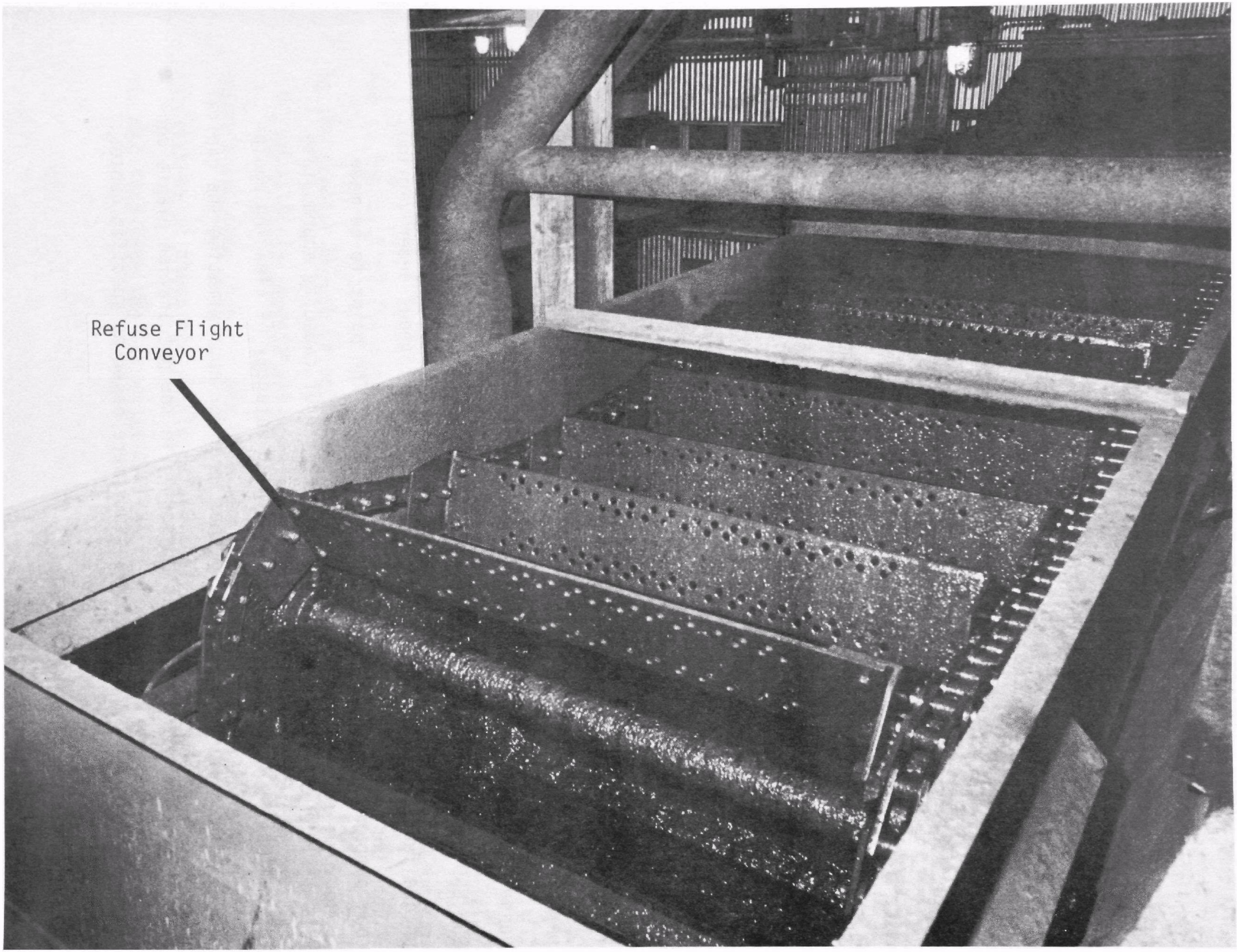


FIGURE 2-17
DANIELS HEAVY MEDIA PRECISION WASHER

2.2.5 Cyclones

Essentially, the cyclone is a hydraulic centrifuge working on the vortex principle. The slurry of coal may be pumped or fed by gravity to this device. When properly applied, this versatile piece of equipment can be an efficient part of the coal preparation plant. Cyclones provide a wide range of functions in a variety of coal preparation circuits. These functions fall into three major categories:

1) Size Separation - Performed by the classifying cyclone.
2) Dewatering - Performed by the thickening cyclone.
3) Separation of Refuse from Coal - Performed by either a heavy media or water-only (hydro) cyclone.

The size and number of cyclones in any given preparation circuit will vary with the specific application. The size of a cyclone is determined by the physical and chemical nature of the coal slurry to be processed as well as its volume and desired performance. This performance is influenced by such factors as:

1) Solids concentration of the feed.
2) Size distribution and specific gravity of the solids.
3) Desired classification size.
4) Required concentration of underflow and dilution of overflow.

Depending upon the application, cyclones come in a range of sizes and shapes up to 30 inches in diameter. The initial cost of any given type and size cyclone will vary significantly based upon the selection of the lining. These replaceable linings are selected on the basis of their wear resistant qualities. A proper selection of lining to meet the conditions of corrosion and abrasion can aid in reducing maintenance costs. Liners of urethane, ceramic, rubber, Nihard, and other materials are offered by such cyclone manufacturers as Heyl & Patterson and Krebs Engineers. For more abrasive applications all ceramic lining is appropriate. Where less abrasive coal slurry is being fed to the cyclone, a combination of urethane and ceramic lining may be all that is necessary. This concept of using a combination of linings cost-effectively addresses the specifics of the wear factors actually being experienced in various portions of the cyclone. As an example, urethane may be employed to line the upper portions of the cyclone where less wear is experienced, while the extreme abrasion resistance of ceramic is most appropriate in the lower portions. The use of combination linings is made possible by a sectionalized construction where the metal housings are fitted with replaceable linings. This sectionalized approach not only permits an effective matching of lining material to subjected abrasion, but also yields cost savings by eliminating the need to replace the entire lining when only a portion is worn.

When cyclones with expensive wear resistant liners were first introduced, there was a reluctance on the part of industry to adopt them due to high initial cost. This cost can be as much as twice that of a comparable capacity unit. However, over the past eight years, their proven record of reducing long term maintenance costs has brought about acceptance. As a result, the major cyclone manufacturers are now employing this concept of using better grade linings and combinations thereof in spite of their initial higher cost.

Even though significant advances have been made in the construction and application of cyclones used by the coal cleaning industry, it is difficult to get accurate maintenance cost data. Such costs are greatly influenced by the manner in which other portions of the plant are maintained. Specifically, if proper care is taken of the equipment "upstream" from the cyclones, then the feed is consistent with the design and lining. However, improper care such as when screens are not properly maintained, can result in a much coarser feed entering the cyclone and rapidly accelerating wear on the lining.

Heavy Media Cyclones -

Heavy media cyclones can perform an effective and efficient cleaning of intermediate size coals. In these cases where there are large amounts of near gravity material and/or the desired specific gravity of separation is low, these devices play critical roles. These devices provide a degree of operational flexibility in that you may readily vary the specific gravity of separation over a wide range. As the name implies, the separation achieved by these devices is principally controlled by the specific gravity of the medium which in practice ranges between 1.35 to 1.80. In almost all cases this medium is a suspension of magnetite and water. The feed to this type of cyclone may be pumped or gravity fed. Although a heavy media cyclone is normally mounted in the inclined position as shown in Figure 2-18, it is capable of operating in the upright position as well. (The particular heavy media cyclone shown in Figure 2-18 is manufactured by Heyl & Patterson, Inc.).

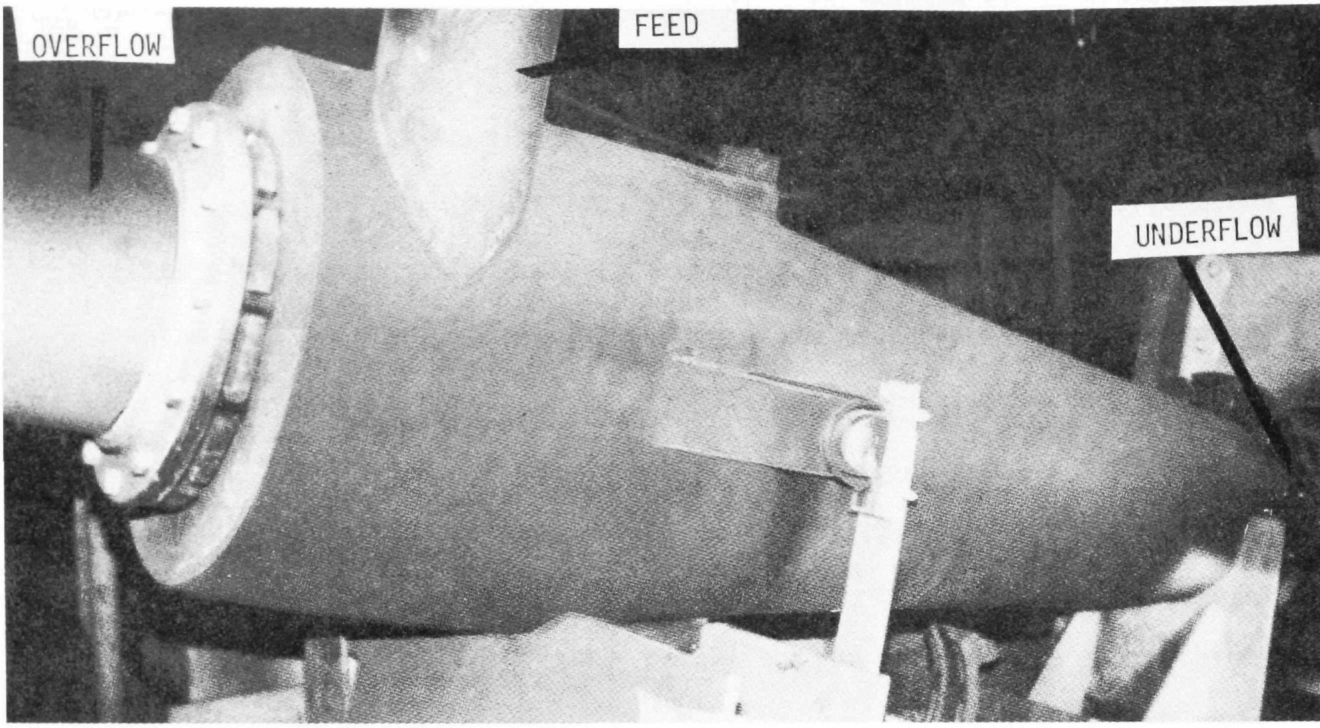


FIGURE 2-18
HEAVY MEDIA CYCLONE IN INCLINED POSITION

To better understand the workings of heavy media cyclones, the reader is referred to Figure 2-19, which is a cutaway view of a washing cyclone. A slurry of water, coal, refuse, and magnetite is fed tangentially into the conically shaped body of the cyclone. As this slurry is carried around the feed chamber, specific gravity differentials are set up which vary from the air core to the cone wall and from the bottom of the vortex finder to the apex of the cone. These differentials create an environment which encourages the lighter particles in the slurry to move toward the core. Conversely, the heavy materials are encouraged to stay against the cone wall, or if caught in the central low gravity section of the cone near

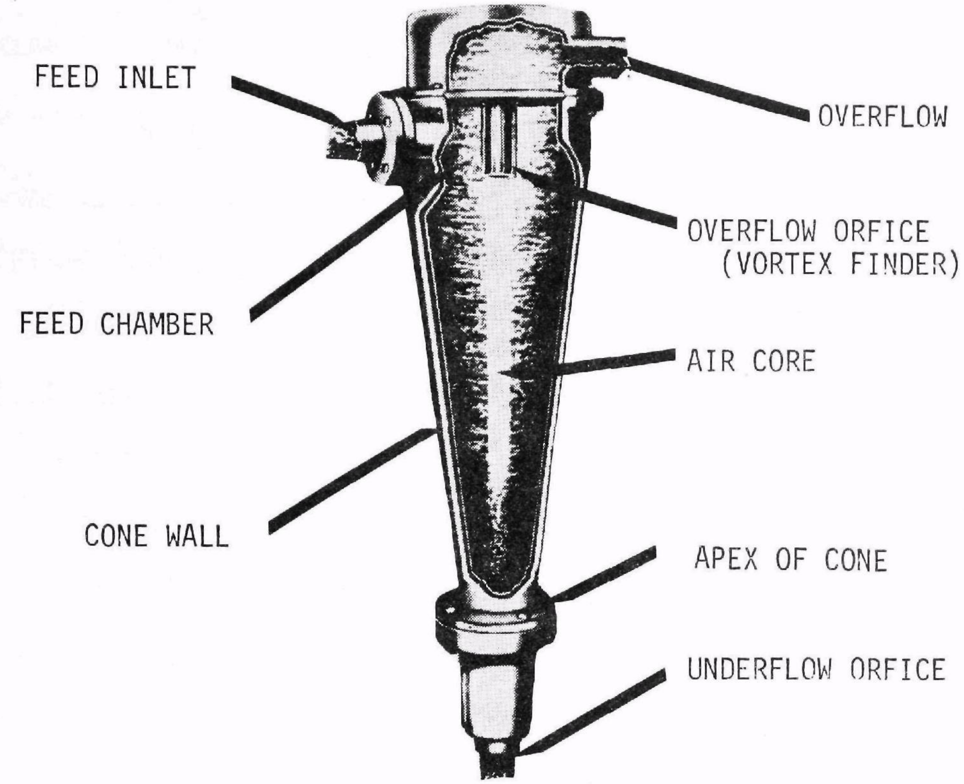


FIGURE 2-19

CUTAWAY VIEW OF OPERATING CYCLONE

the air core to quickly sink away toward the wall. These specific gravity differences and centrifugal effects within the rotating mass of magnetite, water, and solids are responsible for a relatively sharp separation of coal and refuse. Heavy media cyclones come in a variety of sizes up to thirty inches in diameter and several types of linings are available with varying degrees of wear resistance. There are slight design variances among manufacturers, each claiming superior performance characteristics.

Water-Only Cyclones -

Commonly referred to as hydrocyclones, water-only cyclones are gravimetric separators used to sort particles of coal and accompanying refuse according to specific gravity using only water and centrifugal force. Although it may be applied as an independent cleaning unit, this type of cyclone is a particularly valuable processing tool when used in multiple stages or in conjunction with other washing equipment. As shown in Figure 2-20, which is a bank of Heyl and Patterson hydrocyclones, this type of cyclone has a cylindrically shaped body with a conical bottom. It differs from the typical heavy

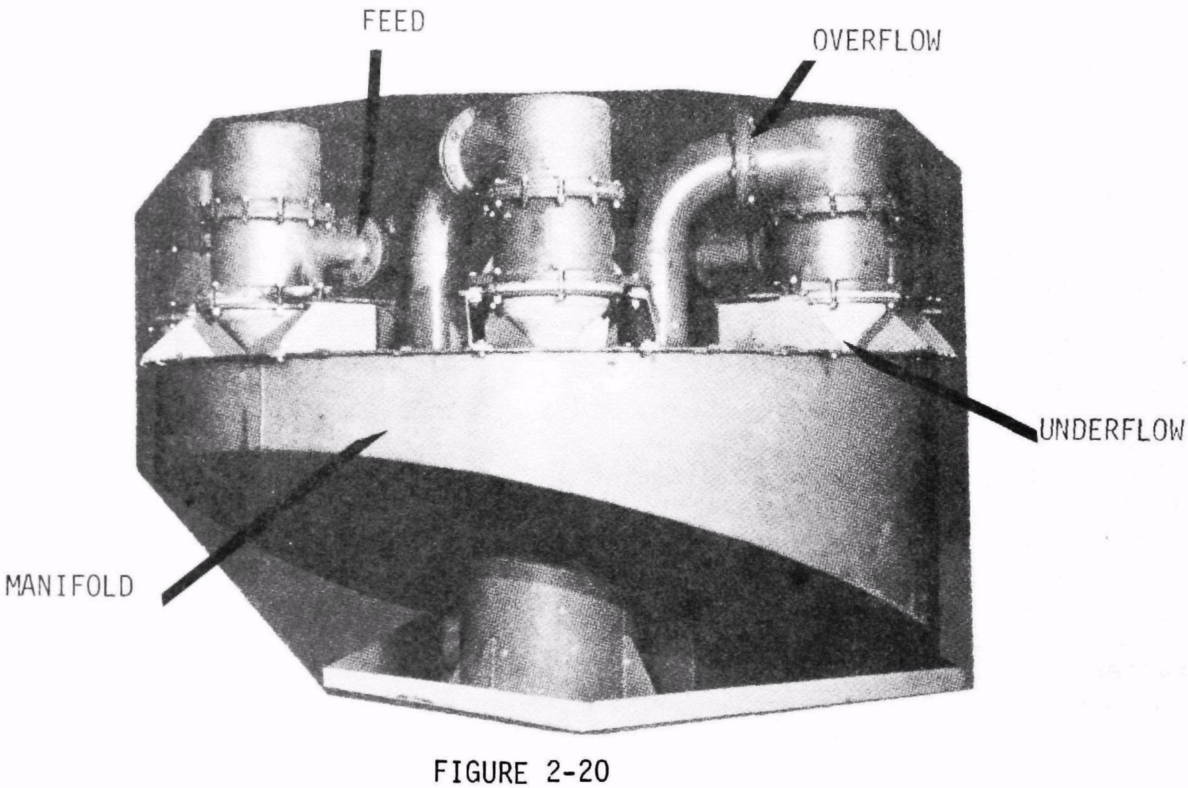


FIGURE 2-20
WATER-ONLY CYCLONE INSTALLATION

media washing cyclone in that it is short and stubby as opposed to a long tapered conical appearance. Additionally, the water-only cyclone has an adjustable vortex finder which is longer and also has larger overflow openings for a given diameter than other type cyclones. There are other design variations depending upon the manufacturer.

From an operational standpoint, the raw feed enters the cyclone tangential to the feed chamber where separation occurs. As in the case of the heavy media cyclone, the lighter particles report up through the vortex finder and exit through the larger overflow opening at the top of the cyclone. The heavier particles (refuse) exit through the opening in the center (apex) at the bottom of the cyclone. The diameter of a water-only cyclone is principally selected on the basis of the size of the coal and the efficiency required. In general, the smaller the particle size, the smaller will be the required diameter. For intermediate size coal, diameters of between 12 and 30 inches are selected as appropriate. Finer sizes are handled by units of 8 to 14 inches in diameter. One popular application is to use 12 or 14 inch hydrocyclones on the 28 x 100 mesh size fraction in combination with froth flotation because of their ability to remove pyrite particles and the difficulty in floating this size.

Other design features which influence performance include: 1) vertical clearance between lower edge of the vortex finder and the cyclone bottom; 2) diameter of the vortex finder; 3)apex diameter; 4) solids concentration in the feed to the cyclone; and 5) pressure at the feed inlet. The particular specific gravity at which the water-only cyclone effects a separation is determined by varying the dimensions of the discharge orifices. This specific gravity of separation is decreased as the diameter of the vortex finder is decreased or the apex diameter is increased. As would be expected, this same result occurs as the vertical clearance between the lower edge of the vortex finder and the cyclone bottom is increased. This latter type of adjustment is made simpler and more precise by water-only cyclones with hydraulic vortex finder lift mechanisms.

Also affecting the operating specific gravity of separation is the solids concentration. This concentration is directly scaled to the hydrocyclone diameter; the smaller the diameter, the lower the percent solids. Normally, this concentration is between 8% and 15% by weight. As the concentration is increased, the specific gravity of separation also increases. This is a critical operating parameter since if feed concentrations are too high or low, undesirable results occur. Specifically, too high a percentage of solids results in increased particle interaction and thus less accurate separation of coal and refuse. At the other end, too low a percentage of solids will also injure performance because the hydrocyclone will begin to separate on the basis of particle size like a classifying cyclone resulting in excessive amounts of misplaced coal.

As long as there is adequate feed pressure to generate a vortex, changing the inlet pressure apparently has little impact on the performance of the water-only cyclone. By increasing the pressure, there will be a slight elevation in the specific gravity of separation as well as the processing capacity. However, it is not recommended as an economical means to achieve this latter objective since such increased pressure accelerates wear on the cyclone lining. As a general rule, the following minimum inlet pressure relations apply:

Cyclone Diameter	Maximum Feed Size	Dry Feed Rate	Inlet Pressure	Maximum % Solids
8	28 mesh	3-5 tph	8 psi	8-10
10	10 mesh	4-8 tph	10 psi	10
12	¼ inch	8-16 tph	12 psi	10-15
15	¼ inch	15-25 tph	12 psi	12
20	½ inch	25-45 tph	15 psi	15
24	3/4 inch	40-70 tph	15 psi	15
26	3/4 inch	50-90 tph	15 psi	20

According to an article by Ellis J. O'Brien of Dravo which appeared in the January 1976 issue of Coal Age, the pros and cons of water-only cyclones are summarized as follows:

Advantages

1. Simple design with no moving parts and little maintenance.
2. Once initial adjustments have been made, usually no further adjustments are necessary.
3. Operate with water only and without a heavy medium or reagent; therefore, heavy-media or reagent consumption is eliminated and no magnetite recovery system is needed.
4. Requires limited space for operations
5. Does not require pre-screening.
6. Will clean oxidized raw coal down to 100 mesh while flotation will not.

7. Will reduce pyritic sulfur more effectively from 28 mesh x 0 coal than flotation.

Disadvantages

1. Large quantities of water are required for proper operation of the hydrocyclone circuit, therefore more horsepower.
2. Separations obtained in a hydrocyclone aren't nearly as sharp as those characteristic of the dense-media cyclone or Deister table.
3. Not for difficult-to-clean coals.
4. Good refuse and a clean coal cannot be produced simultaneously from a single unit.

The prices of all types of cyclones vary with size, lining, and unique design features mostly influenced by the particular manufacturer. Since there is a multitude of size/lining/manufacturer combinations, it was necessary to obtain specific price quotations on those cyclones in the preparation plants addressed under Section 5.0. However, as a general rule for estimating the installed price of the cyclone portion of the coal preparation circuit, a figure of between 2 and 3 times the FOB factory price gives a reasonable approximation including necessary piping and manifolding. In the case of all ceramic linings the lower multiplier would apply and for the same cyclone having a less expensive lining, the higher figure would be appropriate. For heavy media cyclone installations, there will be the additional cost of the media control and recovery circuitry which adds appreciably to the total installed price.

2.2.6 Concentrating Tables

Commonly referred to just as "tables" or as Deister tables (the name of the principal domestic manufacturer), the concentrating table has a proven record of efficiently cleaning certain coals in a size range of 3/4 inch to zero. Tables cannot be adjusted to provide separations lower than 1.45 to 1.50 specific gravity. Like jigs, their separation efficiency is adversely affected when more than 10% near gravity material is present.

The concentrating table effects a separation of coal from the accompanying refuse according to size and specific gravity by flowing a mixture of coal and water over a vibrating table having a series of riffles. Basically, the table consists of a pair of steel channels upon which is mounted a rubber-covered deck and a drive mechanism. The flat, rhomboid-shaped deck is approximately 17 feet long on the clean-coal side and 8 feet long on the refuse side. It is supported in an essentially horizontal plane, but slopes enough (perpendicular to the motion of the deck) so that water fed along the upper long side will flow across the table surface and discharge along the lower clean-coal side. The deck is attached to a differential motion drive which gives it a quick return conveying motion, moving material lying on the table surface away from the drive end.

Attached to the rubber covering on the deck is a system of rubber riffles tapering toward the refuse end of the table and parallel to the direction of the conveying motion as shown in Figure 2-21. Standard body riffles are approximately ¼ inch high at the drive end of the table.

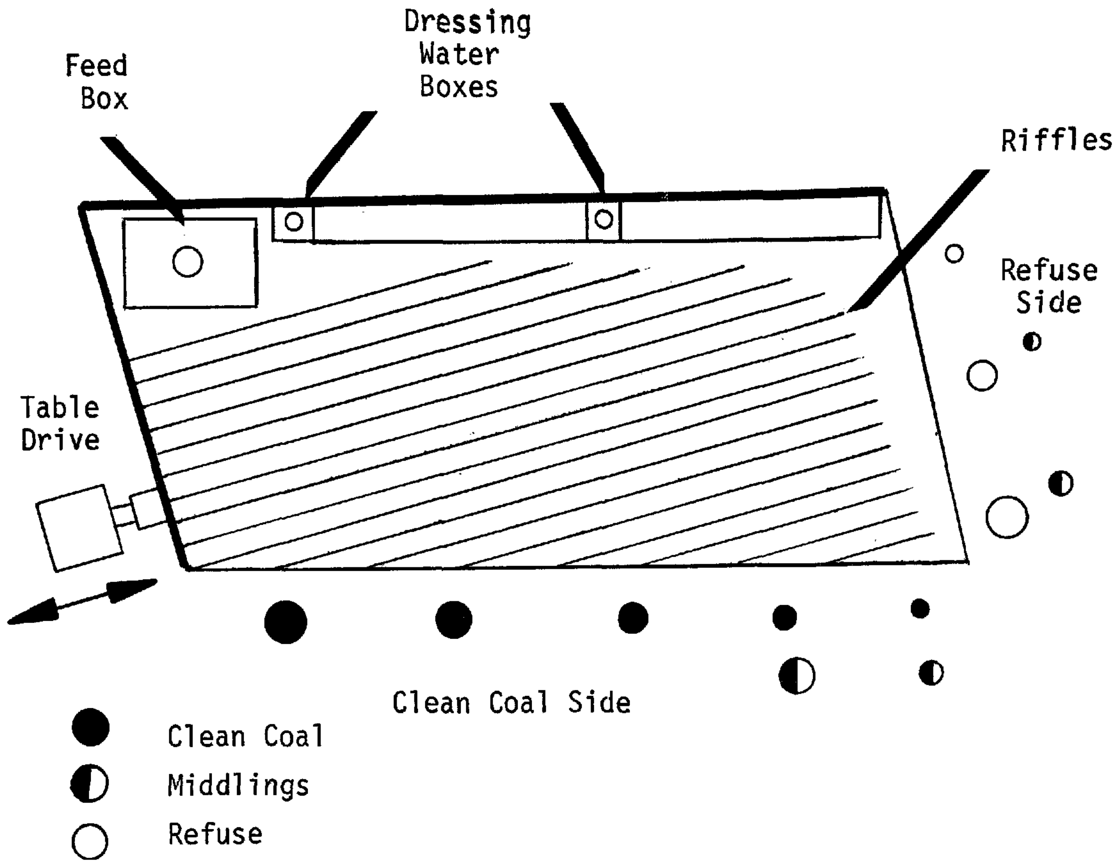


FIGURE 2-21

TOP VIEW OF CONCENTRATING TABLE WITH DISTRIBUTION
OF PRODUCTS BY SIZE

Between each set of three or four body riffles are high (over 1 inch at the drive end) "pool" riffles. These riffles form dams, behind which stratification of the bed occurs. Low-density particles ride over the riffles, reporting to the clean-coal side of the table; high-density particles are carried behind the riffles by the differential-motion drive to the refuse end of the table. At one corner of the long diagonal and above the deck is a feedbox with a slotted bottom to spread the feed onto the deck. Beside the feedbox and along that side of the deck is a trough, having adjustable gates through which the flow of dressing water is distributed to the deck.

Because of the reciprocating action of the table and the transverse flow of water, the feed fans out immediately upon contacting the table surface. The upward slope of the table toward the refuse end, usually 1/8 to ¼ inch per foot, and the retaining effect of the pool riffles cause the slurry to form a pool near the feedbox. In this pool, the bed of material is several particles deep and substantially above the standard riffles. This area becomes the zone of primary stratification. In this zone, the shaking motion of the deck combined with the cross current of water stratifies the particles by density, similar to the action of the jig washer described in Section 2.2.3.

The essence of table performance is the stratification according to size and specific gravity that occurs behind the riffles. This results from the differential shaking action of the deck. The particles that make up the feed become arranged so that the finer and heavier (more dense) particles are at the bottom and the coarser and lighter (less dense) particles are at the top. The finer, more dense particles are carried out by the table movement toward the refuse side at a faster rate than the coarser, more dense particles. The larger pieces of lower specific gravity ride on the top layer of particles and flow on down the slope of the deck reporting to the clean coal side. Such movement is encouraged by the cross flow of wash water at right angles to the shaking movement of the table. Since stratification and separation of particles are not complete as a result of any one riffle, a series of riffles is used, repeating the cycle of stratification and hindered settling from riffle to riffle, obtaining purer refuse products as the particles spread out and progress forward and downward over the table. Conversely, the purer, cleaner coal is discharged at the drive side of the table.

As presented in Figure 2-21, successive samples collected along the clean and refuse sides of the table, starting at the drive motor side, show a steady increase in ash content and a steady decrease in the average particle size for each individual specific gravity fraction.

Concentrating tables are provided with a number of adjustments which are used to obtain the best possible operation. Among these are: (1) reciprocating speed, (2) length of stroke, (3) feed rate, (4) amount and distribution of wash water, (5) water-to-solids ratio of the feed pulp, (6) uniformity of feed, (7) riffle design, (8) side tilt and (9) end elevation. The reciprocation of the deck usually is 260 to 290 strokes per minute depending on the characteristics of the raw coal and the feed rate. If there are high percentages of refuse in the raw coal or if the feed rate is high, an increase in the frequency is required.

Closely related to the frequency is the amplitude. The amplitude and frequency are varied to maintain the mobility of the bed necessary for stratification while retaining the coal on the deck long enough for proper separation. In order to move large quantities of refuse material along the deck, an amplitude as long as 1¼ inches may be required. Conversely, the stroke may be less than ½ inch long when coals containing high percentages of near-gravity material are washed. The amplitude and frequency of the stroke are decreased as the amount of near-gravity material in the feed increases. A nominal 3/8 inch x 0 feed would require a stroke amplitude of about 3/4 inch and frequency of 275 strokes per minute. Generally, a fine feed will require a higher speed and shorter stroke than a coarse feed.

The cross slope and amount and distribution of dressing water to the table can be changed easily and quickly to compensate for minor variations in feed rate and composition. The cross slope is generally less than 5 degrees, and the dressing water side of the table is higher than the clean-coal side. The feed dilution (water to solids ratio) used on a table washing 3/8 inch x 0 is 2 to 1. As the top size of the feed increases the water to solids ratio increases.

Perhaps the most important of all table adjustments is the end elevation or the amount of upward inclination of the deck measured along the line of motion from the feed end to the discharge end. By creating a moderate slope which the high specific gravity particles will climb more readily than will the low specific gravity material, the separation is greatly improved. The high specific gravity particles are forced to spread out in a thin, wide band which permits a much sharper separation to be made between clean coal, middling, and refuse products. The amount of end elevation increases with feed size and specific gravity. Typically, a 3/8 inch X 0 feed would require approximately 3 to 4 inches of end elevation depending upon the specific gravity of the refuse.

The capacity of a concentrating table is a function of the size consist, the percentage of reject, and the washability of the feed.

As a general rule, capacity increases directly with the size consist, limited by the percentage of reject above 20%. However, as the difficulty of cleaning decreases, feed rates can be increased. The majority of all installations treating bituminous coal are handling the 3/8 in. x 0 or ¼ in. x 0 size fractions. Most of the tables installed in recent years have a double-deck configuration.

The two major double-deck design configurations manufactured by the Deister Concentrator Company are the regular Concenco "88" Diagonal-Deck Coal Washing Table and the High Capacity Refuse Discharge (HCRD) version of the same. This latter configuration is designed for washing coals containing more than 20% reject. As depicted by Figure 2-22, the "88" series tables are built for suspension mounting via wire ropes in vertical pairs or in a four-deck stack arrangement. This arrange-

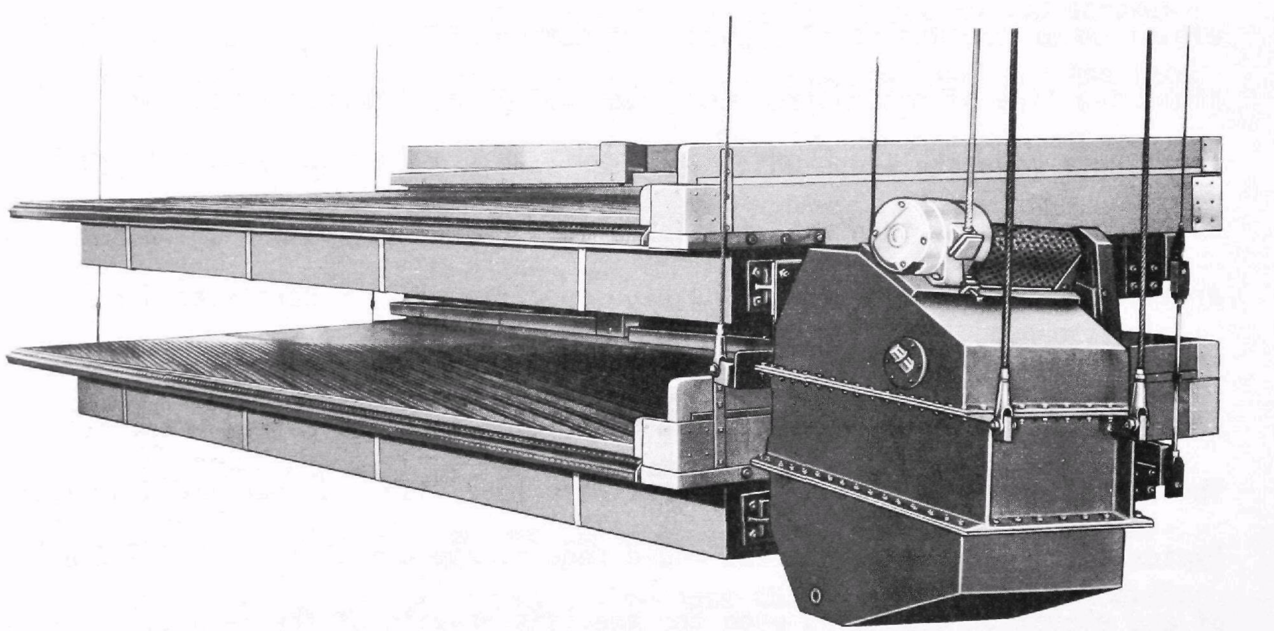


Figure 2-22

DOUBLE-DECK CONCENTRATING TABLE (DEISTER CONCENCO "88") ment eliminates to a large extent two of the major disadvantages of concentrating tables. Specifically, it reduces the floor space requirements and the need for shock absorptive mounting to handle the impact of the drive mechanisms. As a general rule, each twin-deck is capable of efficiently washing up to 25 tons per hour (tph) of ¼ x 0 or 30 tph of 3/4 x 0 feed containing less than 20% reject. The FOB factory price as of mid-1977 for the standard model twin-deck table was $18,326. The HCRD model is approximately $2,000 more per double-deck. Both prices include the necessary drive motor, mounting hardware, controls, and up to six days field service for start-up and demonstrating the satisfactory performance of the tables. In addition to the basic price of the tables, there is an additional hardware expense associated with the feed distributors. These devices divide the stream of slurry into predetermined amounts consistent with the capacity of the table. The primary importance of feed distributors is to assure uniform feed to all deck surfaces so that common table settings will provide consistent separating results. They come in stationary or revolving configurations which are selected on the basis of capacity and the required number of splits. As an indication of their cost, a stationary 8-way distributor sells for $2,500 and a comparable capacity revolving type has an F.O.B. factory price of $6,500. These prices were used for approximating the capital cost of those preparation plants considered under Section 5.0 where tables were part of the cleaning circuit.

2.2.7 Froth Flotation

As mentioned at the beginning of this section, froth flotation relies upon the surface chemistry of coal to effect a separation of coal from its accompanying refuse. This is the major process capable of cleaning particle sizes down to zero. To achieve this separation, frothing and conditioning reagents are added to a slurry of water and fine feed (coal and refuse particles). Then, as air is bubbled up through the slurry, the coal particles attach themselves to the bubbles and are carried to the surface where they can be collected as a concentrated overflow product. The refuse particles remain below the surface and are discharged at the underflow opening at the bottom of the vessel.

As shown in Figure 2-23, the froth flotation process is performed in large steel tanks having a series of compartments or cells. This picture clearly shows the coal laden froth floating at the top of each cell and the skimmers which remove this product. Each cell has its own agitating device at the bottom of the tank to keep the slurry in suspension and distribute the air bubbles. These agitating devices vary substantially among the several domestic manufacturers which include the Daniels Company, Denver Equipment Divison of Joy, Heyl & Patterson, and WEMCO Division of Envirotech. A slurry of coal, frother, conditioners, and water is fed into one end of the series or bank of cells. The solids concentration of this slurry will vary between 4% and 12%. A series of several cells is necessary in order to assure adequate time for the coal to come in contact with the air bubbles. The slurry moves from one cell to the other during which time that coal which has been floated to the surface overflows the edge of the cell as a concentrate of about 25% solids. This concentrate is normally routed to a vacuum

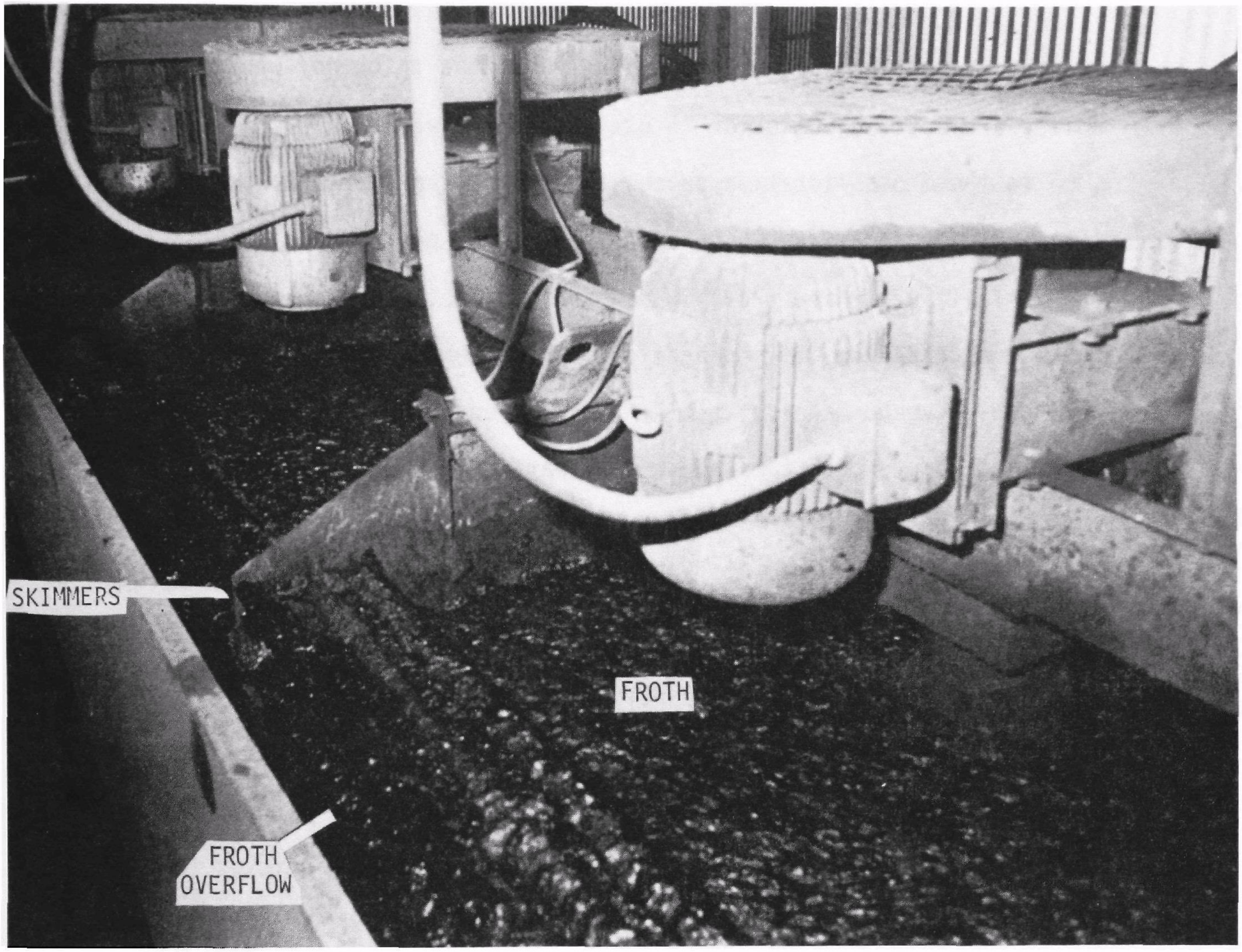


Figure 2-23

FROTH FLOTATION CELLS IN OPERATION

filter or other dewatering device before going to a thermal dryer for final moisture reduction. The non-coal particles also move from cell to cell but below the surface until they reach the far end of the tank. Here they are rejected through a discharge box or similar mechanism with the bulk of the vessels' fluid. In most of the preparation plants today, this high moisture reject product is routed to the static thickener where the solids are settled out prior to ultimate disposal.

In the froth flotation process, one of the significant expenses is the necessary additives which are essential to performance. These reagents fall into three groups which are: 1) frothers; 2) collectors or promoters; and 3) modifying agents. As the name implies, the frother or frothing agent makes possible the creation of a stable froth which will last long enough to support coal particles on the surface and hold them there until they are removed. MIBC (Methyl Isobutyl Carbinol) is the most common frother used today. Since these frothing agents are not recoverable, they must be carefully selected not only on the basis of their effectiveness with the particular coal but also their price. Also, as their name implies, the collectors or promoters perform the function of promoting contact between the coal particles and the air bubbles by selectively forming a thin coating over only the coal particles to make them water repellent. The most common substances used as collectors are fuel oil and keorsene. There are some newer reagents which have both frothing and collecting properties, thereby reducing the number of additives.

The final group of additives, the modifying reagents, perform a variety of functions as appropriate to the particular coal being treated. Within this classification are: depressing agents, activating agents, and pH regulators. Depressing agents are used to inhibit the flotation of non-coal particles by coating them so they will not adhere to the air bubbles picking up the coal. Substances used for this purpose include sodium and potassium cyanides which have proved effective on iron sulfide (pyrite) particles. Activating agents alter the surface chemistry of the coal so that it more readily responds to the filming action of the collector reagent. The pH regulator controls the degree of acidity or basicity of the flotation slurry. Establishing the proper pH level is a critical operating parameter which greatly influences the performance of the flotation process. When the pH is between 6 and 7.5, recovery of most coals is highest. As a general rule, the ash content of the froth increases with the pH, and the pyritic sulfur content goes down.

The price of froth flotation installations will vary with the size and number of cells as well as the manufacturer. Since each set or bank of cells has only one feed box where the slurry enters and one discharge chamber through which the refuse is rejected, there is not a simple per cell price for a given capacity installation. Therefore, it is necessary to price out the particular configuration. For example, one manufacturer offers a bank of three flotation cells, each having a volume of 300 cubic feet (nominally 15-20 tph of feed per cell) for $34,000 and a bank of four for $38,000. This latter configuration is offered by another firm for $35,000. Although the 300 cubic feet capacity cell seems to be the most popular, smaller cells of 100 cubic feet each and larger ones at 500 cubic feet are also used for treating bituminous coal. A four cell installation of 100 cubic feet per cell sells for $28,000 and the 500 cubic feet version sells for $45,000.

One manufacturer currently has a cell with 1000 cubic feet which is supposedly capable of handling up to 40 tons per hour of feed at a solids concentration of between 5% and 10%. These larger capacity cells have not been required to any great extent in the past since only a small percentage of the preparation plant feed normally is processed to this extent. However, as more larger fine coal plants are put into operation, there will be an increase in demand.

These mid-1977 F.O.B. factory prices were used to approximate the capital cost of the froth flotation portions of the coal preparation plants considered in Section 5.0. These prices are only the "tip of the iceberg" for a fully installed flotation system. This is because there are extensive pumping and piping requirements which add appreciably to the cost as well as the system for controlling the flow of necessary chemical additives. As a general rule, the total installed price will be slightly over three times the basic equipment cost.

2.3 Other Equipment and Facilities

Besides those major pieces of coal handling and storage equipment described in Section 2.1 and the cleaning equipment covered in the preceding section, there are other principal components of the modern coal preparation complex. Although a limited number of these facilities and equipment are located within the preparation plant, the majority are separate structures. Many of these other items play a critical role in the overall performance of the plant. These functions include dewatering of the clean coal and refuse products, water clarification, and accurate sampling of the clean coal at the end of the preparation process prior to shipment. In the following sub-sections, brief descriptions of these other items are presented along with their cost as a function of size and sophistication.

2.3.1 Dewatering Equipment

As covered previously, most physical coal preparation techniques employed today involve wet cleaning processes. During these processes, the clean coal and refuse products created pick up substantial moisture which must normally be reduced to some extent. In the case of the clean coal, the amount of dewatering required is a function of the purchase specification as well as the economic and practical realities of transporting and handling a high moisture commodity. Dewatering of refuse is a less defined issue since the preparation plant operator need only reduce the moisture content to the point where the material can be properly disposed. Since fine solids have a larger surface area per unit weight than coarser size fractions, they retain relatively more water and therefore necessitate the availability of greater dewatering capacity at the preparation plant. Depending upon the amount of finer coal and refuse generated by the particular process, the dewatering function can constitute a significant portion of the capital and operating cost of a plant. There are several forms of dewatering equipment which are applied as appropriate to the size consist of the material and the required final moisture content. These are categorized as centrifugal, vacuum filter, and thermal. Brief descriptions of these equipments and their cost is presented in the balance of this subsection.

2.3.1.1 Centrifugal Dewatering Equipment

As would be expected, this category of dewatering equipment performs its moisture reducing function by subjecting the wet material (coal or refuse) to centrifugal forces sufficient to drive out as much of the unwanted water as possible. The design objective of these machines is not only to reduce the moisture content of the feed but also to maximize its recovery with minimum degradation. Centrifugal dewatering equipment is offered in a range of sizes and configurations by a number of domestic manufacturers each having their own unique design features. However, the majority of this equipment can be categorized by the following types:

1. Vibrating Screen Basket (Horizontal and Vertical Types)
2. Scroll-Type
3. Screen Bowl Type
4. Solid Bowl Type

(1) Vibrating Screen Basket Type

Vibratory screen basket type centrifugal dryers are offered by several firms in horizontal and vertical designs. Figure 2-24 shows one such unit of the horizontal type manufactured by the WEMCO Division at Envirotech. As depicted by the cross-sectional view of the centrifuge

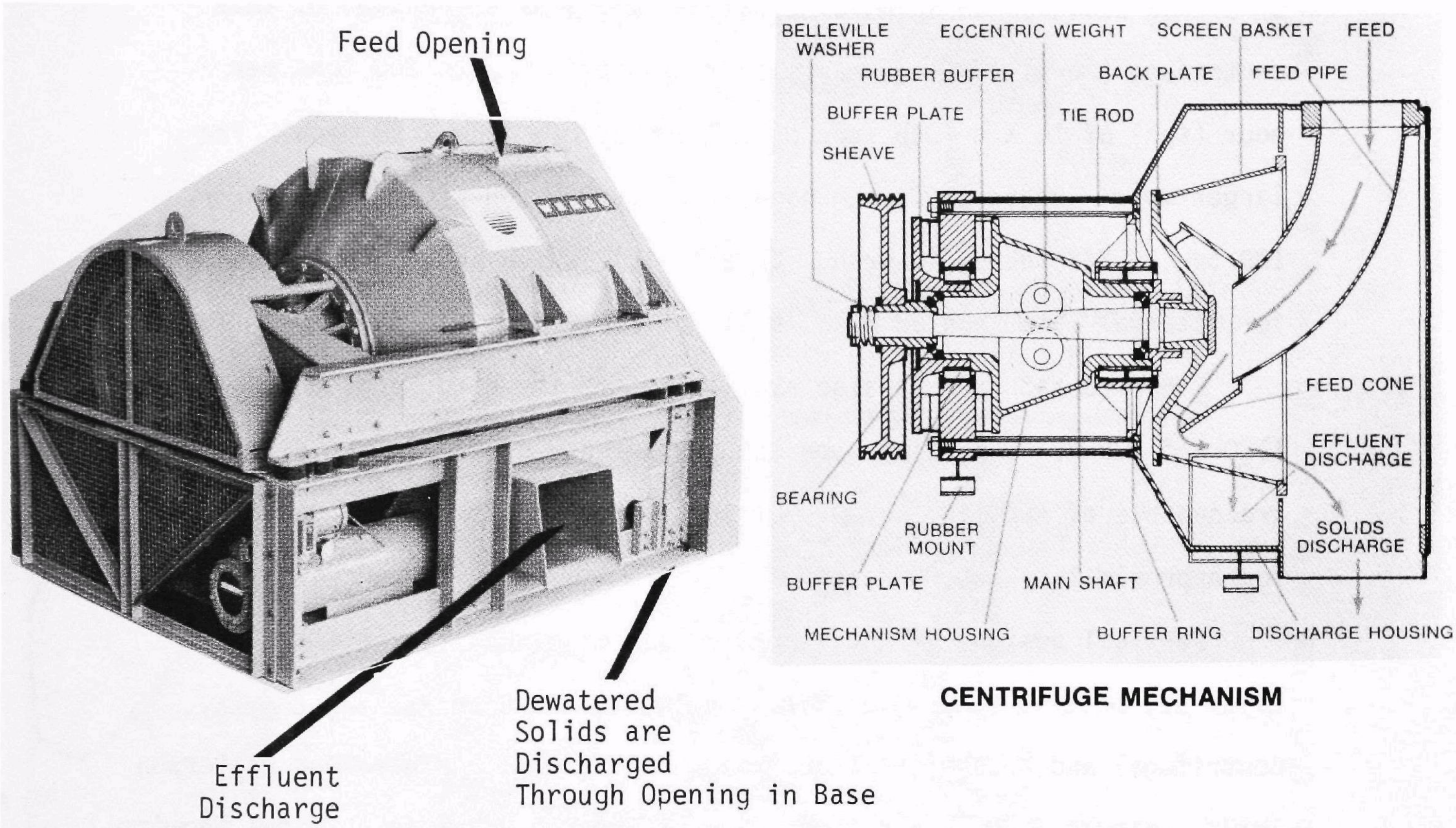


FIGURE 2-24

VIBRATING SCREEN BASKET CENTRIFUGAL DRYER-HORIZONTAL TYPE (WEMCO MODEL 1100)

mechanism, the material to be dewatered enters the small end of the revolving cone-shaped screen basket. The free moisture accompanying this material passes through the screen and the solids move outward along the surface of this cone-shaped screen until they are discharged over the edge of the basket. The vibratory action of this revolving basket, aids the dewatering process by breaking up the capillary cavities in the material. According to the manufacturer's data, this unit is capable of reducing the surface moisture of finer size coal from 30-35% to 8-9% and from 6-10% to 3% on coarser size fractions with product recoveries of 97% or better. In terms of capacity, the smaller version of this centrifuge (Model 1100) is capable of dewatering up to 200 tons per hour (tph) of 1¼ X ¼ inch feed or 120 tph of 3/8 inch X 28 mesh. The larger model (Model 1300) can handle nearly 300 tph of 1¼ X ¼ inch or 180 tph of 3/8 inch X 28 mesh. These units, which are not recommended for material less than 28 mesh, sell for $26,000 to $30,000 F.O.B. factory.

A horizontal type is also available from the Bird Machine Co. (Models 1150 and 1300). Depending upon the consistency of the feed, these units are capable of handling throughputs of up to 275 tph. These units sell for approximately $50,000 each.

Vertical designs of the vibrating screen basket type centrifugal dryer are offered by several firms including the Bird Machine Company, Centrifugal and Mechanical Industries, Inc. (CMI), and Heyl and Patterson (H&P). Figure 2-25 is a cutaway view of the H & P Hurricane Model showing how the slurry enters the feed chute at the top and plows down to a feed chamber where a rotating distributor deposits it on the rotating basket. At the same time as vertical vibrations are moving the material up the basket, centrifugal motion is forcing it outward against the basket screen. This process forces the free moisture through the screen where it is discharged. As dewatered solids reach the top of the basket,

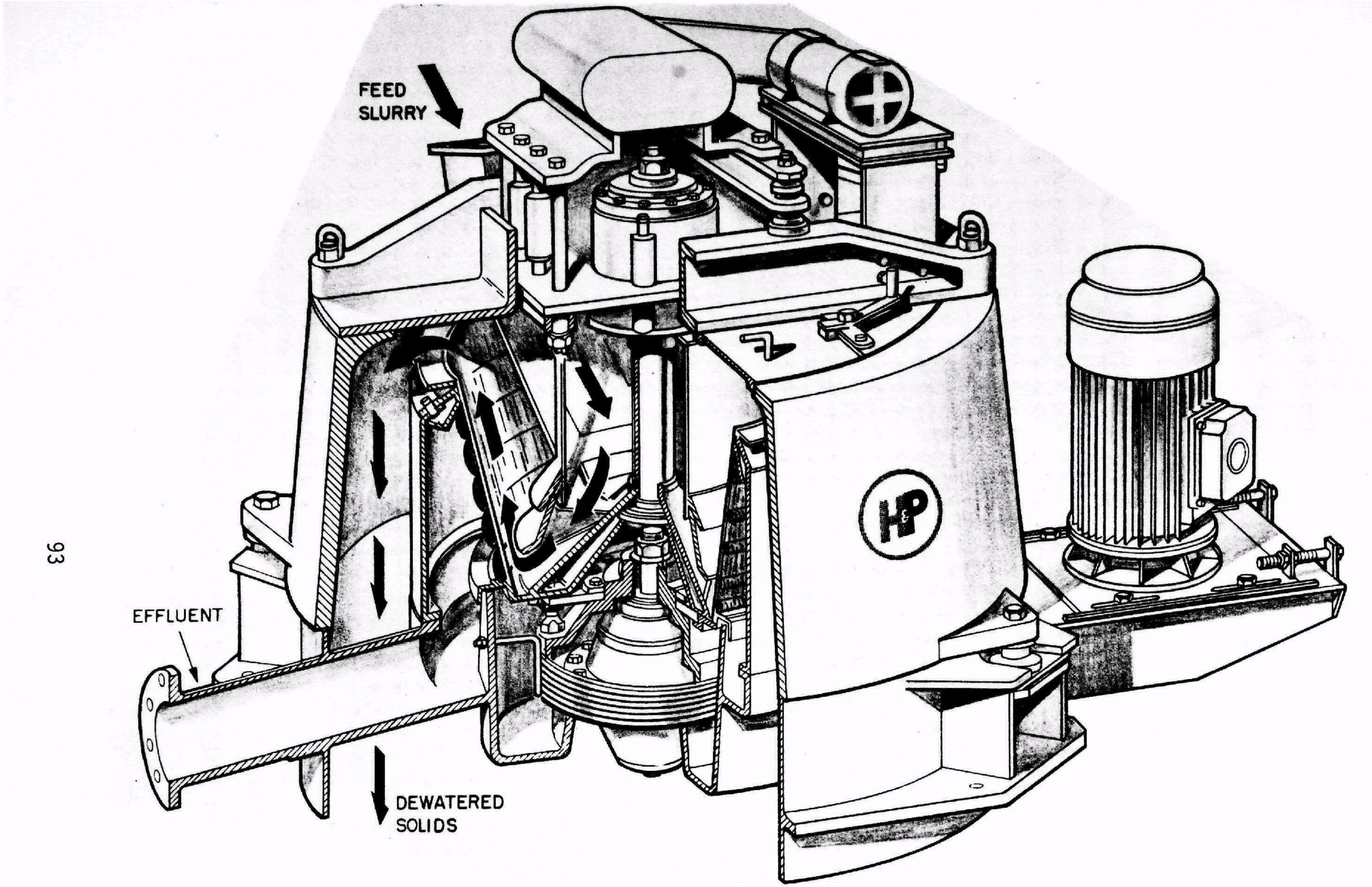


FIGURE 2-25

VIBRATING SCREEN BASKET CENTRIFUGAL DRYER-VERTICAL TYPE (H & P HURRICANE MODEL) they are discharged over the lip and fall through an opening in the base of the machine. As with all centrifugal dryers, the capacity of this machine varies with the consistency of the feed. According to the manufacturer, the Hurricane Model can reduce the moisture content of 150 tph of 1/4 inch X 48 mesh coal from over 20% to less than 6½%. Several manufacturers offer units of this type in a wide range of prices depending upon design features and quality of construction.

CMI also has a line of vertical type vibrating screen basket centrifugal dryers. These are the VC-48 and VC-56 models which have F.O.B. factory prices of $28,200 and $49,800, respectively. According to the manufacturer, these have the capacity and performance at various size fractions as presented in Table 2-2. This data is based upon feed moisture concentrations of 30% or less.

TABLE 2-2

VC-48 AND VC-56 CAPACITY AND PERFORMANCE

Size Fraction	Solids Capacity in tph VC-48	Solids Capacity in tph VC-56	Product Surface Moisture %
3 X ¼ inch	200	325	2.0
2 X ¼ inch	190	315	2.0
1½ X ¼ inch	180	300	2.0
1 X ¼ inch	160	270	2.5
2 inch X 28 mesh	160	270	2.5
1½ inch X 28 mesh	150	255	2.5
½ X ¼ inch	140	235	3.0
1 inch X 28 mesh	140	235	3.5
½ inch X 28 mesh	125	210	5.0
3/8 inch X 28 mesh	115	195	6.5
¼ inch X mesh	110	185	7.5

(2) <u>Scroll Type</u>

One of the most popular scroll type centrifugal dryers is the Model EB-36 manufacturered by CMI. Figure 2-26 shows two of these units installed in a coal preparation plant. This type of unit consists

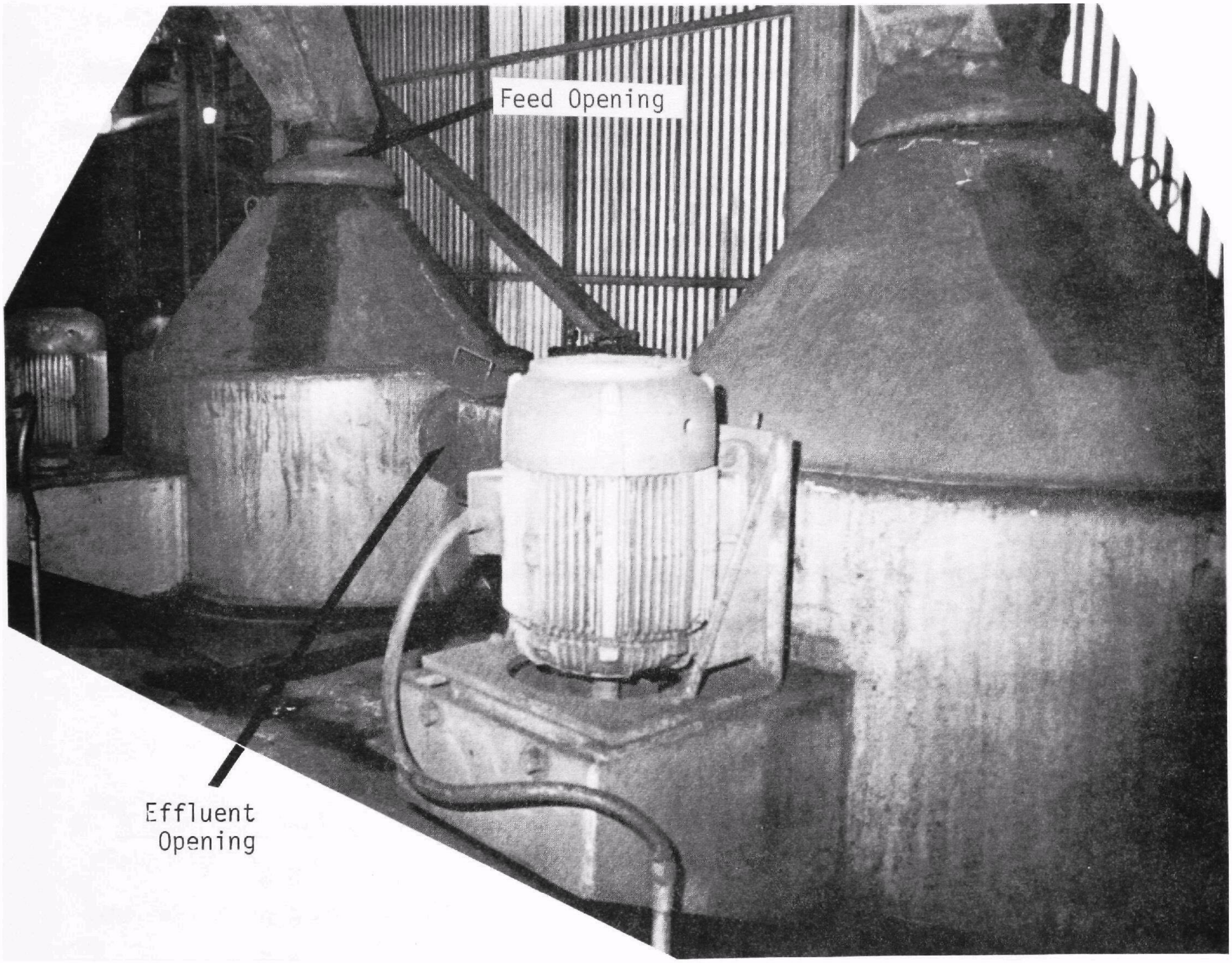


FIGURE 2-26

SCROLL TYPE CENTRIFUGAL DRYERS (CMI MODEL EB-36) of two conical drums; one turning inside the other at a slightly different speed. The outer drum, or basket, is made of stainless steel wire with replaceable screens mounted on its inner surface. The inner (scraper) drum carries the scraper blades or flights which control the solid material movement across the screen. As the material enters at the top, these blades move it downward over the screen through which the moisture is ejected by centrifugal force. Eventually, it is worked down to the discharge area of the dryer where it falls by gravity through an opening in the bottom of the machine. The moisture and any fine particles passing through the screen are gathered in a trough around the periphery of the machine and discharged through effluent openings. The capacity of this equipment is dependent upon the feed size, surface moisture, particle shape, and end product requirements. As a general rule, as the percentage of fines increases, there will be a decrease in capacity and an increase in the surface moisture of the product. According to the manufacturer, the Model EB-36 has the capacity and performance at various size fractions as presented in Table 2-3. This data is based upon feed moisture concentrations of 40% or less.

TABLE 2-3

MODEL EB-36 CAPACITY AND PERFORMANCE

Size Fraction	Solids Capacity in tph	Product Surface Moisture %
3/8 inch X 28 mesh	80	6.0
¼ inch X 28 mesh	60	6.0
1/8 inch X 28 mesh	50	6.5
1/16 inch X 28 mesh	35	7.5

This unit sells for just over $23,000 F.O.B. factory.

(3) Screen Bowl Type

The centrifugal dryers discussed thus far are most effective where the size consist of the wet feed is above 28 mesh. The screen bowl type centrifugal dryer manufactured by the Bird Machine Company is designed to dewater finer size clean coal in the 28 mesh X 0 range. In many applications, this particular equipment can be used instead of a vacuum filter to handle the fine coal concentrate from froth flotation or other finer coal products. According to the manufacturer, this machine can reduce the moisture content of a 28 mesh X 0 flotation concentrate containing 15% to 20% 325 mesh size particles to 12% to 14% while achieving a 96% to 98% solids recovery. This is substantially less than the moisture content of the filter cake produced by vacuum filters which is normally around 20%.

This machine has a horizontal configuration which utilizes some of the same centrifugal dewatering techniques found in the rotating screen basket designs covered earlier. From an operational standpoint, the screen bowl makes a two-step separation. The initial separation takes place in the solid section of the bowl where centrifugal force aids the removal of most of the free moisture in the feed. Following this, the solids move via a conveyor screw onto the screen section of the bowl where most of the remaining moisture is forced through the openings in the rotating screen. At the end of screen section, the dewatered solids are discharged into a collection chamber and drop by gravity through an opening in the base of the machine.

This Bird screen bowl centrifuge is available in various sizes ranging from capacities of 5 tph to as much as 75 tph, depending upon the feed particle size. Units having these capacities sell for $50,000 and $235,000, respectively. Although these units are significantly higher in price than comparable capacity vacuum disc filters, this higher initial cost should be evaluated in terms of the unit's performance and the potential for lower operating and maintenance costs. One readily visible operating cost savings comes from the approximately 30% less power consumption over a disc type filter. Another fertile area for evaluation is the impact on reducing thermal dryer capacity which as discussed later adds appreciably to the cost of coal preparation.

(4) Solid Bowl Type

This final type of centrifugal dewatering equipment is also applicable to finer size material. Such machines are mainly used in the same capacity as refuse vacuum disc filters to handle the underflow from a static thickener. They clarify the water and produce a solid material suitable for disposal. This machine has a horizontal configuration which has two principal elements. One is a rotating bowl which is the settling vessel and the other is a scroll conveyor which advances the settled solids to the discharge ports. The clarified liquid and the solids are discharged at opposite ends of the machine. As the bowl rotates, the centrifugal force causes the slurry to form an annular pool, the depth of which is determined by adjustable effluent weirs. A portion of the bowl at the solids discharge end has a smaller diameter to form a drainage deck above the level of the pool.

According to the Bird Machine Company, which manufactures this type of centrifuge, it is capable of producing a solids product of 30% to 35% moisture and clean liquid when dewatering feeds having a large concentration (75-85%) of particles less than 325 mesh. These units are available for capacities of 2½ tph to 30 tph at a cost of approximately $40,000 to $220,000, respectively. Although they require substantial horsepower to accelerate the heavy slurry, this type of equipment still requires approximately 50% less horsepower than comparable capacity vacuum disc filter installations.

2.3.1.2 Vacuum Disc Filter

The disc type vacuum filter is the principal piece of dewatering equipment used in the coal preparation industry for handling clean coal and refuse with large amounts of material below 28 mesh. As mentioned previously, this equipment is commonly used to reduce the moisture content of the froth concentrate from flotation prior to thermal drying, as well as handle the static thickener underfow. This equipment is offered in a wide range of capacities by such companies as the Denver Equipment Division of Joy and Peterson Filters Corporation.

As shown in Figure 2-27, the vacuum disc filter consists of a series of discs mounted over a trough shaped tank so that slightly less than half of the disc is below the edge. These discs are covered on both sides with a fine mesh filter cloth or other suitable filter medium. To be effective, this medium must permit the passage of air but not become clogged by the material being filtered. The discs are mounted on a hollow shaft with a complex plumbing arrangement permitting

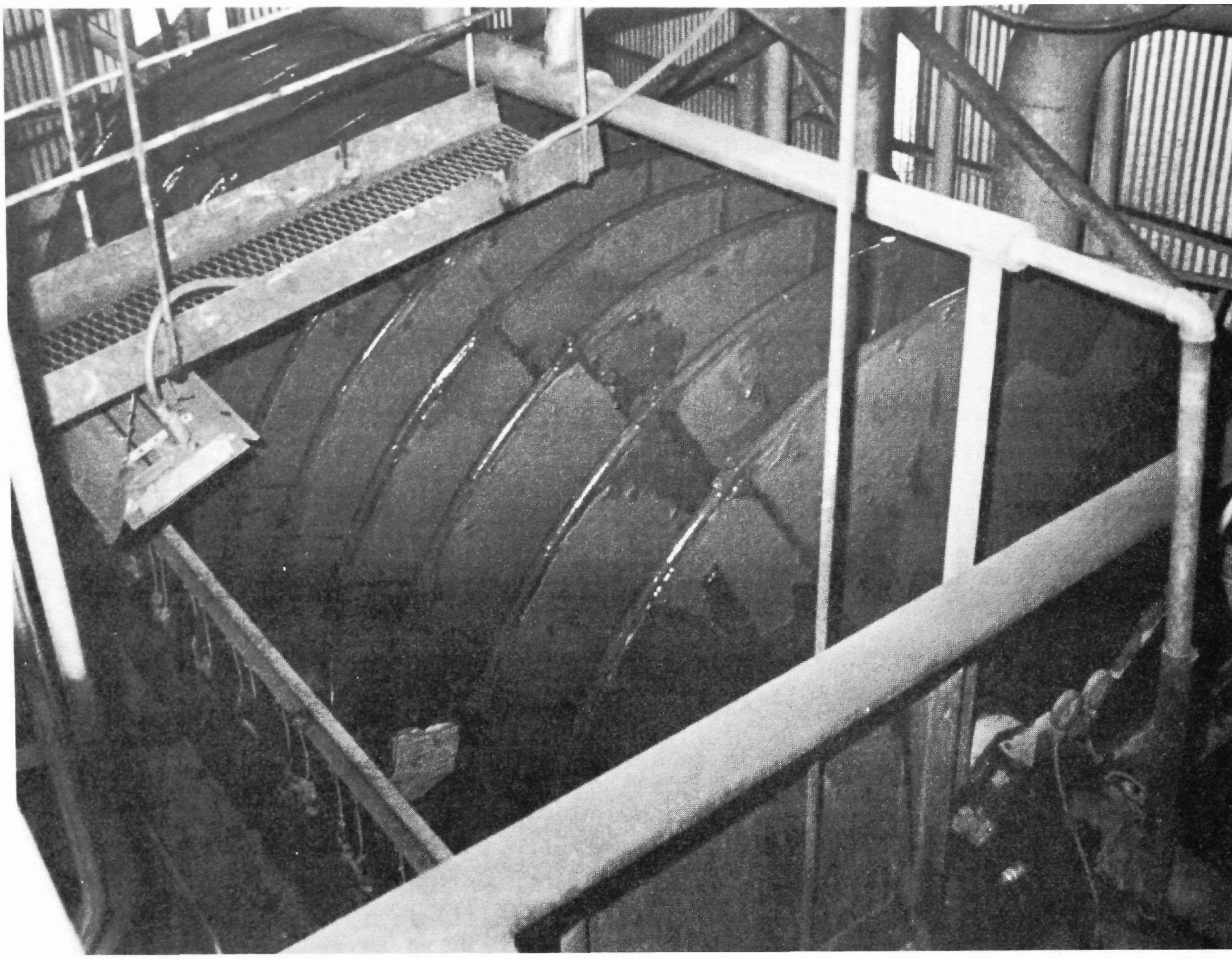


FIGURE 2-27
VACUUM DISC FILTER (10 FT 6 INCH DIAMETER 12 DISC VERSION)

the application of suction and pressure to the surface of each disc, as well as the withdrawal of the fluid collected. The slurry to be dewatered is fed into the trough at which time suction is applied pulling the slurry toward the disc surfaces. In order to pull the fluid through the filter surface, an air flow of about 5 cubic feet per minute (CFM) per square foot of filter surface is normally applied when processing froth concentrate and about 3 CFM per square foot of filtering surface when handling thickener underflow. As a result of this action, the solids portion of the slurry is deposited on the disc surface. Then, the discs are rotated approximately 120 degrees carrying with them the solids or filter cake retained on their surfaces. At this point the filter cake is loosened from the disc surface by reversing the pressure (blower action) and scraped off into a discharge chute. The moisture content of this cake will vary from 20% up, depending upon the makeup of the slurry.

The capacity of a vacuum disc filter is influenced by the solids concentration of the slurry to be dewatered and the amount of material less than 325 mesh. However, as a very general rule, between 40 and 60 pounds per hour per square foot of filtering area is appropriate when dewatering clean coal and about 20 pounds per hour per square foot for refuse. For example, a 12 foot 6 inch diameter disc filter having 12 discs has 2,736 square feet of effective filtering surface. Therefore, on a load philosophy of 40 pounds of clean coal per hour per square foot, this size vacuum filter should be able to handle a maximum of 110,000 pounds or 55 tons per hour. Normally, it is a good idea to have some excess filtering capacity to allow for variations in the concentration of the feed.

Although there are some design differences among the various vacuum disc filters on the market, there is not as much variance in their price for a given capacity unit as might be expected. A representative sample of mid-1977 F.O.B. factory prices is as follows:

Disc Diameter	Number of Discs	Filtering Area	Price
10 ft 6 inches	7	1,085 sq. ft.	$ 90,000
11 ft	6	960 sq. ft.	$ 70,000
11 ft	8	1,280 sq. ft.	$ 85,000
12 ft 6 inches	10	2,280 sq. ft.	$120,000
13 ft	12	2,880 sq. ft.	$128,000

Besides capacity, prices will be significantly influenced by the type of filter medium selected. This is not only an important decision from the standpoint of initial cost, but also operational performance and reduced maintenance. For example, stainless steel wire mesh will cost over three dollars per square foot but last as much as 10 to 15 times longer than a cheaper filter medium such as saran.

2.3.1.3 Vor-Siv

Although one of the major principles governing the operation of the Vor-Siv is centrifugal force, a discussion of this stationary dewatering device was omitted from the earlier section on centrifugal dewatering equipment to allow separate coverage. The Vor-Siv was developed by the Polish coal industry and is currently manufactured in this country by the Perforated Metals Division of the National-Standard Company under an exclusive licensing agreement. It is designed to handle high volumes of solids in a water slurry. Some of the ways this equipment has been applied in coal preparation circuits include dewatering ahead of centrifuges, desliming ahead of concentrating tables, and as protection devices ahead of thickeners and flotation cells. The unit can handle particles less than 3/8 inch size in slurries of 10% to 30% solids concentration. A single unit can handle such a slurry at feed rates up to 3200 gallons per minute and thereby produce 150 tph of dewatered material.

To better understand the operation of this device, the reader is referred to Figure 2-28 which shows the major components and a simulated flow pattern. Feed is introduced to the unit through a directional

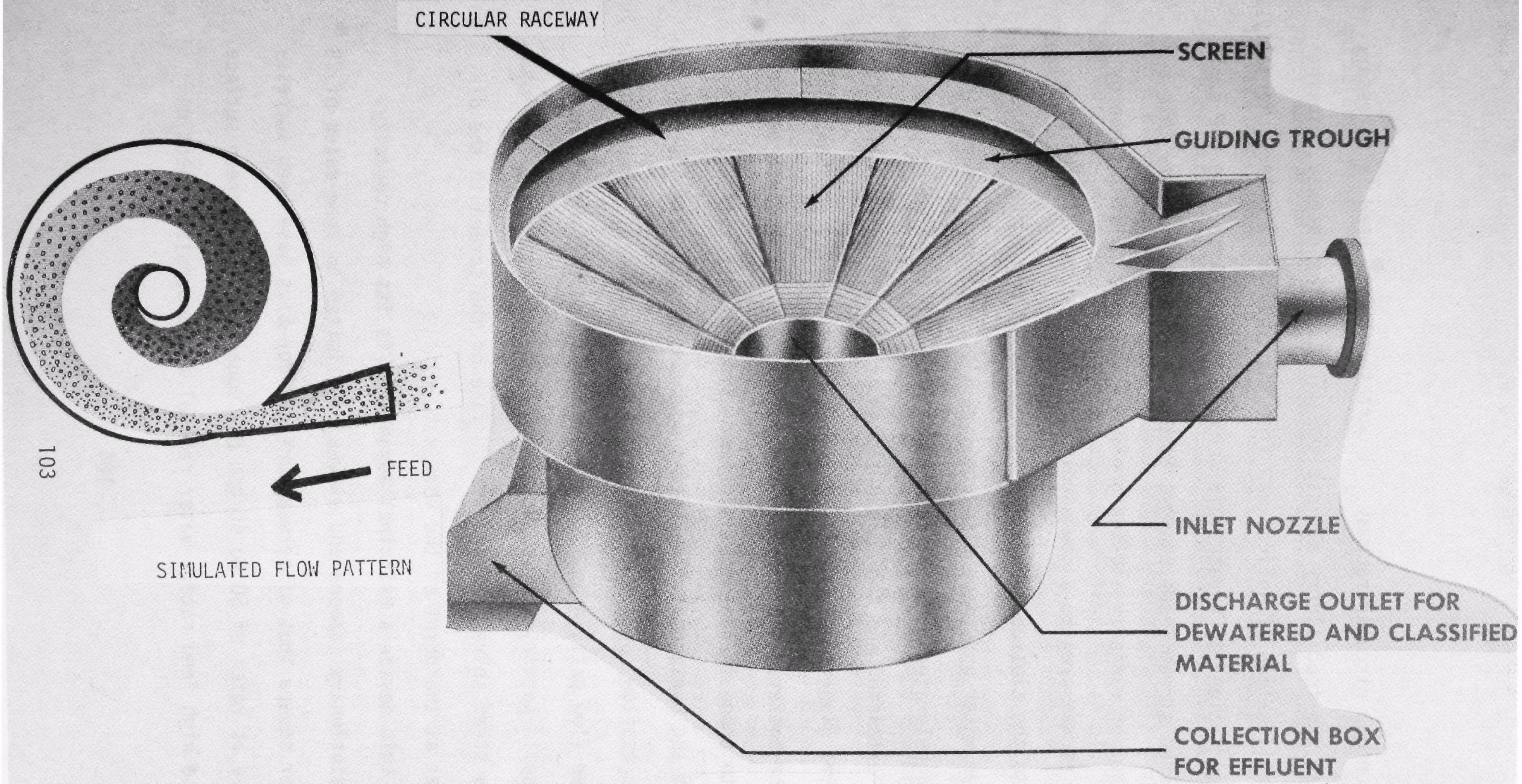


FIGURE 2-28

VOR-SIV CONICAL SIEVE

nozzle and onto a circular raceway. A certain minimum head is necessary to accelerate the feed slurry against the walls of the raceway, causing partial stratification of solids away from the associated water. Normally gravity is sufficient to create this necessary feed force. As the semi-stratified feed stream loses energy, it spills from the raceway into a conical basket of radially slotted profile wire. The remaining energy in the feed stream creates a downwardly spiraling vortex flowing perpendicular to the slotted openings in the upper three fourths of the basket. Free water and, depending upon the slot aperture, undersized solids are accelerated through the basket, becoming an effluent product. As water is extracted and the vortex continues to lose energy, the circular swirl gives away to an axial path downward along the lower one fourth of the basket. Slotted openings in this section are placed perpendicular to those in the upper section. Since feed travel has changed from the horizontal flow into a downward drop, these slots again provide a "crossflow" action enhancing the final stages of water removal. The simulated flow pattern in Figure 2-28, shows how the vortex action causes the solid particles to change their radial position and flow downward along a steep spiral path on the surface of the screen to the discharge outlet at the point of the vortex.

One of this device's principal advantages is its high capacity. While most stationary screens and sieves are limited to feed rates of 28 to 30 gpm per square foot of screen surface, Vor-Sivs have been successfully applied at rates of 50 to 60 gpm per square foot of screen surface. Even at these high feed rates, water removal and undersize rejection efficiency have been equal to or better than achievable with conventional equipment. Other advantages include: they require no lubrication, generate no noise or vibration, require essentially no operator attention or adjustment, and maintain consistent performance over a wide range of feed variables. Capital cost studies have shown the devices to be quite desirable when contrasted with conventional dewatering equipment in new plant design. Retrofit applications have also been quite popular.

As of mid-1977, the F.O.B. factory price of a Vor-Siv was approximately $15,500 to $17,000 depending upon the size of the two-part replaceable screen sections.

2.3.1.4 Thermal Dryer

The final major piece of dewatering equipment to be discussed is the thermal dryer. This evaporation process is normally applied to fine and intermediate (typically less than 1 inch) size clean coal which has not been sufficiently dried to meet the specified moisture level by the various centrifugal and vacuum filter dewatering techniques discussed earlier. Thermal drying is an expensive process from both the standpoint of initial capital requirements as well as the long term operating and maintenance costs. In this country, the application of thermal drying to physically cleaned coal has decreased from 19.8% in 1970, to 13.4% in 1975. Moreover, the actual tons dried have decreased by nearly 50%, i.e., 64,165 in 1970 and 35,681 in 1975. Although there are many forms of dryers, the dominant thermal drying method is fluid-bed which has been growing in acceptance in recent years as shown by Table 2-4. The drop in tons of physically cleaned coal and thus those subjected to thermal drying decreased during the the 1973 to 1975 period due to several factors. The major factor was the sharp increase in demand for coal and thus there was less of a necessity to perform these costly processes. Another influence was the tighter environmental/emission control regulations which have forced the discontinuance of dryers at some locations rather than install and/or modify the facilities to comply. In addition, as noted previously, the operation and maintenance problems and costs are enough by themselves to encourage detailed investigations of other options and strategies before initiating thermal drying. Therefore,

TABLE 2-4

COAL THERMALLY DRIED IN COMPARISON TO ANNUAL PRODUCTION*
(Thousand Short Tons)

Year	Production	Mechanically Cleaned	Thermally Dried	% Dried of Total Production	% Dried of Total Cleaned	% Dried By Fluidized-Bed
1975	648,438	266,993	35,681	5.5%	13.4%	72.5%
1974	603,406	265,150	36,045	6.0	13.6	68.3
1973	591,738	288,918	46,202	7.8	16.0	66.9
1972	595,386	292,829	53,235	8.9	18.2	64.1
1971	552,192	271,401	48,105	8.7	17.7	67.7
1970	602,932	323,452	64,165	10.6	19.8	66.4

* Bituminous & Lignite

Source: Based Upon U.S. Bureau of Mines, Mineral Industry Surveys, Coal-Bituminous and Lignite Annual 1970-75. Prepared in Division of Fuels Data and Division of Coal.

it should be employed only after a careful evaluation of the economies as they relate to the realities of the marketplace. In other words, if it does not pay to dry - don't.

Due to the nature of the process, the thermal drying function is conducted in a separate facility linked only with the main coal preparation plant by way of a conveyor. A view of such an installation appears as Figure 2-29, which is an intermediate size unit manufactured by the FMC Corporation. These are sophisticated installations which can account for over 25% of the capital cost of the total preparation plant complex when a substantial portion of the output is dried. A more precise understanding of this relationship can be obtained from a review of Examples 2, 3, 4, 6, and 8 in Section 5.0 which have varying thermal drying requirements. To meet these various requirements, fluid-bed driers are offered by several companies in a wide range of capacities, each with its own unique design features. Some appreciation for their sophistication can be gained from Figure 2-30, showing a cutaway view of a thermal dryer manufactured by the ENI Division of Lively Manufacturing. Being a well defined portion of the overall preparation process permits a fairly accurate appraisal of the capital and O & M costs associated with thermal drying. The following is an example of the capital cost as of mid-1977 for a medium size fluid-bed dryer.

Description of Drying Requirement:

Bituminous Coal ¼ inch X 0

Reduce Moisture from 13% to 5% at the rate of 350 tons per hour

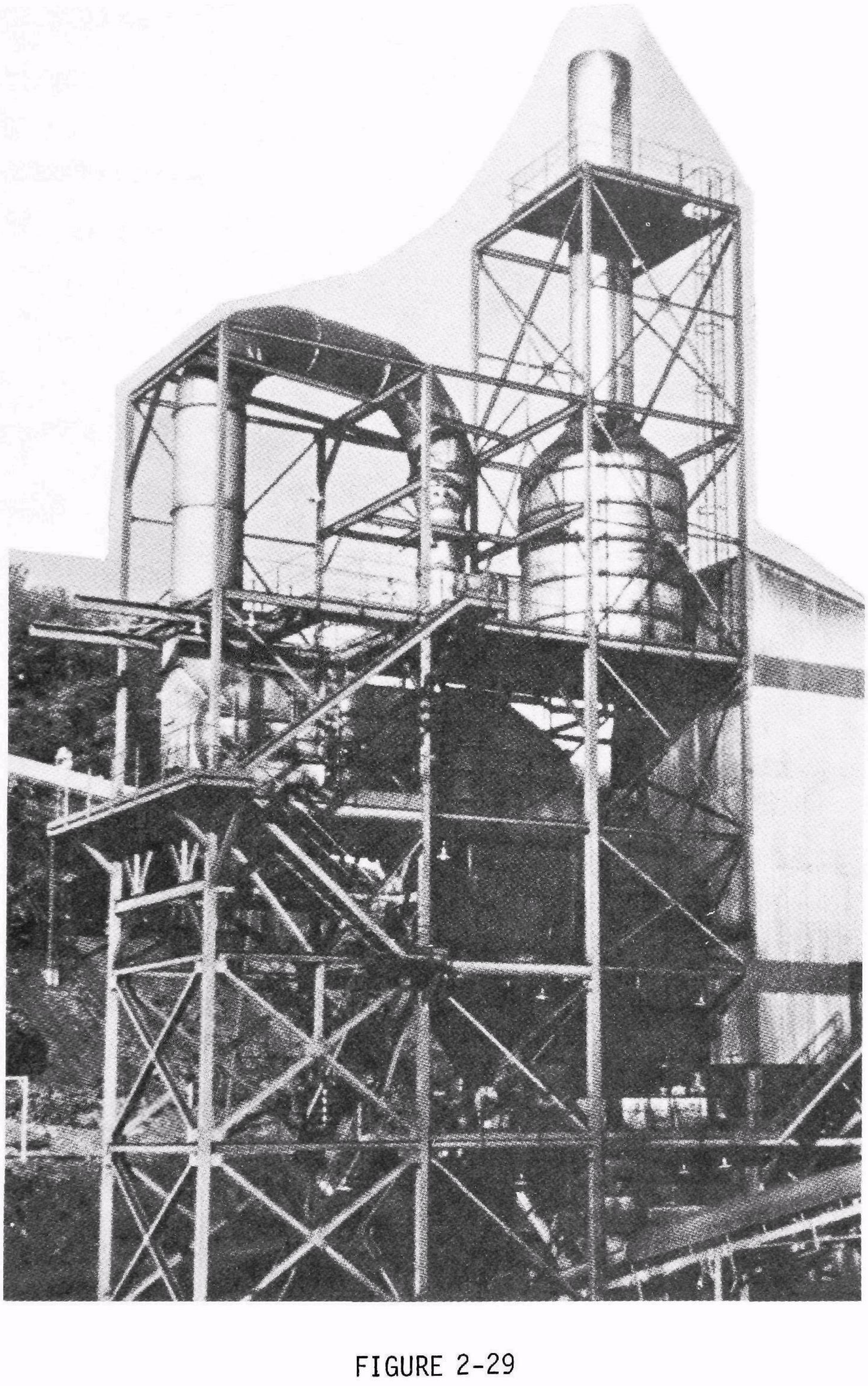


FIGURE 2-29

FLUID-BED THERMAL DRYER INSTALLATION (FMC FLUID-FLO MODEL)

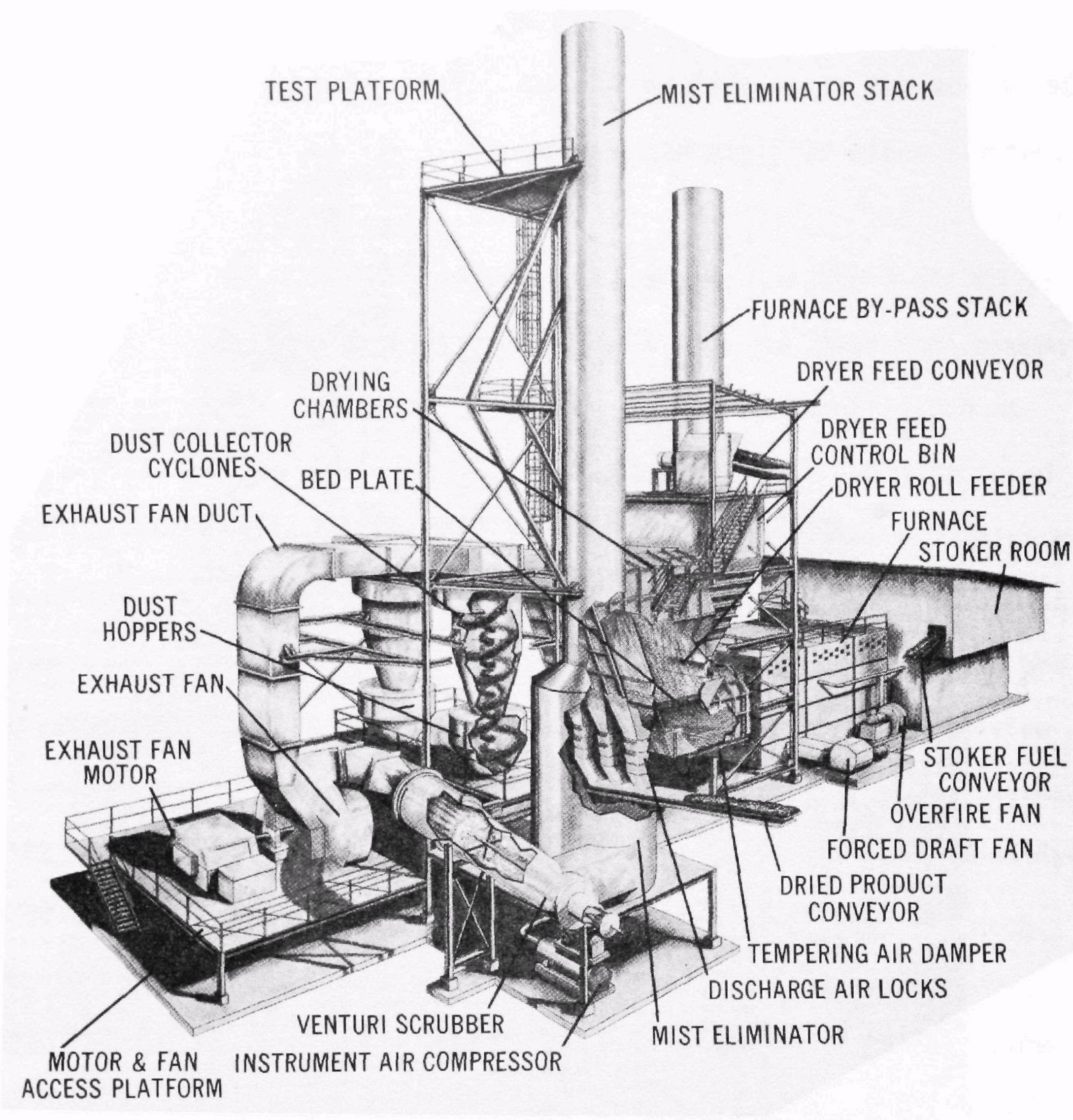


FIGURE 2-30

CUTAWAY VIEW OF FLUID-BED THERMAL DRYER (ENI COAL-FLO MODEL)

Description of Drying Facility:

One (1) 10' X 14' FMC Fluid-Flo Dryer with connected horsepower of 2200 hp. Complete with roll feeder, stoker, furnace, ductwork, fluidization chamber, hood, cyclone dust collectors, exhaust fan, scrubber, stack, feed bin, fuel conveyors, fuel bin, ash conveyor, insulation, dust screws and automatic temperature controls.

Price $ 950,000

Installation of Dryer including foundation, structural steel, motors, motor controls, wiring, piping, field erection, and start-up service.

Price $1,650,000

TOTAL DRYER CAPITAL COST..........$2,600,000

In order to generate the heat necessary to achieve the required moisture reduction, this dryer would be consuming approximately 6 tons per hour of coal having a nominal heat content of 12,500 Btu/lb. If we assume that such a coal has a cost of $20 per ton to the preparation plant operator, then, the fuel cost per ton of dried coal would be:

$$\frac{6 \text{ tons/hr X \$20/ton}}{350 \text{ ton/hr}} = \$0.343/\text{ton}$$

If this particular plant was producing an additional 550 tons per hour of clean coal for a total output at 900 tph, then the fuel cost impact per ton of total product would be:

$$\frac{6 \text{ tons/hr X \$20/ton}}{900 \text{ tons/hr}} = \$0.133/\text{ton}$$

In addition to the fuel (coal) necessary to operate the thermal dryer, electricity is another major operating cost factor. Using the standard relationship between kilowatts and horsepower of 0.745 kw = 1 hp, an estimate of the electric power consumption and cost of operating the thermal dryer can be made. In the case of a dryer having 2200 hp the following calculations apply:

0.745 kw/hp X 2200 hp = 1,639 kw

With 80% efficiency, consumption would be:

$$\frac{1,639}{0.8} = 2,048.75 \approx 2,050 \text{ kw}$$

Assuming an electric rate for a large industrial user of between \$ 0.03 & \$ 0.05 per kilowatt hour, electricity cost per hour would be - \$ 0.04/kwh x 2,050 kw = \$82.00 per hour.

Therefore, if a dryer of this size (2200 hp) is processing 350 tons of coal per hour, the electric cost on a dried ton is -

\$82.00/hour ÷ 350 tons/hour = \$ 0.23/ton

If the plant was producing an additional 550 tons for a total clean coal output of 900 tph, then the impact on each ton of clean coal would be -

\$82.00/hr ÷ 900 tons/hr = \$ 0.09/ton

This tells us that the impact of thermal drying electric cost alone is \$ 0.09 per ton. Since there is normally a comparable volume of horsepower in the balance of the preparation plant, the overall electricity cost will be roughly \$ 0.18 to \$ 0.20 per ton of clean coal. If the electric rate was \$ 0.05 per kwh, then this cost could be as high as \$ 0.23 per ton.

This is just one example of a fluid-bed thermal drying application. Each case will not only vary with the volume and size of the feed but also according to the nature of the coal itself and the specified end product.

However, when some level of thermal moisture reduction is necessary, the volume of material fed to the dryer should be kept to an absolute minimum in order to limit the high capital and O & M costs referred to above. As has been said previously regarding other portions of the preparation plant, the applicability and/or necessity of thermal dryers must be determined on a specific case basis where the further reduction in moisture is weighed against the required end product and how and where it will be handled and eventually consumed.

2.3.2 Static Thickener

The majority of the coal preparation plants in operation today and all those built in recent years have a closed water system. What this means is that the effluent from the cleaning plant must be handled in such a way that the solids and liquid are separated before being released into the environment. With the increase in fine coal cleaning and the use of continuous mining methods, a greater amount of solid material winds up in the waste water from the preparation plant. Although settling ponds are still used to a large extent, the most common method of clarifying this waste water is with the use of a static thickener.

As shown in Figure 2-1, the typical static thickener is a circular tank usually of concrete or steel construction which is located close to the cleaning plant. To understand the workings of this critical piece of water clarification equipment, the reader is referred to Figure 2-31 showing a cross-sectional representation of a static thickener. The liquid effluent from the plant is fed via a trough into the feedwell at

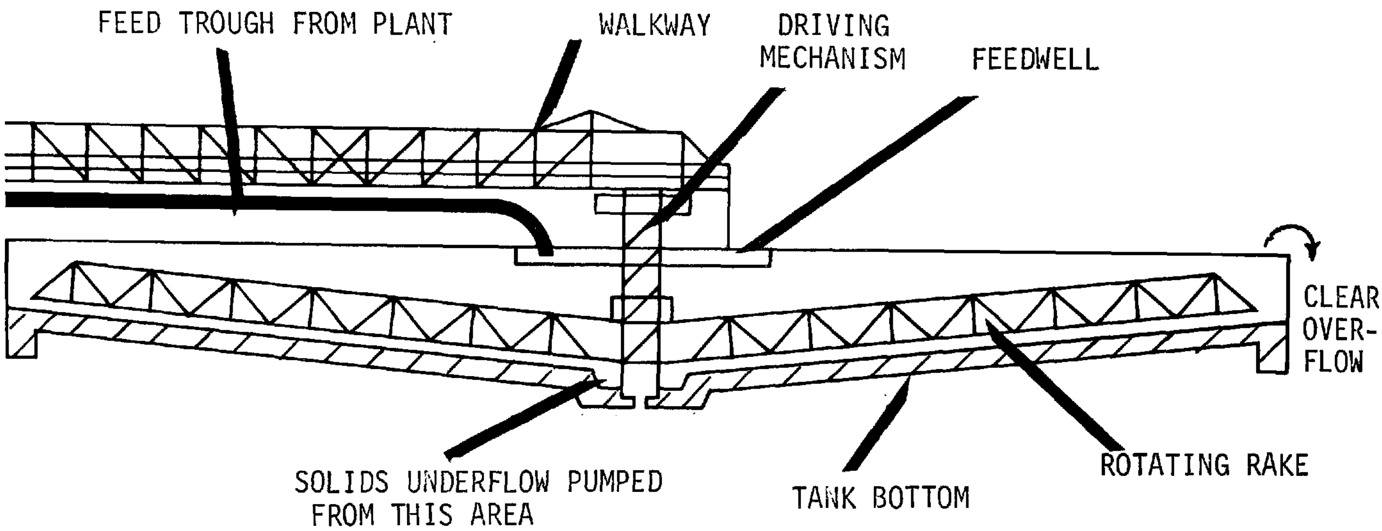


FIGURE 2-31

CROSS-SECTION OF STATIC THICKENER

the center of the thickener. This can be seen in Figure 2-32 which shows the slurry moving out to the center of the tank and into the feed-well whose rim is about one foot above the liquid level. As this slurry flows from the feedwell out toward the edge of the tank, the solids tend to settle. This settling is encouraged by the addition of flocculants and other chemicals. The settled solids are pushed along the bottom of the tank by slow moving rakes. These rakes or plows are driven by a heavy duty, all weather, mechanism located at the center of the tank. Because of the slope of the tank bottom, these solids are moved toward the center of the tank from which they are pumped to a vacuum filter or other dewatering device. Once dewatered, this solid underflow material is normally disposed of with the coarser refuse from the plant. However, in some plants, this thickener underflow has desirable enough properties to warrant blending it back in with the clean coal product. The clarified

FIGURE 2-32

TOP VIEW OF STATIC THICKENER

liquid overflows the outer edge of the tank into a trough from which it is pumped back into the plant's water system for reuse in the cleaning process.

Static thickeners are sized according to the anticipated clarification requirements of the plant plus a reasonable margin for variations in the quality of the raw feed. This is necessary since during the mining of any given seam, substantial variations in composition will be experienced. Also, in cold weather when the coal is damp and muddy, greater amounts of clays and other fine material are brought into the plant and must be handled by the water clarification system. This problem can be particularly acute in the case of strip mined coal.

Depending upon the requirement, static thickeners are constructed in a range of sizes up to over 200 feet in diameter. Although the price will vary with the sophistication and quality of the drive mechanism, a very good approximation of the total installed price of a concrete type between 90 and 200 feet in diameter is $2,000 per foot of diameter. In this size range, the drive mechanism alone will account for 45-55% of the total installed price. This mid-1977 composite price will also be subject to the cost and availability of local materials of construction but to a lesser extent than that for concrete silos discussed in Section 2.1.1.

2.2.3 Coal Sampling Equipment

A detailed discussion of coal sampling techniques and equipment is beyond the scope of this report. However, it will suffice to say that with the trend toward larger and more complex coal preparation plants, there will be an increasing need for efficient and accurate analysis of the clean coal product prior to its leaving the plant. Such data is particularly important where blending is practiced or coal is prepared for slurry pipelining. This need may also be accentuated by the application of pending environmental regulations which might require precise documentation on the amount of sulfur which was present in the as-mined coal and was removed by the cleaning process.

Regardless of the cleaning plant's level of complexity, some analysis of the raw and clean coals is necessary to evaluate performance. Many times the sampling procedure is not just for the benefit of the preparation plant operator, but is part of a purchase specification. Under these circumstances, the coal is sampled before it leaves the plant and then again at the destination. Depending upon the individual contract relationship, this data can provide the basis for applying bonuses or penalties according to variances in the as received product in comparison with predetermined ash, moisture, sulfur, and Btu limits.

Coal sampling equipment is offered in a wide range of sizes and sophistications. There are multi-stage sampling systems which are of such size and complexity that they are constructed as a separate building (tower) adjacent to the cleaning plant or part of the load-out facility. Sampling systems of this type can cost over half a million dollars and are usually found only at very large plants. An indication of this complexity is given in Figure 2-33, which schematically represents a coal sampling system manufactured by the Denver Equipment Division of Joy Manufacturing Co. Since there is such a variance in the application and need for sampling systems, a figure of $300,000 was used to estimate

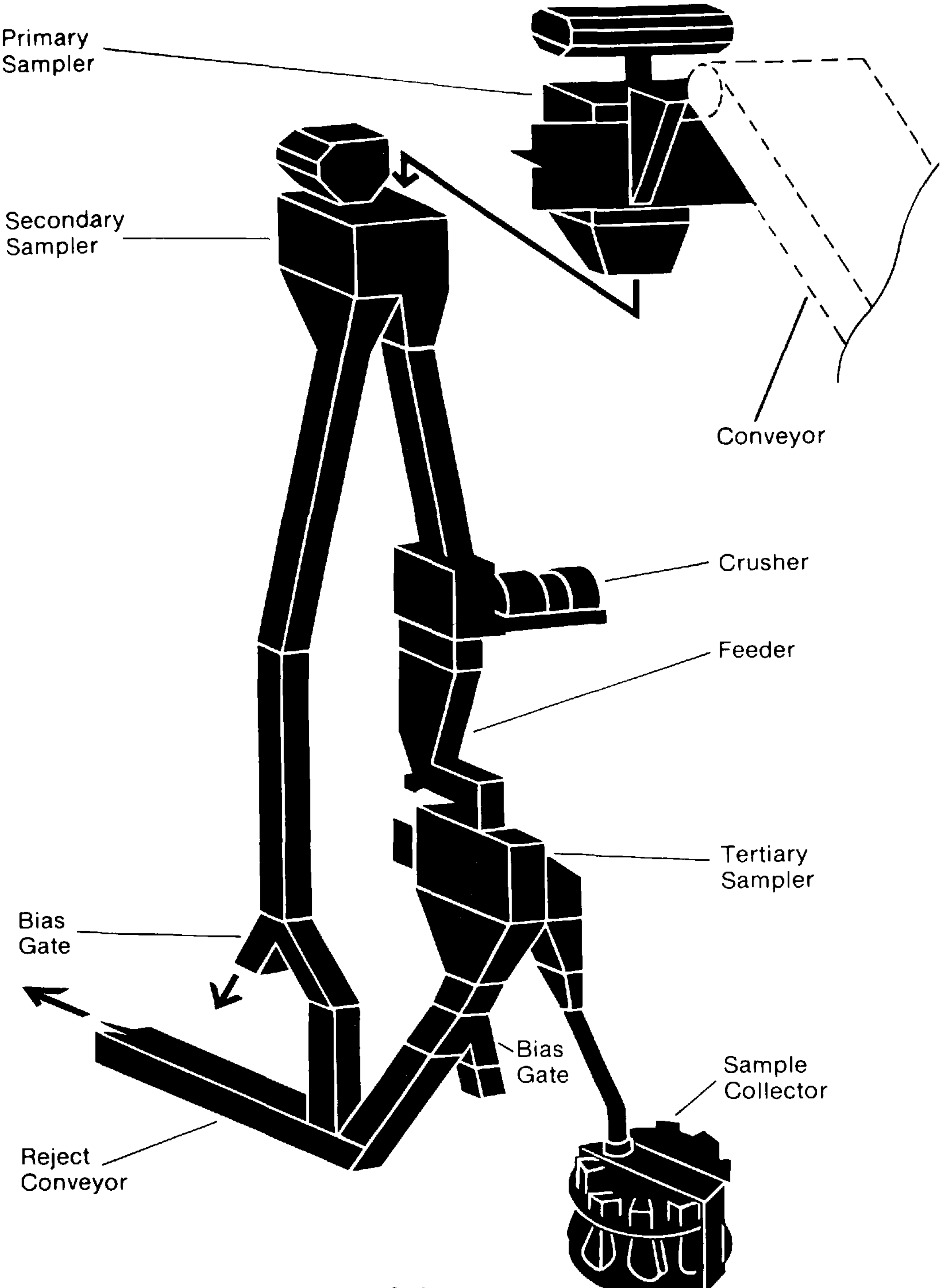


FIGURE 2-33

THREE-STAGE COAL SAMPLING SYSTEM - (DENVER EQUIPMENT DIVISION OF JOY)

this capability for all larger preparation plants considered under Section 5.0 rather than the cost of the system actually being used. This way the total capital cost of any given plant was not biased for comparative purposes because of its particular system.

SECTION 3.0

SMALLER SIZE PREPARATION PLANTS

3.0 SMALLER SIZE PREPARATION PLANTS

Although the major thrust of this study was to more accurately define the costs associated with preparation plants of 500 tons per hour raw coal input or greater, it may be useful to the reader to have some indication of the costs related to smaller scale operations. As in the case of larger plants, the final cost of the plant is a function of the many variables unique to the particular situation. Two of the most important variables are the washability of the coal and the end product specification. These will dictate the make-up of the cleaning circuit and to what extent the material must be dried. As indicated elsewhere in this report, the extent to which the product must be dewatered has a very significant impact upon the initial capital requirements and the on-going O & M costs.

Preparation plants can meet a variety of needs in the smaller scale operation. In some cases, a mine can clean a portion of its production with a simple "semi-portable" plant and come up with a marketable product. There are a number of smaller size plants being offered by such firms as Coal Processing Equipment, Inc., Jeffrey Manufacturing Division of Dresser Industries, and RAPCO, Inc. These plants come in a wide range of sophistications, some of which are even capable of finer size coal recovery. Although there is not much interest yet, one application for these smaller plants may be in the recovery of coal from existing refuse piles. The economics of such an arrangement can be quite favorable under some circumstances since there is no mining or mine development cost necessary and therefore more investment in cleaning equipment can be made while still yielding an acceptable rate of return.

Jeffrey Unitized Jig Coal Cleaning Plant

One smaller size coal preparation plant is the Jeffrey unitized jig plant. This is a packaged coal washing plant utilizing a Jeffrey two-cell diaphragm jig as the cleaning unit. The plant which has a nominal capacity of 150 tph of feed is structurally arranged as shown in Figure 3-1 below.

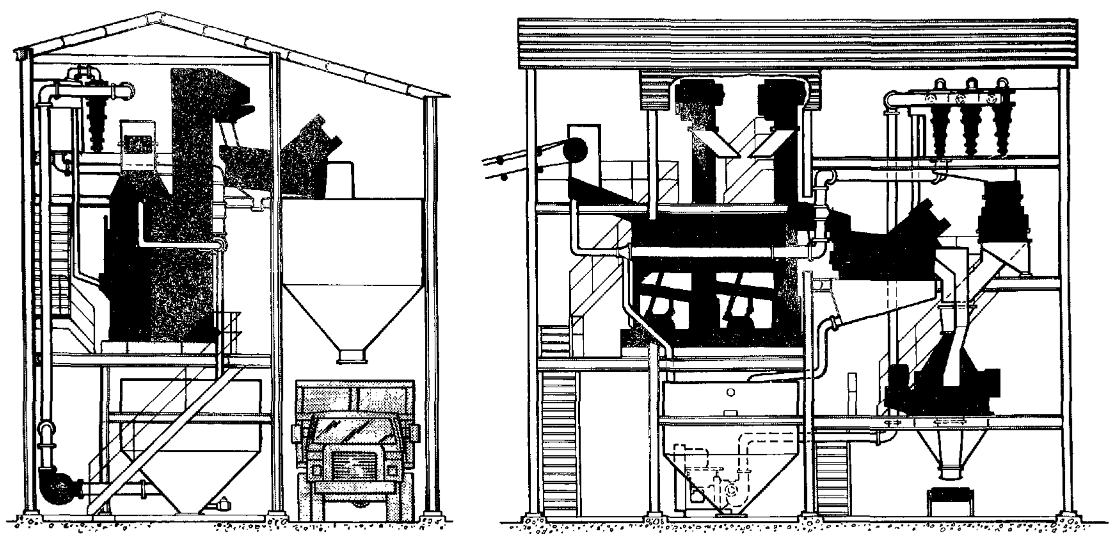


FIGURE 3-1

LAYOUT OF UNITIZED JIG

The plant comes as a package containing all equipment, structural steel, interconnecting chutes, piping, electrical distribution system, lighting, siding and roofing and other materials necessary for construction. The purchaser supplies an appropriate site, foundations, power supply and fresh water supply. The cost of the raw coal delivery system and the clean coal handling system is not included and can be supplied either by Jeffrey or the purchaser.

General Process Description -

As shown in Figure 3-2, the raw coal is delivered by belt conveyor to the jig feed chute where the raw coal is mixed with water.

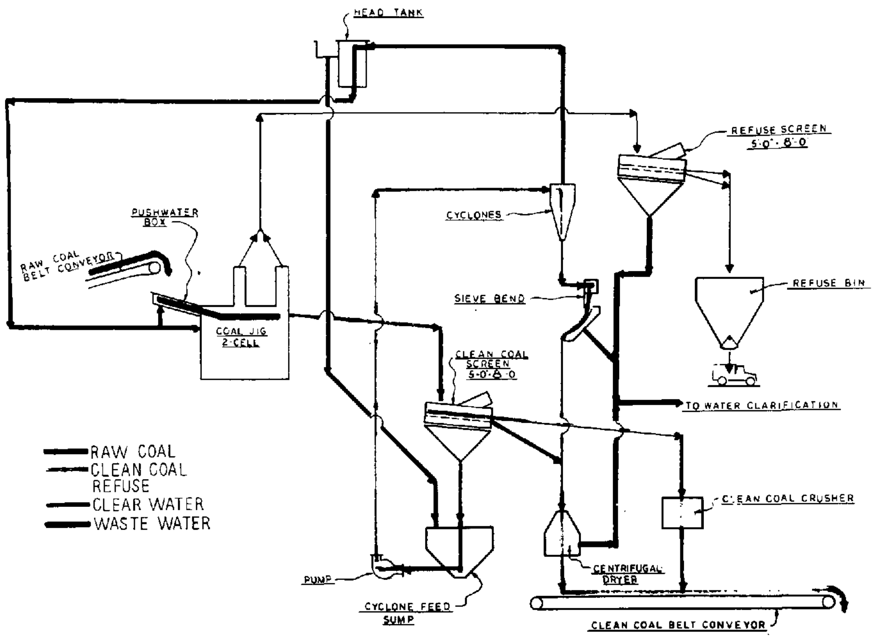


FIGURE 3-2

FLOW SHEET OF UNITIZED JIG PLANT

The raw coal then reports to the two-cell diaphragm jig where the coal is washed. The refuse material is removed from the jig by bucket elevators for dewatering. The refuse is dewatered on a double deck screen with the coarse refuse reporting to a 50 ton refuse bin. The fine refuse (-28 mesh) and water report to waste.

The clean coal from the jig is dewatered and sized on a double deck vibrating screen. The 1/2 inch coal passing over the top deck of the dewatering screen is crushed to the desired product size. The 1/2 X 1/4 inch coal passing over the second deck of the screen is further dewatered in a centrifugal dryer. The 1/4 inch X 0 material reports to a sump from which it is pumped to clarification cyclones. The underflow from these cyclones is partially dewatered and deslimed by sieve bends before being combined with the 1/2 X 1/4 inch material for centrifugal drying. The overflow from these cyclones reports to a head tank for recirculation to the jig. The slimes and water from the sieve bends and the centrifuge combine with the fine refuse and report to waste. The clean coal from the crusher and the centrifugal dryer is collected as a final product for loading or storage.

The fine waste (fine refuse and slimes from the sieve bends and centrifugal dryer) will generally report to settling ponds for clarification. A closed circuit using a thickener and vacuum filter could be provided as an option. Such an option has not been considered in the estimated price of the system appearing at the end of this section.

The mechanical action bringing about the separation of the raw feed into clean coal (float) and refuse (sink) is shown by Figure 3-3, which also identifies the major component of a two-cell jig.

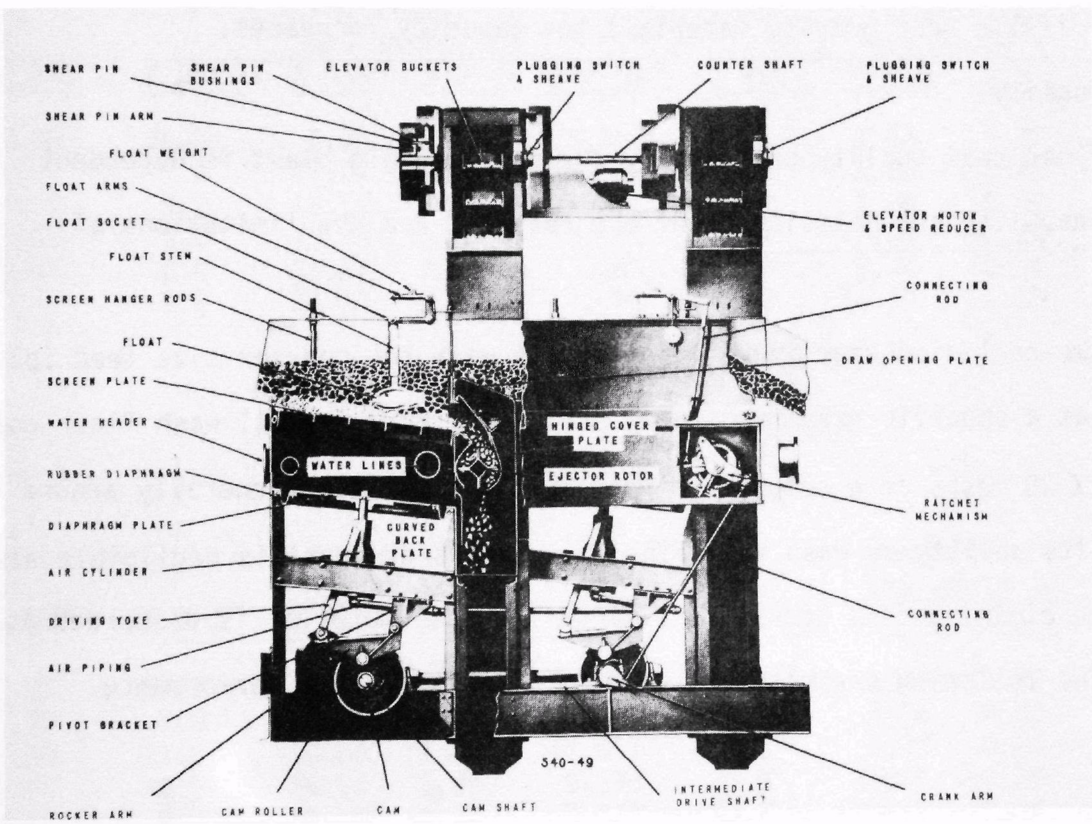


FIGURE 3-3

TWO-CELL DIAPHRAGM JIG

Plant Performance -

1. Capacity

The performance of the unitized jig plant is dependent strictly on the performance of the jig since it is the only piece of washing equipment used. All other equipment has been sized to handle the maximum tonnages and flows which the jig is capable of handling. The nominal capacity of the jig is 150 tph. The actual capacity of an individual plant is based on the size consist of the coal to be washed and its washability characteristics. As the separation becomes more difficult (i.e., fine coal cleaning or a large amount of near gravity material), the capacity of the jig is reduced to allow for proper cleaning. As the separation becomes easier (i.e., coarse coal washing or little near gravity material), the capacity increases.

2. Coal Quality

The clean coal quality produced by the unitized jig plant is dependent on the washability characteristics of the raw coal and the limitations of the jig.

The two-cell diaphragm jig will generally wash the coarser size feed (plus 1/4 inch) at a specific gravity between 1.50 and 1.60. It will wash finer coal (1/4 inch X 28 mesh) at a somewhat higher specific gravity, generally around 1.80, and its ability to wash very fine coal (minus 28 mesh) is negligible although some cleaning does occur. The minus 100 mesh material is discarded as refuse. The following example will help to illustrate this performance.

Given a raw coal with the following washability characteristics:

ANALYSIS OF THE RAW FEED

Size Fraction	% of Total	% S	Btu/lb	% Ash
+1/4 inch	57.12	1.05	11,947	14.23
1/4 inch X 28 mesh	33.17	0.95	11,602	16.07
28 mesh X 100 mesh	8.77	1.12	9,555	21.27
-100 mesh	0.94	1.84	7,890	30.44
Total	100.00	1.03	11,585	15.61

WASHABILITY DATA - PLUS 1/4 INCH

57.12% of Total Sample

Specific Gravity		Individual Dry Basis				Cumulative Dry Basis			
SINK	FLOAT	% REC.	% ASH	% S	Btu/lb	% REC.	% ASH	% S	Btu/lb
-	1.35	68.8	4.64	0.72	13,515	68.8	4.64	0.72	13,515
1.35	1.40	7.4	11.04	1.07	12,541	76.3	5.26	0.75	13,420
1.40	1.50	9.2	18.52	1.34	11,350	85.4	6.69	0.82	13,198
1.50	1.60	3.0	25.85	1.81	10,130	88.4	7.34	0.85	13,094
1.60	1.80	2.4	38.28	2.72	7,900	90.8	8.14	0.90	12,959
1.80	-	9.2	74.21	2.58	1,982	100.0	14.23	1.05	11,947

WASHABILITY DATA - 1/4 INCH X 28 MESH

33.17% of Total Sample

Specific Gravity		Individual Dry Basis				Cumulative Dry Basis			
SINK	FLOAT	% REC.	% ASH	% S	Btu/lb	% REC.	% ASH	% S	Btu/lb
-	1.35	66.7	4.15	0.65	13,535	66.7	4.15	0.65	13,535
1.35	1.40	7.8	10.96	0.89	12,437	74.5	4.86	0.68	13,420
1.40	1.50	7.8	18.86	1.31	11,091	82.3	6.19	0.74	13,199
1.50	1.60	3.0	29.56	2.05	9,331	85.3	7.01	0.78	13,063
1.60	1.80	2.7	42.05	2.56	7,226	88.0	8.09	0.84	12,884
1.80	-	12.0	74.59	1.80	2,203	100.0	16.07	0.95	11,602

If only the coarser size (+1/4") was washed the following clean coal quality from the plant would be expected on a dry basis:

% WT. RECOVERY	% MOISTURE	% ASH	% SULFUR	Btu/lb	% Btu RECOVERY
88.4	<6	7.34	0.85	13,094	96.9

This is the quality of the + 1/4" material only. The quality of the composite clean coal (+1/4" clean coal and -1/4" raw coal) would be:

% WT. RECOVERY	% MOISTURE	% ASH	% SULFUR	Btu/lb	% Btu Recovery
93.4	<6	12.08	0.92	12,259	98.8

If all the raw coal sizes were fed to the plant, the following clean coal quality would be expected:

% WT. RECOVERY	% MOISTURE	% ASH	% SULFUR	Btu/lb	% Btu Recovery
89.3	<6	8.97	0.87	12,673	97.7

The choice between washing only the coarser coal or all raw coal sizes is a judgement decision, dependent on the desired clean coal quality and the washability. In some cases the -1/4 inch material needs little if any cleaning and could bypass the plant with very little detrimental effect on the clean coal quality. In other cases, as the one above, the washing of the fine coal along with the coarse coal produces a better overall clean coal.

3. Capital Cost

The initial capital cost of a unitized jig plant excluding raw coal and clean coal handling facilities, site preparation, foundations, power supply and fresh water supply, is approximately $650,000. The cost of the excluded items will vary greatly, depending on site configuration and location. However, the average expected cost of these items would be approximately $450,000. This gives a total average cost of $1.1 million. Placed on the basis of 150 tph raw coal input, this translates to $7,300 per ton hour input. As would be expected, this is slightly higher than larger simple jig plants of the type described by Example 1 in Section 5.0.

SECTION 4.0

OPERATIONAL AND OTHER FACTORS INFLUENCING COST

4.0 OPERATIONAL AND OTHER FACTORS INFLUENCING COST

This section is devoted to a brief discussion of the major factors which influence the cost of coal preparation irrespective of the type of cleaning process. Although some of these factors such as plant utilization are controllable to some extent, others like diminishing coal quality are more a reality of the times.

4.1 Plant Utilization

Obviously, there are 8,760 hours in most years (24 hours/day x 365 days/year). Although these can be considered the maximum potential number of working hours per year, there are some practical considerations brought on by custom and the nature of the process as well as the legal and union realities of the environment in which business functions. By custom, we are referring to the fact that most workers today are geared to a forty hour or less work week, the observance of certain holidays, and annual vacations. Also limiting the number of hours a particular process can be fully functional are the practical/economic limits imposed by the necessity to shut down for scheduled and unscheduled maintenance and the doubtful availability of an unlimited pool of qualified personnel to fill-in when the regular staff is absent. Additionally, in some industries, such as coal preparation, there is not a continuous supply of raw material available. Finally, the legal and union restrictions on the number of hours and designated days an employee can work without being paid premium wages influence the total number of hours a particular operation will be productive during any given year.

In a capital intensive industry such as coal preparation, the greater the plant can be productive, the less will be the capital cost burden carried by each ton of clean coal. Additionally, the more the plant can run continuously, the less time will be lost in start-up and shut down. To try and assess the impact of such "lost" time, the influence of the union contract imposed work hours is discussed below.

Plant Efficiency - Impact of Union Contract

The most recent National Bituminous Wage Agreement of 1974, which was effective through 5 December 1977, provided for preparation plant and supporting personnel (outside employees) to have a 7 hour and 15 minute work day. Included in the 7.25 hours is a 30 minute lunch break. For this 7.25 hours per day and 36.25 hours per week, the employer must pay the overtime wage rate of time and one-half for the additional time worked.

Considering the practical application of this number of hours to the efficient operation of a preparation plant gives some food for thought which has encouraged operators to use overtime in spite of the cost. It is standard practice at plants to conduct three shifts per day beginning at 8 A.M., 4 P.M. and 12 A.M. Assuming two of these shifts are operating and no overtime is incurred, it will take 30 minutes to an hour to start-up and the plant will be shut-down between 30 minutes and an hour before the shift is over if overlapping scheduling of workers is not permitted. This means that a minimum of one hour and 45 minutes of potential operating time is lost before the next operating shift comes on duty; i.e., half an hour starting up, half an hour to shut down plus 45 minutes between shifts. Then, it will take the second operating shift between 30 minutes and an hour to get the plant functioning at capacity again. Toward the end of this shift, the plant will again have to be shut down which will mean a loss of another 30 minutes to one hour. Therefore, during the period from 8 A.M. to 12 midnight when there was potentially sixteen hours of operating time, the plant only produced coal during a maximum of 12.5 hours. This was calculated as follows:

Total Potential Operating Hours Between 8 AM and 12 Midnight	16.0	
Less:		
8 A.M. Shift Start-Up	0.50	
8 A.M. Shift Shut-Down	0.50	
Break Between Shifts	.75	
4 P.M. Shift Start-Up	0.50	
4 P.M. Shift Shut-Down	0.50	
Break Between Shifts	.75	
Total Lost Operating Time	3.50	
Net Operating Time		12.5

Since the half an hour at the beginning of the day and the conclusion of the second shift is essential, an additional 2.5 operating hours might be picked up if overtime was incurred.

One way of evaluating the impact of this lost operating time is to look at the additional expenses and income associated with the extended period. For the purposes of this analysis, it is assumed the preparation plant is capable of producing 1000 tons of clean coal per hour and that a profit of $2.00 per ton is realized. This amount is meant to be a conservative estimate of the profit after considering all normal mining and preparation costs. Therefore, on the income side, if an additional 2,500 tons of clean coal were produced, $5,000 would be available to cover the increased labor costs.

Current Industry Practice

During the initial phase of this study conducted during 1975-1976, we had determined that preparation plants typically operate approximately 3,380 hours per year out of a possible 8,760 for an annual utilization of 38.6%. This was based upon data collected from plant operators and other industry sources. However, data collected during the first half of 1977 indicate that our previous utilization level was high. Many instances were recorded where operators ran the plant two shifts and performed maintenance on a third. Unfortunately, although they were paying for 14.5 operating hours (two 7.25 hour shifts), the plant would only function 11 to 13 hours per day. Compounding this problem of utilization was the fact that with vacations, holidays, special leave, sick days, and unaccountable absences, the plant might only operate 200 days per year. Variations of these current conditions are reflected in the operating and maintenance costs of the actual preparation plants examined in Section 5.0.

Those costs such as capital amortization which are sensitive to output (plant utilization) have been allocated on the basis of the given plant functioning at the nominal capacity indicated on its flow sheet for 2600 hours per year. This is equivalent to two 7.25 hour operating shifts (UMWA) 200 days per year reduced by 1.5 hours per day to allow for start-up on the first shift and shutdown on the second. This assumes overlapping of workers on operating shifts. Although this represents only a 30% utilization of the plant on an annual basis, it is not uncommon in recent years due to unscheduled work stoppage, mining production delays, and other factors. However, it is assumed that not all operations are plagued by these difficulities and those that are, will be able to increase their utilization. Therefore, the operating and maintenance costs presented for each preparation plant example are summarized on the basis of a raw coal input and clean coal output under both a 30% and 40% utilization. This latter utilization figure equates to 13 hours per day for 270 days per year (3510 hours) and represents an upper bound on being able to retain a maintenance shift for every two operating shifts with the plant layout considered. Higher utilization can obviously be achieved if redundant preparation circuits were to be included which would permit ongoing maintenance without total plant shutdown. Although there may be definite economic advantage associated with such an approach under certain conditions, only one such plant was examined and thus no definite conclusions can be drawn.

4.2 Coal Quality

The material withdrawn from the coal seam before being subjected to any form of preparation is referred to as run-of-mine. In addition to actual coal, this mined product includes rock and other impurities taken from the ground as part of the mining operation. Since the introduction of modern mining machinery and methods, the quality of this material has diminished. This reduced quality is reflected in lower yields from preparation plants due to the greater amounts of refuse in the raw feed. In order to compensate for this situation, existing plants have had to be redesigned to provide greater refuse handling capacity so as not to reduce the desired quality of the clean coal product. Several years ago, plant yields of 80 - 90 % were not uncommon. However, today, it is equally not uncommon to observe coal preparation plants having yields in the range of 50 %. Needless to say, this requirement for greater refuse handling capacity makes for higher capital and operating and maintenance costs, not to mention the larger refuse disposal problem. This latter problem can be particularly acute due to the environmental regulations governing refuse disposal and the lack of suitable landfill areas.

Some of the specific factors which contribute to the degradation of the run-of-mine coal are as follows:

1. Mining Machinery - Increased usage of continuous mining equipment. Due to the manner in which this equipment functions, greater amounts of material above and below the coal seam (roof and floor) are loaded out with the coal than occurs in conventional mining.
2. Mining Methods -
   A) Greater use of water for dust control. In an attempt to meet dust limitations, an increasing amount of water is now used in the mining process. This water places into suspension such undesirable impurities as clay and rock

dust which are eventually loaded out with the coal and wind up at the preparation plant.

B) Requirement for continuous clean-up. Federal regulations direct the removal of excess material from the mining area to keep passages fully open. Thus, it is more convenient for the miner to load out all the material in the way at one time rather than make a separate coal and rock cycle.

3. Quality of Coal Seams - Many of the coal seams being mined today contain large amounts of impurities which cannot be avoided in the mining process and are therefore loaded out directly with the coal.

This diminishing coal quality is reflected in terms of higher capital cost for the same capacity plant. Additionally, operating and maintenance costs are affected especially in the areas of refuse disposal and chemical expense associated with water clarification.

4.3 Capital Amortization

4.3.1 Capital Amortization Defined

Whether a plant is bought outright, financed through a third party, or leased over an extended period, the total capital costs represent an outlay of funds to someone which must be accounted for in determining the overall cost of coal cleaning. If the company operating the preparation plant had sufficient liquidity to purchase the installation without outside assistance, they still must account for these funds invested which they have elected to withdraw or divert from other income producing opportunities. Not only do they want to recover these funds during the useful life of the plant, but they should also receive a fair rate of return based upon other investment alternatives. If a plant is fully leased through an outside source, the operator's total lease payments consist of both the plant cost and a "fair rate of return" to a third party in the form of interest. Although the period of recovery and the rate of return/interest will vary, this same "cost of capital" reasoning applies regardless of the source of funds; only the mechanics differ. This mechanical process normally takes the form of spreading the cost of the plant over its output and is referred to as capital amortization.

Where a company has purchased the plant with its own or borrowed funds, the capital is "recovered" as depreciation and is listed as an expense attributable to each unit of output. If the preparation plant is leased, the payments are also allocated as an expense to each ton of clean coal produced. Therefore, it is obvious that whether any given plant is financed or leased, the capital cost per unit of output will be reduced as the plant produces more clean coal. This becomes a significant factor in the case of larger more sophisticated preparation plants, due to the increasingly capital intensive nature of their processes. A general indication of this trend comes from the following summarization of current capital requirements for a variety of preparation plant sizes and complexities as covered in Section 5.0.

Example	Type Of Plant	Input Feed Rate	Capital Cost Per Ton Hr Input
1	Jig - Simple	600 tph	$ 6,600
2	Jig - Intermediate	1000 tph	13,700
3	Jig - Intermediate	1000 tph	12,100
4	Jig - Complex	1600 tph	14,300
5	Heavy Media - Simple	1400 tph	13,800
6	Heavy Media - Complex	600 tph	22,400
7	Heavy Media - Complex	600 tph	14,000
8	Heavy Media - Complex	900 tph	23,200

These figures are only intended to show the magnitude of preparation capital costs and do not imply any general relationship concerning the capital cost of one process over another. Such a discussion is reserved for Section 5.0 where the reader has the opportunity to review the make-up of the individual plant and better understand why its cost differs from another plant of comparable input capacity.

In the following sub-section, an explanation is given of the factors influencing capital amortization and the rationale used to develop the approach applied under Section 5.0. It is noted that the approach discussed therein is only one of many possible ways of spreading the cost of the preparation complex over the output of the plant. Should the readers feel another approach better represents their particular circumstance, it may be substituted without affecting the accuracy of the other costs of operation presented for each of the preparation process examples.

4.3.2 Capital Amortization Applied

As indicated earlier, there are a variety of approaches to spreading the preparation plant capital cost over the material processed. Whether you are allocating this cost to each ton of raw coal fed to the plant or each ton of clean product, the figure arrived at under all approaches is sensitive to the following factors:

1) total capital required

2) plant capacity

3) operating hours per period (utilization)

4) cost of money

5) period over which plant is written-off

Certainly, the first two factors will be directly related to the magnitude and complexity of the particular preparation plant. For most operations today, the third factor, that of plant utilization, will vary within a range of between 30% and 40%. It is acknowledged that some exceptions do exist at either end of this range. However, in the absence of redundant preparation equipment, it is uncommon for a plant to actually operate more than 40% of the time. This is equivalent to a plant operating 12 to 13 hours per day 270 days per year for a total of approximately 3,500 hours per year out of a possible 8,760.

With regard to the cost of money, a range of values will occur in practice whether the plant is purchased with borrowed or internal funds. If the funds are acquired outside the firm, their cost will be a function of the current prime interest rate, term of loan, and the credit of the borrower. Even larger firms experience loan rates of 2 to 3 percentage points over prime for purchases of this type. If the plant is to be funded directly by the firm, consideration must be given to the rate of return which might be realized by alternative uses.

The final variable in determining capital amortization is the write-off period. Although this is influenced by the anticipated life of the plant and Internal Revenue Service depreciation guidelines, its final determination is made on the basis of individual company fiscal policy. Certainly, many elements comprising the total plant when properly maintained will last 20 to 30 years whereas others will require replacement within 5 to 10 years. Therefore in practice, the period over which the plant is written-off will be a composite of the anticipated replacement cycles limited by the IRS and specific company fiscal policy previously noted.

Realizing the diversity of approach as well as the myriad of values which could be assigned to the factors influencing capital amortization, we have, for the purposes of the various preparation plants covered by this study, taken a straightforward approach which is easily understood and adaptable to individual circumstances. Under this approach, it is assumed that the plant is entirely financed by an equal monthly payment self-liquidating loan granted at an annual interest rate of 9% (7% prime plus 2%). By considering both the principal and interest portions of this self-liquidating loan as costs, this approach gives equivalent results to depreciating the principal over the life of the plant. Further, we are considering loan repayment periods of both 10 and 15 years to provide a range indicative of the write-off periods actually being observed for preparation plants by industry. Finally, we have considered a 30% and 40% plant utilization which relates to approximately 2600 and 3500 operating hours per year, respectively.

Based upon the above assumptions, the following relationships are presented which are applied in Section 5.0 to determine the allocation of capital cost for each of the preparation plants examined therein.

CC_M = Capital Cost Per Month = Capital Cost X Periodic Payment Factor

Periodic Payment Factor = $P_F = \frac{i\ (1 + i)^n}{(1 + i)^n - 1}$

Where: n = period of loan in months

i = interest rate per month

Therefore:

When i = prime rate + 2%

$$i = \frac{0.07 + 0.02}{12} = 0.0075 \text{ per month}$$

And n = 120 months (10 years)

$$P_F = \frac{0.0075\ (1 + 0.0075)^{120}}{(1 + 0.0075)^{120} - 1}$$

$$P_F = 0.012668$$

When n = 180 months (15 years)

$$P_F = 0.010143$$

Based upon these periodic payment factors, the monthly capital cost per million dollars of plant investment would be --

CC_M for 10 years = $\$10^6$ X 0.012668 = \$12,668

and

CC_M for 15 years = $\$10^6$ X 0.010143 = \$10,143/month

Obviously, the annual capital cost per million dollars of plant investment would be --

CC_Y = Capital Cost Per Year = CC_M X 12

Therefore:

CC_Y for 10 years = \$152,016

And

CC_Y for 15 years = \$121,716

This being the case, plants which operate 30% (2,600 hrs) and 40% (3,500 hrs) of the time will have hourly capital costs per million dollars of plant investment of --

CC_H = Capital Cost Per Hour = $CC_Y \div$ Utilization

At 30% Utilization

CC_H for 10 years = $152,016 ÷ 2,600 = $58.47 and

CC_H for 15 years = $121,716 ÷ 2,600 = $46.81

At 40% Utilization

CC_H for 10 years = $152,016 ÷ 3,500 = $43.43 and

CC_H for 15 years = $121,716 ÷ 3,500 = $34.78

Now, knowing these four factors, they can be applied to any plant given the total capital required and the input/output capacity. For example, an 11 million dollar plant which is processing 900 tons per hour (tph) of raw coal and producing 720 tph of clean coal would have capital costs as follows:

For 10 Year Amortization - 30%

$58.47 X 11 ÷ 900 = $0.71 per ton of raw coal

$58.47 X 11 ÷ 720 = $0.89 per ton of clean coal

Summarizing the various values based upon either 30% or 40% utilization gives:

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization	
	30%	40%
10 Year Period		
Per Ton of Raw Coal	$0.71	$0.53
Per Ton of Clean Coal	$0.89	$0.66
15 Year Period		
Per Ton of Raw Coal	$0.57	$0.43
Per Ton of Clean Coal	$0.72	$0.53

As mentioned above, there are many portions of the preparation plant which, with proper maintenance, will last substantially longer than the 10 to 15 years write-off period. This being the case, one might assume that following this write-off period, capital amortization would no longer be an applicable cost of preparation and the clean coal produced after that time would be "cheaper" since it would not be burdened with this expense. However, this is not what occurs. Industry experience indicates that coal preparation plants are essentially "replaced" from a capital standpoint every 7 to 10 years. What this means is the operator will reinvest an amount equivalent to the initial cost of the plant approximately every ten years. Another way of looking at this subject is to think of the operator incrementally "rolling over" his capital during the life of the plant, thus never eliminating capital amortization but making it a recurring expense. These fresh capital funds are typically required to handle major equipment replacement and refurbishment as well as periodic modification and/or additions to the preparation plant. This latter requirement can be brought on by the availability of more effective equipment, variances in the composition of the raw coal, and/or changes to the clean coal specification. Although these major expenses can be anticipated to some extent, they are not considered part of the routine operation and maintenance cost of the preparation plant. This being the case, although a 10 or 15 year write-off period is used, the allowance for capital amortization will be a recurring expense for the total life of the plant to properly account for the periodic influx of "fresh" capital into the plant.

4.4 Cost of Btu Loss In Cleaning

During the cleaning process some portion of the heat content of the raw feed is lost. Since the raw coal had some value before cleaning, the heat content lost also had a definite value. This amount lost should be accounted for and allocated as an additional cost of coal cleaning. The specific cost attributed to this Btu loss is a function of the raw coal value, the Btu content of the raw coal, and the Btu recovery of the particular coal cleaning process. For ease of understanding, we have approached this quantity as the difference between the output cost and input cost per million Btu. To illustrate how this quantity is determined, the following example is given:

Assume -

Raw Coal Cost of \$15.00 per ton

Btu Content of Raw Coal 9,000 Btu per lb

Btu Recovery of Cleaning Process 94%

This gives an input cost of -

$$\text{Input Cost} = \$15.00/\text{ton} \div (9{,}000 \text{ Btu/lb} \times 2000 \text{ lb/ton})$$

$$\text{Input Cost} = \$0.833/10^6 \text{ Btu}$$

Since the Btu recovery of the process is 94%, the output cost will be -

$$\text{Output Cost} = \text{Input Cost} \div 0.94$$

$$\text{Output Cost} = \$0.833/10^6 \text{ Btu} \div 0.94$$

$$\text{Output Cost} = \$0.886/10^6 \text{ Btu}$$

Therefore, the Btu loss will be -

$$\text{Btu Loss} = \text{Output Cost} - \text{Input Cost}$$

Btu Loss = $\$0.886/10^6$ Btu - $0.833/10^6$ Btu

Btu Loss = $\underline{\$0.053/10^6 \text{ Btu}}$

This approach is observed in determining the Btu loss for each of the preparation processes examined under Section 5.0. In all cases a raw coal value of $15.00 per ton is assumed. Obviously, the other two variables, raw coal Btu content and Btu recovery, are based upon the specifics of the example presented.

As covered in Section 5.0 on a plant by plant basis, there is much discussion on whether or not it is appropriate to apply the "cost" of these "lost" Btu's to coal preparation. This question arises since the material discarded in cleaning, which contained these "lost" Btu's, is essentially large quantities of the undesirable raw coal constituents such as ash and sulfur whose removal was the very purpose of the preparation process. It is for this reason that the individual process should be evaluated to determine whether or not a maximum economic Btu recovery point has been reached. If the process is performing reasonably close to well conceived design Btu recovery limits, it might be more appropriate to not consider these "lost" Btu's as a cost. However, if the process is either poorly conceived from the standpoint of economic Btu recovery or the plant is not performing close to its design capabilities, then an inefficiency "penalty" might be assessed to reflect this discarded heat content which was lost unnecessarily. This being the case, the "cost" of this "lost" heat content has been treated as a separate element which the reader may apply or not as seen fit.

Btu Content of Clean Coal -

In order to make an accurate calculation of the Btu content of the clean product from the preparation plant, consideration must be given to the final moisture content. If the Btu content of the clean coal on a moisture free (MF) basis is known, the true Btu content can be calculated as follows:

Assume - Btu Content (MF) of Clean Product = 13,056 Btu/lb

Moisture Content of Clean Product = 4.6%

Then - True Btu Content of Clean Product =

$$(1-.046)\ Btu_{MF} = .954\ (13,056)$$

True Btu = 12,455 Btu/lb

If the Btu content of the coal on a moisture and ash free (MAF) basis is known, the true Btu content of the clean product can be calculated as follows:

Assume - Btu Content (MAF) of Coal = 14,511 Btu/lb

Moisture Content of Clean Product = 4.6%

Ash Content of Clean Coal = 10.03% (Dry Basis)

Then - True Btu of Clean Product =

$$\left[(1-.1003)\ (1-.046)\right]\ Btu_{MAF} = .8583\ (14,511)$$

True Btu = 12,455 Btu/lb

The above computation was used for determining the final Btu content of the clean product in Example 3 presented in Section 5.0. A similar approach was used in the other examples where sufficient data was available. In the absence of such data, reasonable assumptions were made.

SECTION 5.0

PREPARATION PROCESS EXAMPLES

5.0 PREPARATION PROCESS EXAMPLES

Presented within this section are summaries of eight actual coal preparation plants along with their individual capital and operating and maintenance (O&M) costs as of mid-1977. These plants span a spectrum of currently applied coal preparation technology from a relatively simple jig process to rather complex circuits utilizing heavy media, froth flotation, and thermal drying. Each of these plants is discussed separately with an analysis of the specific process and the level of cleaning achieved based upon the particular coal being processed.

Through these examples of actual operating plants, the reader is made aware of the sensitivity of the total cost of coal preparation to such major elements as plant capital cost and the presence of thermal drying in the circuit. Further, the influence of plant utilization on the amortization of fixed costs is noted for each example. Since these costs are presented on a uniform mid-1977 time base, they may be updated to subsequent periods with appropriate index adjustment.

All cost data relative to these eight plants are presented from the perspective of the preparation plant operator and do not assess the many user oriented benefits resulting from coal cleaning. In addition to increased heat content, these benefits include lower emission control, transportation, boiler maintenance, and ash disposal costs. These costs must be quantified on a site specific basis and set-off against the preparation costs presented herein to arrive at the net cost of coal cleaning.

5.1 Example 1 - Jig Process - Simple

5.1.1 General Description

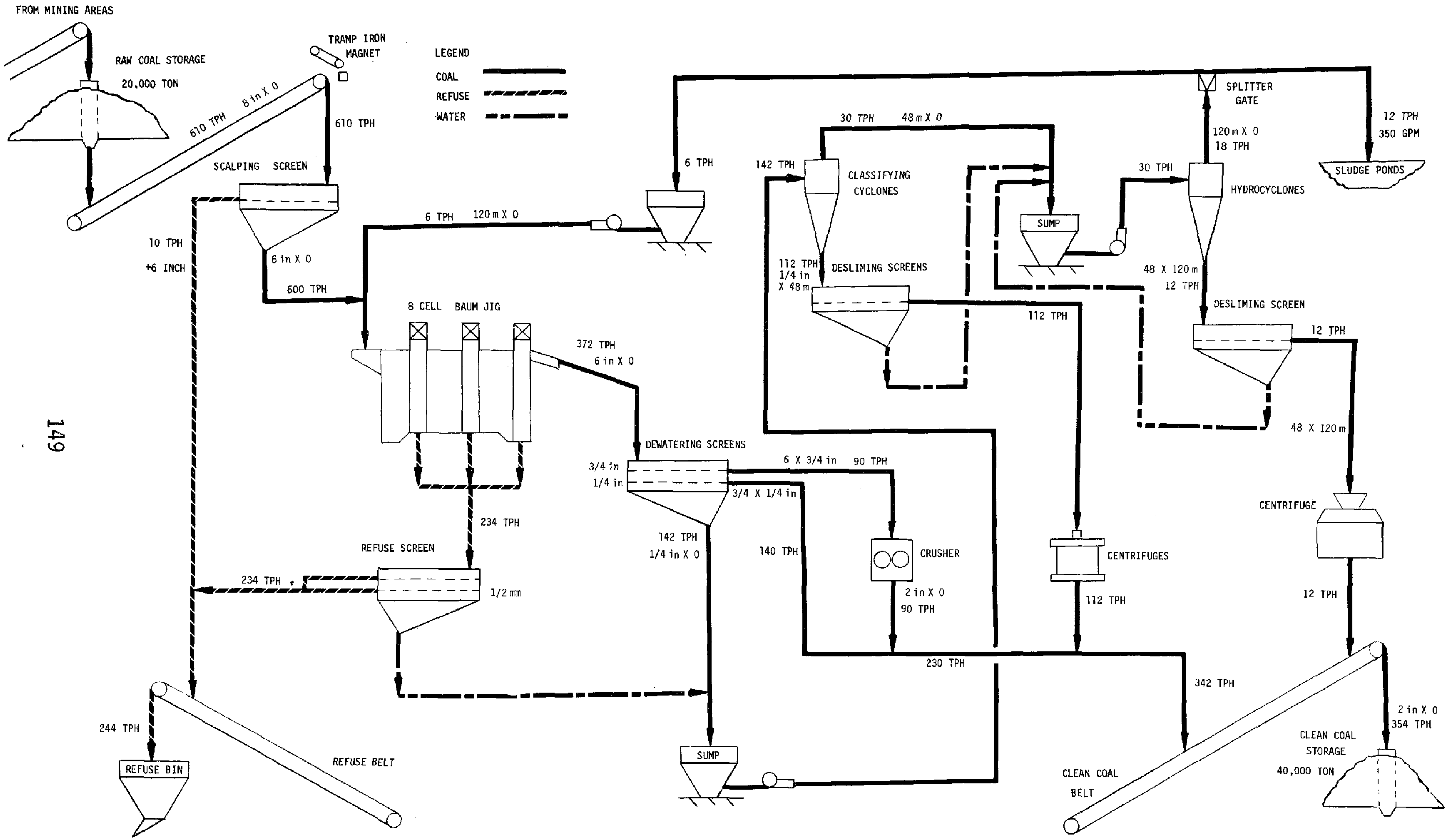
Although there are more basic preparation processes utilizing a jig as the primary separation vessel, this plant is categorized as "simple" to place it in a range with the other jig processes examined under Examples 2, 3, and 4.

This particular plant is designed to handle a variety of coals from both surface and underground mines. The separation achieved by the process as presented in the flow sheet, Figure 5-1, is based upon processing a deep mined coal using continuous mining equipment.

From the raw coal storage area, the 8 inch X 0 material is conveyed via a 42 inch wide belt to a 6 X 16 foot single deck vibrating screen. As a result of the force of being dropped onto this screen and the vibrating action, the larger pieces of coal are fractured to 6 inches or less. The small amount of material which does not reduce to 6 inches or less passes over the screen and reports to the refuse belt. The 600 tph of 6 inch X 0 raw coal is fed to an eight cell three compartment Baum type jig. Of the material entering the jig, 372 tph "floats" out and 234 tph sink as refuse. This refuse goes to a 5 X 10 foot double deck vibrating screen with 1/2mm openings in the bottom deck where it is partially dewatered before reporting to the refuse belt.

The 372 tph of "float" from the jig goes to two 6 X 16 foot vibrating double deck screens having 3/4 inch and 1/4 inch openings in the top and bottom decks, respectively. Approximately 90 tph of 6 X 3/4 inch coal passes over the top deck and goes to a crusher where it is reduced to 2 inch X 0 before dropping onto the clean coal belt. Passing over the

FIGURE 5-1
EXAMPLE 1 - JIG PROCESS - SIMPLE
PREPARATION PLANT FLOW SHEET



lower deck is 140 tph of 3/4 X 1/4 inch material which goes directly to the clean coal belt. The 1/4 inch X 0 material passing through both decks reports to a sump from which it is pumped to four 20 inch diameter Nihard classifying cyclones at the rate of 142 tph. The 112 tph of 1/4 inch X 48 mesh underflow from these cyclones goes to two 6 X 16 foot desliming screens. All measurable material passes over these screens and is fed to two centrifugal dryers which recover essentially all of the feed. From the dryers, the 1/4 inch X 48 mesh material goes to the clean coal belt.

The 30 tph of 48 mesh X 0 overflow from the 20 inch classifying cyclones reports to a sump from which it is pumped to five 14 inch diameter rubber lined hydrocyclones. Of this total cyclone feed, 12 tph of 48 X 120 mesh material reports as underflow and goes to a 3 X 12 foot single deck desliming screen. Essentially all of this material passes over this screen and goes to a centrifugal dryer before going to the clean coal belt. There is 18 tph of 120 mesh X 0 overflow from the hydrocyclones which is split between the jig feed sump and the sludge ponds. Of the 18 tph, 6 tph reports to the sump from which it is pumped back to the jig and the balance (12 tph) is sluiced to the sludge ponds along with approximately 350 gallons per minute of water.

A total of 354 tph of 2 inch X 0 material having a heat content of 13,236 Btu/lb drops onto the 36 inch wide clean coal belt and is conveyed to a 40,000 ton open storage area awaiting unit-train load-out. Based upon a plant feed of 600 tph with a heat content of 8,523 Btu/lb, this plant yields an impressive 91.6% Btu recovery. Other performance figures are presented in Table 5-1.

The personnel necessary to operate and maintain this plant are listed under Table 5-4. As indicated in Table 5-5, the turn-key construction cost of this plant is 3.95 million dollars based upon mid-1977 price quotations.

TABLE 5-1

EXAMPLE 1 - JIG PROCESS - SIMPLE

PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
6 X 3/4 inch	180		8,120	41.17	0.60
3/4 inch X 0	420		8,693	35.34	0.67
	600	7.0	8,521	37.09	0.65

Clean Coal Product From Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
2 inch X 0	354	8-9.0	13,236	7.68	0.79

Net Performance:

Weight Yield 59.0% Btu Recovery 91.6% Btu of Clean Coal with 8-9% Moisture 12,111 Btu/lb

* Btu, Ash, & Sulfur Presented on Dry Basis

TABLE 5-2

EXAMPLE 1 - JIG PROCESS - SIMPLE

WASHABILITY DATA OF ASSUMED PLANT FEED - +3/4 INCH FRACTION*

Specific Gravity of Separation	Weight %	Ash %	Sulfur %	Btu/lb	Cumulative Float Weight %	Cumulative Float Ash %	Cumulative Float Sulfur %	Cumulative Float Btu/lb
Float 1.40	46.42	4.75	0.78	14,003	46.42	4.75	0.78	14,003
1.40- 1.45	2.67	13.33	0.76	12,352	49.09	5.23	0.78	13,913
1.45- 1.50	1.22	23.63	0.93	10,990	50.31	5.66	0.78	13,842
1.50- 1.55	1.06	29.50	0.51	9,880	51.37	6.15	0.78	13,760
1.55- 1.60	1.55	55.96	0.42	5,263	52.92	7.61	0.77	13,512
SINK- 1.60	47.08	78.89	0.41	2,060	100.0	41.17	0.60	8,120

* 29.75% of Total Feed

TABLE 5-3

EXAMPLE 1 - JIG PROCESS - SIMPLE

WASHABILITY DATA OF ASSUMED PLANT FEED - 3/4 INCH X 0 FRACTION*

Specific Gravity of Separation	Weight %	Ash %	Sulfur %	Btu/lb	Cumulative Float Weight %	Cumulative Float Ash %	Cumulative Float Sulfur %	Cumulative Float Btu/lb
Float 1.40	47.23	4.69	0.78	13,810	47.23	4.69	0.78	13,810
1.40- 1.45	4.49	14.67	0.80	11,737	51.72	5.55	0.78	13,630
1.45- 1.50	3.0	16.61	0.94	10,219	54.72	6.16	0.79	13,443
1.50- 1.55	2.04	21.69	0.87	9,712	56.76	6.72	0.79	13,309
1.55- 1.60	1.99	35.99	0.76	7,707	58.75	7.71	0.80	13,119
SINK- 1.60	41.25	74.68	0.47	2,388	100.0	35.34	0.67	8,693

* 70.25% of Total Feed

TABLE 5-4

EXAMPLE 1 - JIG PROCESS - SIMPLE

PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Manager (1/4 time)		1
Operating Shift (2 per day)		
Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Electrician/Mechanic	4-A	1
Repairman Helper (Greaser)	2-F	1
Utility Man	1-H	2
Mobile Equipment Operator (Raw and Clean Coal Handling)		
Dozer Operator	3-A	2
	Total	8
Maintenance Shift (1 per day)		
Foreman	NU*	1
Mechanic	4-C	3
Utility Man	1-H	1
	Total	5
Personnel Summary		
General Management		1
Operating Shifts		16
Maintenance Shift		5
	Total	22

*NU-Non-Union

TABLE 5-5

EXAMPLE 1 - JIG PROCESS - SIMPLE
PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Storage Area		
20,000 Ton Capacity with Stacking Tube,		
Reclaiming Feeders, and Tunnel		$300,000
Raw Coal Belt To Plant		
42 Inch Wide - 200 Feet @ $520 per foot		104,000
Tramp Iron Magnet		
Explosion Proof - Self Cleaning Type		20,000
Total Raw Coal Storage & Handling Cost		$424,000
PREPARATION PLANT:		
Equipment Cost -		
6 X 16 Foot Single Deck Vibrating		
Scalping Screen		
1 @ $17,500	$ 17,500	
Eight Cell Baum Type Jig		
1 @ $176,000	176,000	
6 X 16 Foot Double Deck Vibrating		
Dewatering Screens		
2 @ $23,000 each	46,000	
5 X 10 Foot Double Deck Vibrating Refuse		
Dewatering Screen		
1 @ $18,000	18,000	

Crusher		
1 @ $12,100	$ 12,100	
Classifying Cyclones		
20 Inch Diameter - NiHard		
4 @ $2,400 each	9,600	
Hydrocyclones		
14 Inch Diameter - Rubber Lined		
5 @ $1,300 each	6,500	
3 X 12 Foot Single Deck Desliming Screen		
1 @ $12,000	12,000	
Centrifugal Dryer		
1 @ $23,200	23,200	
Centrifugal Dryers		
2 @ $28,200 each	56,400	
6 X 16 Foot Single Deck Desliming Screens		
2 @ $16,000 each	32,000	
Sumps		
3 @ $10,000 each	30,000	
Pumps	75,000	
Total Preparation Plant Equipment Cost	$514,300	
Total Cost of Preparation Plant		
Including Site Preparation, Construction of		
Building, Electrical Service, Piping, etc.		
$514,300 X 3.0		$1,542,900

OTHER FACILITIES & EQUIPMENT:

Clean Coal Belt	
36 Inch Wide - 300 Feet @ $480 per foot	$ 144,000
Clean Coal Storage Area	
40,000 Ton Capacity with Stacking Tube, Reclaiming Feeders, etc.	350,000
Refuse Belt	
36 Inch Wide - 250 Feet @ $480 per foot	120,000
Refuse Bin	50,000
Raw Coal and Refuse Handling Equipment	
2 - Dozers @ $150,000 each	300,000
Unit-Train Loading Facility	500,000
Total Other Facilities & Equipment	$1,464,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 424,000
Preparation Plant	1,542,900
Other Facilities and Equipment	1,464,000
Contingency (Interest during construction, etc.)	515,000
Total Capital Requirement	$3,945,900

BASED UPON THE 600 TON PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $6,600 PER TON HOUR INPUT

5.1.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 1 is as follows:

Total Capital Required: $3.95 million

Capacity:

Raw Coal Input - 600 tph

Clean Coal Output - 354 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	40%
10 Year Period		
Per Ton of Raw Coal	$0.38	$0.29
Per Ton of Clean Coal	$0.65	$0.48
15 Year Period		
Per Ton of Raw Coal	$0.31	$0.23
Per Ton of Clean Coal	$0.52	$0.39

5.1.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-6 are based upon:

- o Raw Coal Input of 600 Tons Per Hour
- o Clean Coal Output of 354 Tons Per Hour
- o Btu Recovery of 91.6%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-6

EXAMPLE 1 - JIG PROCESS - SIMPLE

OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.044	$0.075
Operating & Maintenance (Union)	0.303	0.514
Overhead -		
Fringe Benefits - 25% Non-Union	0.011	0.019
- 21% Union	0.064	0.108
Other - Includes Welfare Fund, Payroll Taxes, Property Taxes, Insurance, etc.	0.059	0.100
Supplies -		
Operating	0.155	0.262
Maintenance	0.148	0.251
Major Maintenance - Scheduled repairs and plant improvements	0.134	0.228
Electricity -	0.073	0.123
Subcontract Services to Dip Sludge Ponds, Haul Refuse & Miscellaneous Expenses	0.599	1.016
O & M Cost - Not Including Capital Amortization	$1.59	$2.70
Capital Amortization - 10 Yrs. - 30% Utilization	0.38	0.65
Total Operating & Maintenance Cost	$1.97	$3.35
Cost Per Million Btu (12,111 Btu/lb)		$0.138

5.1.4 Discussion of Performance and Cost

As indicated by the performance data summarized in Table 5-1, the Example 1 plant is capable of significantly reducing the ash content of this particular coal while still maintaining a reasonable Btu recovery. Since the majority of the already small sulfur content of this raw coal is organic in nature, the net effect of the cleaning process is to slightly increase the overall sulfur percentage in the final product. Although this result is expected since organic sulfur is not removed by physical cleaning, it does not imply that this process will produce comparable results with all coals. When handling coals having greater pyritic sulfur contents, processes of this type can contribute favorably to reducing the overall sulfur content of the clean coal product.

From the washability data given in Tables 5-2 and 5-3, it can be observed that the jig is effecting a separation at between 1.50 and 1.60 specific gravity. Looking further at the data, it is clear this point provides a relatively simple or "black and white" separation due to the limited amount of near gravity material. Such a clear separation makes for the efficient application of the Baum jig which loses much of its effectiveness as the percentage of near gravity material exceeds 10%. Even though slightly over 40% of the feed to the plant is discarded as refuse, the process still recovers 91.6% of the feed's Btu content. This occurs since the composite ash content of the material which sinks at a specific gravity of 1.60 is 76% and has a heat content of only 2,290 Btu/lb. Although a charge can be applied to the total preparation cost to cover these lost Btu's, it is debatable whether such a penalty is appropriate since the tangible value of this discarded material is questionable. If such a penalty is assessed in the manner covered by Section 4.4, it would have the effect of increasing the cost per million Btu by $0.081 to $0.219.

Under normal conditions, this plant functions five days per week, operating two full shifts a day with one shift devoted to maintenance. As indicated by Table 5-4, the number of personnel required to operate and maintain a plant of this size and complexity are quite small. Although greater utilization of this plant is technically possible, mining difficulties and other unscheduled stoppages have prevented operating hours from exceeding 2,600 per year. This limited utilization is reflected in higher fixed charges such as capital amortization, supervisory salaries, and some overhead costs. In spite of this less than optimum utilization, the overall cost of cleaning is quite reasonable considering the results achieved. The $3.35 per ton is a small price to pay for taking an 8,500 Btu/lb coal containing nearly 40% ash and producing a product having less than 8% ash. This cost could be even lower if it were not for the large expense ($1.02 per ton) associated with maintaining the sludge ponds and hauling refuse. A modification to the plant is currently being considered which would help to alleviate this expensive problem.

Simpler coarse cleaning plants of this type have a definite place in the future of coal preparation. With many coals, they can cost-effectively produce a product which is less expensive to handle and consume. The savings associated with these benefits such as lower transportation cost, ash disposal, boiler maintenance, etc. have not been deducted from the bottom-line cost in Table 5-6 since these benefits must be assessed on a site specific basis to be meaningful. However, it should be noted that when these benefits are quantified and deducted from the cleaning cost, the net cost of coal preparation can be significantly less.

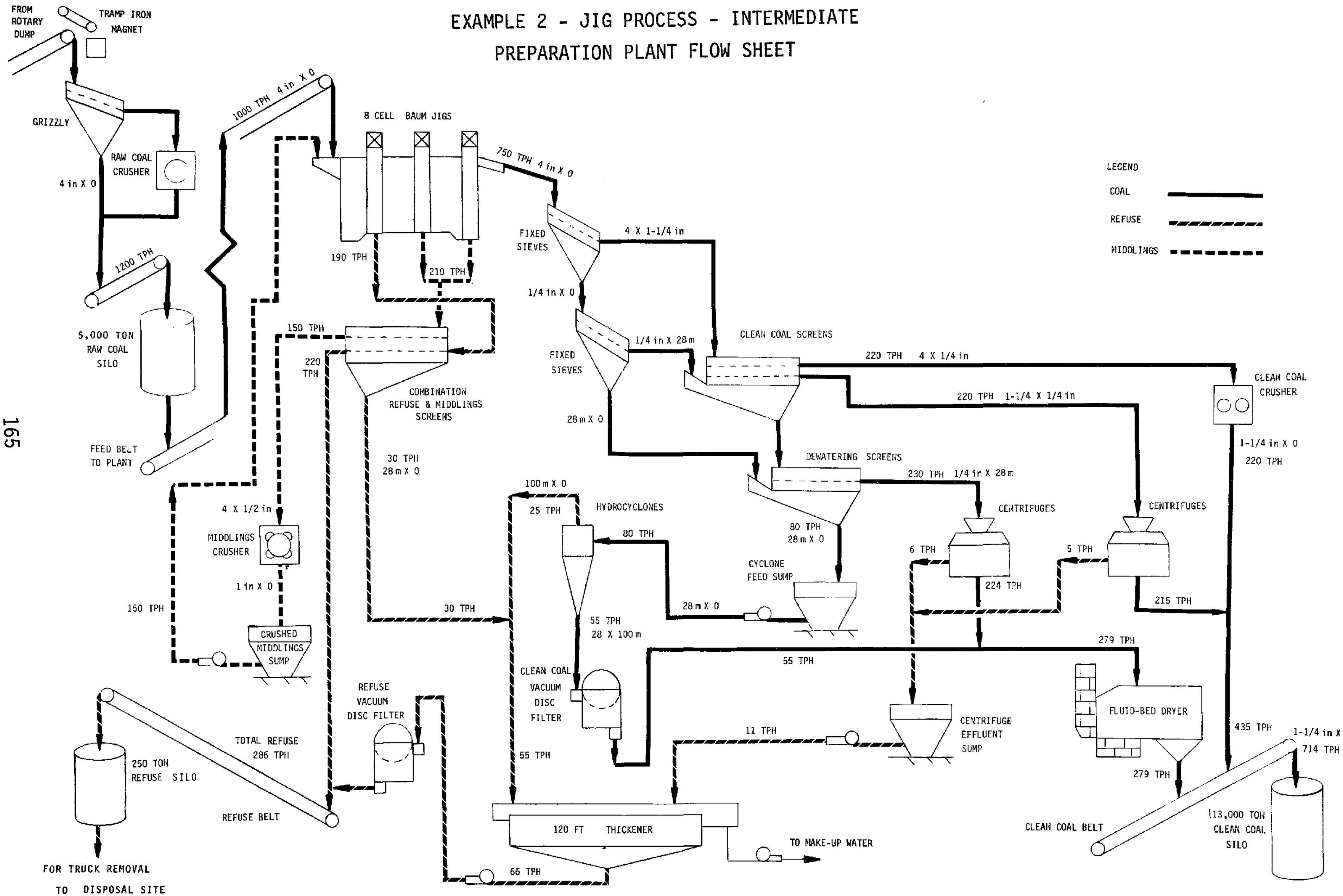
5.2 Example 2 - Jig Process - Intermediate

5.2.1 General Description

This particular plant is processing coal from the Pittsburgh Number 8 Seam which is mined mainly with continuous miners. The plant is located near the mouth of the mine from which the coal is brought in mine cars to a rotary dump. After being unloaded, the 10 inch X 0 coal is conveyed to two 6 X 16 foot single deck inclined screens designed to separate the raw material at four inches as shown on the flow sheet, Figure 5-2. On its way, the raw coal passes under a tramp iron magnet for the removal of ferrous matter such as broken mining bits. The less than 4 inch material passes through these screens and is conveyed to a 5,000 ton concrete silo. The plus 4 inch material passing over the screens goes to a crusher where it is reduced to four inches or less before being conveyed to the silo.

From the silo, the 4 inch X 0 raw coal is fed into the plant at the rate of 1,000 tph via a 48 inch belt to two eight cell three compartment Baum type jigs where the initial separation takes place. Under the manner in which the plant is operated, the sink from the first compartment is considered refuse. However, the sink from the second and third compartments is treated as middlings. A portion of these middlings is recovered on two double deck 5 X 14 foot combination refuse and middlings screens. This is accomplished by routing the middlings to the top deck having 1/2 inch openings and the refuse to the lower deck which has 28 mesh screen. By this arrangement, the 4 X 1/2 inch material passing over the top screen goes to a crusher where it is reduced to 1 inch or less before being pumped back to the jigs for further separation. The 4 inch X 28 mesh material passing over the bottom deck goes directly to the 36 inch wide refuse belt. The fine material passing through both decks

FIGURE 5-2
EXAMPLE 2 - JIG PROCESS - INTERMEDIATE PREPARATION PLANT FLOW SHEET



goes to the 120 foot diameter concrete thickener.

The 4 inch X 0 material "floating" out of the jigs passes to fixed sieves having screen openings of 1/4 inch. The 4 X 1/4 inch material passing over these sieves goes to four double deck 8 X 16 foot vibrating screens. The 1/4 inch X 0 material passing through these sieves goes to four fixed sieves having 28 mesh screening. The 1/4 inch X 28 mesh material passing over these 28 mesh sieves goes to four 6 X 12 foot single deck dewatering screens. The 28 mesh X 0 material passing through the 28 mesh sieves reports to two sumps along with any fines passing through the 6 X 12 foot dewatering screens. From these sumps, a slurry of 28 mesh X 0 material is pumped at the rate of 80 tph to four 24 inch diameter hydrocyclones. These cyclones are essentially performing a thickening function since the 25 tph 100 mesh X 0 overflow goes to the static thickener. The 55 tph of 28 X 100 mesh underflow from these cyclones is considered clean coal and goes to a vacuum disc filter for partial dewatering before being conveyed to the fluid-bed thermal dryer. This filter is 12 feet 6 inches in diameter and has 14 discs, giving an effective filtering surface area of 3,190 square feet. A load factor of 40 pounds per hour per square foot of filtering space allows for approximately 10% excess filtering capacity.

Returning to the 8 X 16 foot double deck screens, the top deck has screen openings of 1-1/4 inches and the bottom has 1/4 inch. The 4 X 1-1/4 inch clean coal passing over the top deck goes directly to two crushers at the rate of 220 tph where it is reduced to 1-1/4 inch X 0 before going to the 48 inch wide clean coal belt for load-out into a 13,000 ton concrete silo. The 1-1/4 X 1/4 inch material passing over the second deck goes to two centrifugal dryers at the rate of 220 tph for further dewatering. These dryers recover 215 tph (97-98%) of the feed which then goes directly to clean coal storage. The 5 tph of effluent reports to a sump from which it is pumped to the thickener. The 1/4 inch X 0 material passing through both decks of the 8 X 16 foot screens joins the overflow from the 28 mesh sieves and is fed to four 6 X 12 foot single deck vibrating dewatering screens having 28 mesh openings. The 1/4 inch X 28 mesh material passing over these screens at the rate of 230 tph is fed to two centrifugal dryers for further dewatering. The 224 tph (97%) recovered by these centrifuges goes to the thermal dryer. The 6 tph of effluent from these centrifuges is considered refuse and is pumped to the thickener. The thermal dryer receives a total of 279 tph of 1/4 inch X 0 coal having a surface moisture of around 13%. Following drying, the moisture is between 5% and 6%. This is roughly the moisture content of the entire 714 tph of 1-1/4 inch X 0 clean coal produced by this plant.

Underflow from the static thickener is pumped at the rate of 66 tph as a slurry containing approximately 35% solids to a vacuum disc filter. From this 12 feet 6 inch diameter filter with 15 discs, the filter cake goes to the refuse silo where it is combined with larger size material permitting it to be trucked to a landfill site.

The staff necessary to operate and maintain this plant are presented in Table 5-9.

TABLE 5-7

EXAMPLE 2 - JIG PROCESS - INTERMEDIATE

PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
4 inch X 0	1000	4.3	9,610	32.32	3.42

Clean Coal Product From Plant:

1-1/4 inch X 0	714	6.9	12,974	12.24	3.16

Moisture & Ash Free Btu -- 14,784 Btu/lb

Net Performance:

Weight Yield 71.4% Btu Recovery 96.4% Btu of Clean Coal with 6.9% Moisture 12,079 Btu/lb

*1] Btu, Ash, & Sulfur Presented on Dry Basis

TABLE 5-8

EXAMPLE 2 - JIG PROCESS - INTERMEDIATE

CUMULATIVE WASHABILITY DATA OF ASSUMED PLANT FEED *

Specific Gravity of Separation	Recovery %		Cumulative Float		Cumulative Sink	
	Weight	Btu	Btu/lb	Ash %	Wt. %	Ash %
FLOAT 1.40	54.88	78.2	13,690	7.40	100.0	32.34
1.40- 1.50	59.97	84.7	13,570	8.17	45.12	62.64
1.50- 1.60	62.90	88.0	13,440	8.98	40.03	68.51
1.60- 1.70	64.84	90.0	13,340	9.73	37.10	71.90
SINK- 1.70	100.00	100.0	9,610	32.32	35.16	73.99

*Btu & Ash Presented on Dry Basis

TABLE 5-9

EXAMPLE 2 - JIG PROCESS - INTERMEDIATE
PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Manager		1
General Foreman		1

Operating Shift (1st)

Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator - Central	4-E	1
Stationary Equipment Operator (Thermal Dryer)	3-C	1
Electrician	4-A	2
Mechanic	4-C	1
Mobile Equipment Operator		
Truck Driver (Refuse)	3-A	2
Dozer Operator	3-A	1
Repairman Helper (Greaser)	2-F	2
Utility Man	1-H	2
Car Dumper	1-B**	1
	Total	14

Operating Shift (2nd)

Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator - Central	4-E	1
Stationary Equipment Operator (Thermal Dryer)	3-C	1
Mechanic	4-C	1
Mobile Equipment Operator		
Truck Driver (Refuse)	3-A	2
Dozer Operator	3-A	1
Utility Man	1-H	2
Car Dumper	1-B**	1
	Total	10

Maintenance Shift	Union Classification	Quantity
Foreman	NU*	1
Mechanic	4-C	11
Car Dumper	1-B**	1
	Total	13

Personnel Summary		
General Management		2
Operating Shifts		24
Maintenance Shift		13
	Total	39

* NU-Non-Union

**Car Dumper Operator is paid at Job Class 3 Rate of Pay when equipment is being operated to dump the car.

TABLE 5-10

EXAMPLE 2 - JIG PROCESS - INTERMEDIATE

PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Belt To Grizzly		
48 Inch Wide - 100 feet @ $560 per foot		$ 56,000
Tramp Iron Magnet		
Explosion Proof - Self Cleaning Type		20,000
Grizzly (Scalping) Tower		
Includes screens and structure		250,000
Raw Coal Crusher		66,000
Raw Coal Belt To Silo		
48 Inch Wide - 550 feet @ $560 per foot		308,000
Raw Coal Silo (Concrete)		
5,000 ton capacity @ $110 per ton		550,000
Raw Coal Belt To Plant		
48 Inch Wide - 300 feet @ $560 per foot		168,000
Total Raw Coal Storage & Handling		$1,418,000
PREPARATION PLANT:		
Equipment Cost -		
Baum Jig - Eight Cell		
2 @ $176,000 each	$352,000	
5 X 14 Foot Double Deck Vibrating Screen		
2 @ $26,000 each	52,000	

8 X 16 Foot Double Deck Vibrating Screen	
4 @ $36,000 each	$144,000
Fixed Sieves	
8 @ $7,000 each	56,000
6 X 12 Foot Single Deck Dewatering Screen	
4 @ $16,000 each	64,000
Hydrocyclones - 24 Inch	
4 @ $3,500 each	14,000
Sump - Hydrocyclone Feed	
2 @ $10,000 each	20,000
Sump - Centrifuge Effluent	
1 @ $10,000	10,000
Sump - Crushed Middlings	
2 @ $10,000 each	20,000
Pumps	
Centrifugal Dryers - Bird Model 1150D	
4 @ $48,000 each	192,000
Vacuum Disc Filter - Refuse	
12 Feet 6 Inch Diameter - 15 Disc	
1 @ $135,000 each	135,000
Vacuum Disc Filter - Clean Coal	
12 Feet 6 Inch Diameter - 14 Disc	
1 @ $130,000	130,000
Crusher - Middlings	
2 @ $12,100 each	24,200
Crusher - Clean Coal	
2 @ $20,400 each	40,800
Total Preparation Plant Equipment Cost	$1,254,000

Total Cost of Preparation Plant	
Including Site Preparation, Construction of Building, Electrical Service, Piping, etc.	
$1,254,000 X 3.0	$3,762,000
OTHER FACILITIES & EQUIPMENT:	
Fluid-Bed Thermal Dryer	
Complete with structural steel, motors, motor controls, wiring, piping, field erection, and start-up service	2,500,000
Static Thickener (Concrete)	
120 feet in diameter @ $2,000 per foot	240,000
Refuse Belt To Refuse Silo	
36 Inch Wide - 300 feet @ $480 per foot	144,000
Refuse Silo	
250 ton capacity @ $200 per ton	50,000
Refuse Handling Equipment	
2 - 50 Ton Trucks @ $75,000 each	150,000
1 - Dozer (Spreding & Compacting)	150,000
Coal Sampling System	300,000
Clean Coal Belt To Silo	
48 Inch Wide - 450 feet @ $560 per foot	252,000
Clean Coal Silo	
13,000 ton capacity @ $110 per ton	1,430,000
River Barge Loadout Facility	
1000-1500 tph capacity including loading equipment with telescoping tube and necessary docking facilities	1,500,000
Total Other Facilities & Equipment	$6,716,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 1,418,000
Preparation Plant	3,762,000
Other Facilities and Equipment	6,716,000
Contingency (Interest during construction, etc.)	1,785,000
Total Capital Requirement	$13,681,000

BASED UPON THE 1000 TON PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $13,700 PER TON HOUR INPUT

5.2.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 2 is as follows:

Total Capital Required: $13.7 Million

Capacity:

Raw Coal Input - 1000 tph

Clean Coal Output - 714

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	40%
10 Year Period Per Ton of Raw Coal	$0.80	$0.59
Per Ton of Clean Coal	$1.12	$0.83
15 Year Period Per Ton of Raw Coal	$0.64	$0.48
Per Ton of Clean Coal	$0.90	$0.67

5.2.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-11 are based upon:

- o Raw Coal Input of 1000 Tons Per Hour
- o Clean Coal Output of 714 Tons Per Hour
- o Btu Recovery of 96.4%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-11

EXAMPLE 2 - JIG PROCESS - INTERMEDIATE
OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.039	$0.054
Operating & Maintenance (Union)	0.464	0.650
Overhead -		
Includes Training Wages, Welfare Fund, Payroll Taxes, Workmen's Compensation, etc.	0.211	0.296
Supplies -		
Operating - Water Conditioners, Flocculants, Electric Repairs & Parts, etc.	0.141	0.198
Maintenance - Replacement Parts, etc.	0.183	0.256
Fuel and Power -	0.233	0.326
Refuse Expense -		
In house and purchased services associated with refuse disposal such as truck parts, maintenance, etc.	0.132	0.185
Thermal Dryer Fuel - Based Upon 4.7 Tons/Hr. Coal Consumption & Cost of Coal $20/Ton.	0.094	0.132
Miscellaneous Expense - Repair & Maintenance Items Not Normally Inventoried or Requiring Outside Subcontract Svcs.	0.321	0.449
O & M Cost - Not Including Capital Amortization	$1.82	$2.55
Capital Amortization 10 Yrs. - 30% Utilization	0.80	1.12
Total Operating & Maintenance Cost	$2.62	$3.67
Cost Per Million Btu (12,079 Btu/lb)		$0.152

5.2.4 Discussion of Performance and Cost

The Example 2 plant is representative of many jig circuits currently in existence which can achieve a substantial reduction in ash and some sulfur removal with certain coals. As presented in Table 5-7, this plant recovers, an almost unbelievable, 96% of the Btu content in the raw feed. Looking at the washability data in Table 5-8, there appears to be a fairly clear separation at 1.60 specific gravity which could theoretically be effected by a jig. However, the reprocessing of the middlings from the jig seems to be increasing the weight yield and thus Btu recovery, but degrading the quality of the final product. Obviously, the manner in which a plant is operated at any given time is influenced by the economic realities of the clean coal specification the operator must meet.

As presented in Table 5-11, the total operating and maintenance cost, including capital amortization, is $3.67 per ton of clean coal. On the basis of a nearly 7% moisture clean coal having 12,079 Btu/lb, this equates to $0.152 per million Btu. If a cost penalty is assessed against the process for the limited Btu loss (3.6%), the total cost of preparation would increase by $0.029 to $0.181 per million Btu.

Using the performance of this plant with this particular coal as an example, processes of this general type can produce a fairly good quality coal at a reasonable cost. This cost is quite sensitive to the amount of thermal drying required and whether or not the plant can be kept operating for significant periods of the year. As presently operating, this plant is drying almost 40% of the total production which greatly impacts electricity consumption and maintenance expense. Further, the presence of the dryer adds personnel and increases capital requirements by 20%. Currently, the plant is barely operating 30% of the time which keeps the capital amortization at an artifically high level. If the plant could be operated an additional 10% of the year, a savings of $0.30 per clean ton could be realized from capital amortization alone; not to mention the favorable impact on other fixed charges.

The cost data presented in the foregoing tables is intended to give the reader insight regarding the capital and O & M costs which are required to establish and run a plant of this general make-up and capacity. When plants of this type are properly applied, efficient cost-effective results can be achieved which yield a product having cost saving benefits at the user level. These benefits include lower transportation, ash disposal, and maintenance costs, as well as limit the required particulate and FGD emission control capacity. As mentioned elsewhere, these benefits can be quantified on a site specific basis and go to improve the overall economics of coal preparation.

5.3 Example 3 - Jig Process - Intermediate

5.3.1 General Description

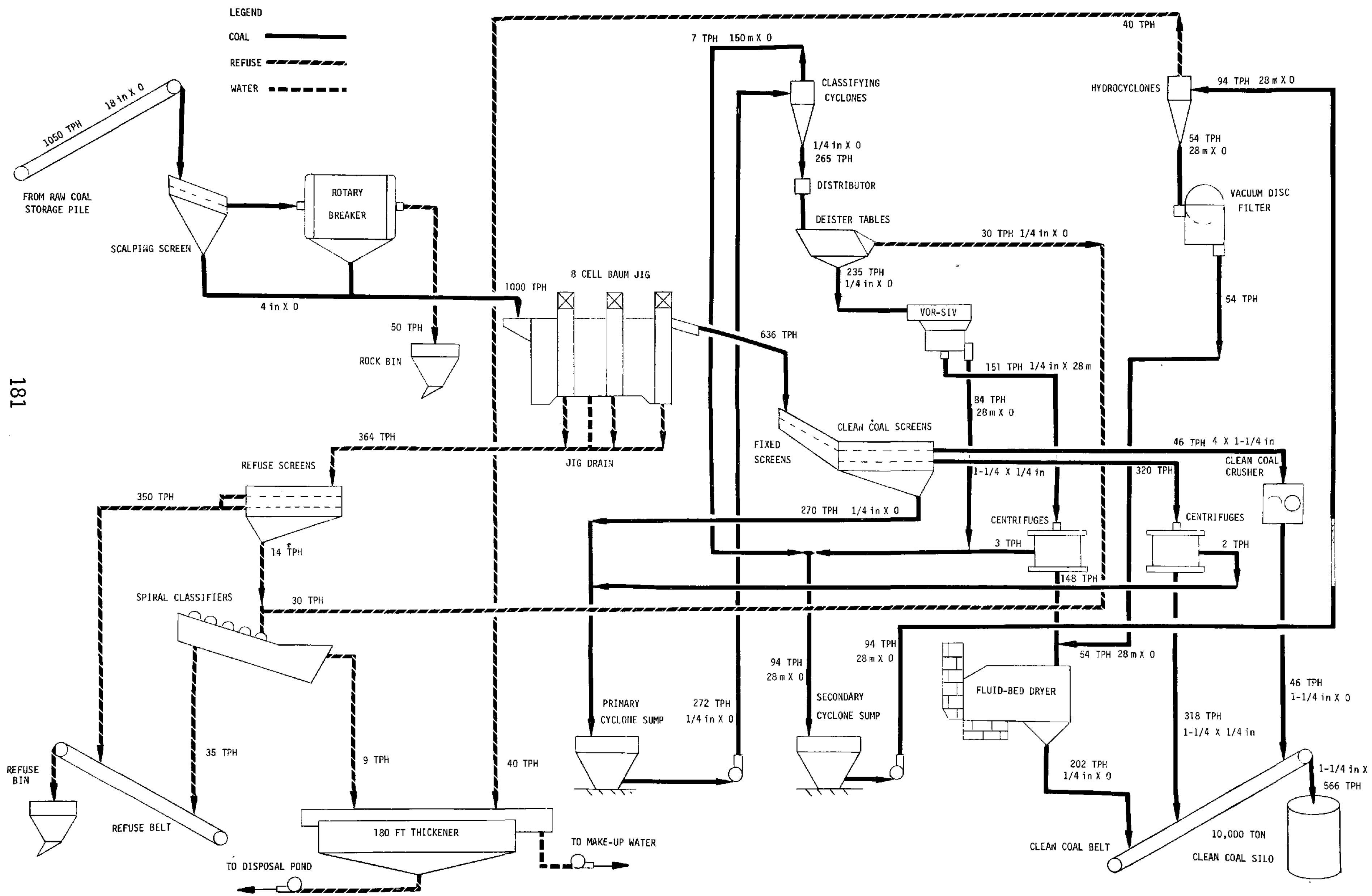
Preparation plants utilizing the Baum type jig as the major cleaning vessel can turn out an acceptable product at an attractive price with a variety of coal seams. Plants employing the jig can be combined with a myriad of other equipment combinations to make for increasingly complex cleaning circuits. The particular plant discussed herein is referred to as "intermediate" since in addition to the jig, several other pieces of equipment aid the cleaning process, thus further improving the quality of the clean coal product.

In this plant, 18 inch X 0 raw coal, mined mostly by continuous mining, is conveyed at the rate of 1,050 tons per hour from the open raw coal storage area to scalping screens where the 4 inch X 0 material is separated to by-pass the rotary breaker as shown on the flow sheet, Figure 5-3. The plus 4 inch material goes to a rotary breaker with 4 inch openings in the screen plates. That material which does not fracture to 4 inches or less passes through the refuse end of the breaker and goes to a rock bin for disposal. Approximately 50 tph of rock and other debris are removed by the rotary breaker.

The 4 inch X 0 material is fed to two eight cell Baum type jigs at the rate of 1000 tph. Of this amount, 636 tph "floats" out of the jigs and passes over fixed screens ahead of 8 X 16 foot double deck clean coal screens for sizing and dewatering. The 4 X 1-1/4 inch material passing over the top decks of these screens goes to a crusher where it is reduced to 1-1/4 inch or less before being conveyed to the 10,000 ton capacity concrete clean coal silo. Passing over the lower decks is the 1-1/4 X 1/4

FIGURE 5-3

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE PREPARATION PLANT FLOW SHEET



inch material which goes to centrifugal dryers where the surface moisture is reduced from about 16.5% to less than 5% before being conveyed to clean coal storage. The 1/4 inch X 0 material passing through both decks of the 8 X 16 foot clean coal screens goes to a primary cyclone sump from which it is pumped to a bank of classifying cyclones where further sizing into 150 mesh X 0 and 1/4 inch X 150 mesh is effected. The 1/4 inch X 150 mesh underflow from these cyclones is distributed over double deck Deister tables to separate some of the refuse which was not removed by the jigs.

The refuse from the tables goes to a spiral classifier where the material is partially dewatered to aid disposal. The clean coal from the tables goes to Vor-Sivs for dewatering. The coarser material (1/4 inch X 28 mesh) leaving the Vor-Sivs is centrifugally dried to bring the surface moisture down to less than 10% before being conveyed to the fluid-bed thermal dryer. The finer material (28 mesh X 0) leaving the Vor-Sivs goes to a secondary cyclone sump. This same sump is also fed by the 150 mesh X 0 overflow from the classifying cyclones.

From the secondary cyclone sump, a 28 mesh X 0 coal slurry is fed at the rate of 94 tph to hydrocyclones where a separation into clean coal and refuse occurs. The 40 tph of overflow from these cyclones goes to the 180 foot diameter static thickener and the 54 tph of underflow goes to the 10 foot six inch, ten disc vacuum filters for partial dewatering before going to the thermal dryer. The filters reduce the surface moisture of the 28 mesh X 0 coal to around 20%.

The total feed to the fluid-bed dryer is 202 tph of 1/4 inch X 0 coal having a total surface moisture of approximately 15%. Following drying, the surface moisture is close to 5%.

Of the 1000 tph being fed to the jigs, 566 tph of 1-1/4 inch X 0 with a surface of moisture of around 5% is considered clean coal. This equates to a 56.6% weight yield.

The material ejected from all three compartments of the eight cell jigs is considered refuse and goes to 7 X 16 foot double deck refuse screens for dewatering. The larger material passing over both decks goes to the refuse bin for disposal with the finer material going as a slurry to the spiral classifiers for thickening.

With the aid of modern electronic monitoring and controls, this plant is operated and maintained by the personnel as presented in Table 5-15. A plant of this general make-up could be constructed at a capital cost of $12.1 million in terms of mid-1977 dollars. Table 5-16 gives a breakdown of this cost by major component.

The operating and maintenance costs are summarized in Table 5-17.

TABLE 5-12

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE

PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %
4 Inch X 0	1000	4.5	8,908	35.97	3.01	4.30

Clean Coal Product From Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %
1-1/4 Inch X 0	46	3.7	12,745	11.06	--	4.64
1-1/4 X 1/4 Inch	318	4.5	13,242	9.0	--	4.30
1/4 Inch X 0	202	5.1	12,833	11.41	--	3.83
Total	566	4.6	13,056	10.03	2.87	4.16

Moisture & Ash Free Btu -- 14,511 Btu/lb

Net Performance:

Weight Yield 56.6%   Btu Recovery 83.0%   Btu of Clean Coal with 4.6% Moisture 12,455 Btu/lb

*Btu, Ash & Sulfur Presented on Dry Basis

Table 5-13

EXAMPLE 3 - JIG PROCESS INTERMEDIATE

Composition of Assumed Plant Feed By Size Fraction*

Size Fraction	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %	% Weight	% Cumulative Wt.
4 Inch X 2 Inch	3,492	70.03	3.89	4.37	11.1	11.1
2 Inch X 1 Inch	7,160	46.99	3.19	4.24	18.0	29.1
1 Inch X 1/2 Inch	9,821	30.59	2.49	3.87	21.6	50.7
1/2 Inch X 1/4 Inch	11,122	22.48	2.51	4.02	19.4	70.1
1/4 Inch X 8 Mesh	10,688	24.97	2.51	3.97	12.2	82.3
8 Mesh X 14 Mesh	9,992	28.04	5.91	7.43	4.9	87.2
14 Mesh X 0	9,069	33.88	2.98	4.67	12.8	100.0

*Btu, Ash, & Sulfur Presented on Dry Basis

TABLE 5-14

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE

CUMULATIVE WASHABILITY DATA OF ASSUMED PLANT FEED*

Composite Of 4 Inch X 14 Mesh Fraction - 87.2% of Feed**

Specific Gravity of Separation	Recovery % Weight	Recovery % Btu	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %
FLOAT 1.30	19.46	30.9	14110	4.44	.59	2.56
1.30- 1.35	43.91	68.7	13907	5.61	1.07	2.99
1.35- 1.40	53.07	82.1	13747	6.57	1.50	3.39
1.40- 1.50	59.43	90.8	13577	7.60	1.89	3.74
1.50- 1.60	61.93	93.8	13464	8.28	2.08	3.91
1.60- 1.70	63.14	95.1	13387	8.75	2.17	3.99
1.70- 1.80	63.94	95.9	13321	9.15	2.22	4.04
SINK- 1.80	100.00	100.0	8884	36.28	3.01	4.25

*Btu, Ash, & Sulfur Presented on Dry Basis

**12.8% is 14 Mesh X 0 Containing 9,069 Btu Per Pound, 33.88% Ash, 2.98% Pyritic Sulfur, and 4.67% Total Sulfur

TABLE 5-15

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE
PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Manager (1/4 time) -		1
General Foreman -		1
Operating Shift (Two per day)		
Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	1
Mechanic	4-C	2
Mobile Equipment Operator (Dozer, Front End Loader, and Refuse Truck Driver)	3-A	4
Welder	4-D	1
Stationary Equipment Operator (Thermal Dryer Operator)	3-C	1
Repairman Helper (Greaser)	2-F	1
Utility Man	1-H	2
	Total	14
Maintenance Shift		
Foreman	NU*	1
Electrician	4-A	1
Mechanic	4-C	3
Mobile Equipment Operator	3-A	1
Utility Man	1-H	2
	Total	8
Personnel Summary		
General Management		2
Operating Shifts		28
Maintenance Shift		8
	Total	38

*NU-Non-Union

TABLE 5-16

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE

PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Storage Area		
20,000 ton capacity with reclaiming feeders and tunnel		$300,000
Raw Coal Belt To Scalping Tower		
48 Inch Wide - 200 feet at $560 per ft.		112,000
Scalping Tower		
Including Single Deck Vibrating Screen, Rock Bin, and Structural Work for Rotary Breaker		350,000
Rotary Breaker -		
10 Ft diameter - 12 ft. long		150,000
Raw Coal Belt To Plant		
48 Inch Wide 300 feet at $560 per foot		168,000
Total Raw Coal Storage & Handling Cost		$1,080,000
PREPARATION PLANT:		
Equipment Cost -		
Eight Cell Baum Jigs		
2 @ $176,000 each	$ 352,000	
8 X 16 Foot Double Deck Vibrating Clean Coal Screens - 4 @ $36,000 each	144,000	

7 X 16 Foot Double Deck Vibrating Refuse Screens -	
2 @ $30,500 each	$ 61,000
Clean Coal Crusher - 1	33,000
Centrifugal Dryers - 5 @ $28,200 each	141,000
Classifying Cyclones - Ceramic lined	
12 @ $3,800 each	45,600
Deister Tables - 13 Double Deck @	
$21,000 each	273,000
Vor-Siv - 4 @ $17,000 each	68,000
Hydrocyclones - 20 @ $1,700 each	34,000
Clean Coal Vacuum Disc Filter	
1 - 10'6" ten disc	120,000
Spiral Classifiers - 36 Inch Diameter	
2 @ $18,000 each	36,000
Primary Cyclone Sumps - 2 @ $10,000 each	20,000
Secondary Cyclone Sumps - 2 @ $10,000 each	20,000
Pumps	100,000
Total Preparation Plant Equipment Cost	$1,447,600

Total Cost of Preparation Plant Including Site Preparation, Construction of Building, Electrical Service, Piping, etc. $1,447,600 X 3.0		$4,342,800

OTHER FACILITIES & EQUIPMENT:

Fluid-Bed Thermal Dryer Complete with structural steel, motors, motor controls, wiring, piping, field erection, and start-up service		$2,100,000

Static Thickener	
180 feet @ $2,000 per foot	$ 360,000
Refuse Belt	
36 Inch Wide - 150 feet @ $480 per foot	72,000
Refuse Bin	
Fabricated Part	50,000
Refuse Handling Equipment	
2 - Dozers @ $150,000 each	300,000
1 - Front-End Loader @ $50,000	50,000
2 - Trucks @ $75,000 each	150,000
Coal Sampling System	300,000
Clean Coal Silo	
10,000 Ton Capacity at $110 per ton	1,100,000
Clean Coal Belt To Silo	
42 Inch Wide - 200 feet at $520 per foot	104,000
Unit-Train Loading Facility	500,000
Total Other Facilities & Equipment	$ 5,086,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 1,080,000
Preparation Plant	4,342,000
Other Facilities and Equipment	5,086,000
Contingency (Interest during construction, etc.)	1,576,000
Total Capital Requirement	$12,084,000

BASED UPON THE 1000 TONS PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $12,100 PER TON HOUR INPUT

5.3.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 3 is as follows:

Total Capital Required: $12.1 Million

Capacity:

Raw Coal Input - 1000 tph

Clean Coal Output - 566 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	% Utilization 40%
10 Year Period Per Ton of Raw Coal	$0.71	$0.53
Per Ton of Clean Coal	$1.25	$0.93
15 Year Period Per Ton of Raw Coal	$0.57	$0.42
Per Ton of Clean Coal	$1.00	$0.74

5.3.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-17 are based upon:

- o Raw Coal Input of 1000 Tons Per Hour
- o Clean Coal Output of 566 Tons Per Hour
- o Btu Recovery of 83%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-17

EXAMPLE 3 - JIG PROCESS - INTERMEDIATE
OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.054	$0.095
Operating & Maintenance (Union)	0.428	0.757
Includes miscellaneous salaries for watchmen, etc.		
Overhead -		
Fringe Benefits - 26% Non-Union	0.014	0.025
- 22% Union	0.094	0.167
Other - Includes Welfare Fund, training costs, etc. (15% of total labor)	0.072	0.128
Supplies -		
Includes water conditioners, replacement parts, lab supplies, health & safety expenses, necessary equipment rental, etc.	0.538	0.950
Fuel and Power -	0.170	0.301
Thermal Dryer Fuel - Based upon 3.4 Tons/Hr Coal Consumption and Cost of Coal $20/Ton	0.068	0.120
Miscellaneous - Subcontract Services, etc.	0.076	0.127
O & M Cost - Not Including Capital Amortization	$1.51	$2.67
Capital Amortization - 10 Yrs. - 30% Utilization	0.71	1.25
Total Operating & Maintenance Cost	$2.22	$3.92
Cost Per Million Btu (12,455 Btu/lb)		$0.157

5.3.4 Discussion of Performance and Cost

This Example 3 plant is essentially a coarse cleaning process designed for the purpose of reducing ash. However, following the initial separation in the Baum jig, the finer size fractions (less than 1/4 inch) of "float" from the jig are classified and subjected to additional cleaning by Deister tables and cyclones. This secondary cleaning has a favorable impact on further reducing ash as well as lowering the pyritic sulfur content which is relatively high in the smaller size fractions. Although this plant does not effect a dramatic reduction in sulfur, it is achieving its design objective of significantly reducing the ash in the particular coal currently being treated. Some consideration is being given to a plant modification which would increase the capacity of the finer cleaning portion of the circuit and promote further pyritic sulfur removal.

With the coal now being treated, this plant recovers approximately 56% of the raw feed by weight and only 83% of the heat content. Greater Btu recovery from this particular coal could probably be achieved by crushing the larger size fractions from the jig and further treating them in an expanded version of the finer cleaning portion of the circuit. However, this would involve additional capital expenditures not necessarily appropriate at this time since the company is meeting their contractual product specification as is. Before taking such a step, careful analysis would have to be performed to determine whether further upgrading of the product would show economic advantage to the producer as well as provide the purchaser with a product still having the required characteristics critical to the particular combustion application.

Under current procedures, this plant is scheduled to function three shifts per day, five days per week with two shifts operating and one for maintenance. However, because of unscheduled stoppages and other recurring problems, this plant has not been running coal more than the equivalent of 2600 hours per year or roughly 30% of the time. Limited utilization has a negative cost impact upon overall plant operating cost since fixed charges such as capital amortization, management, certain overhead expenses, etc. are still incurred even though the plant is functioning well below capacity. This point is made by the fact that if this plant could be utilized an additional 10% of the time, the capital amortization per ton of clean coal would decrease by $0.32. If this were true, the O & M cost per ton of clean coal would drop from $3.92 to $3.60 before accounting for the Btu loss from cleaning.

Another aspect of this plant which contributes significantly to its operating and maintenance cost is the thermal dryer. Although it only dries 36% of the total clean coal product, it nearly doubles the electricity consumption, adds personnel, and accounts for 20% of the capital cost of the entire facility. In spite of the high cost of thermal drying, a good case can many times be made for its use on the basis of lower handling and transportation expenses, not to mention the moisture specification required by the purchaser.

As summarized in the preceding Table 5-17, the total O&M cost of $3.92 per ton of clean coal translates to $0.157 per million Btu. To this, an amount of $0.172 per million Btu can be added to account for the 27% of the heat content in the raw coal "lost" during the cleaning process. If this were done, it would more than double the cost of preparation, bringing the total to nearly $0.33 per million Btu. This is a stiff penalty to "pay" for having thrown away a low Btu material high in ash and sulfur. There is much room for discussion on whether it is appropriate to assess such a high price to this refuse and thus more than double the effective cost of coal preparation to the producer. However, in this particular case, where the Btu recovery is only 83%, it does accentuate the need to analyze the process to see if greater recoveries are not possible through alternate cleaning approaches.

Although the Example 3 process when applied to this coal is quite expensive considering the results achieved, it is representative of many plants currently in existence which are profitable since the material produced is capable of selling for more than the raw coal plus the cost of cleaning including a return to the producer. However, the producer's cost is not the end-of-the-line when evaluating the overall economics of coal preparation to determine whether or not the process is cost effective. This is true since the producer's cost as presented in Table 5-17 makes possible a product which has measureable cost benefits to the user. When these benefits such as lower transportation, ash disposal, etc. are quantified, they can be set off against the producer's cost to determine the net cost of cleaning. These cost benefits are not addressed further at this point since they can only be accurately quantified on a site specific basis knowing such things as the distance between the coal source and the user.

5.4 Example 4 - Jig Process - Complex

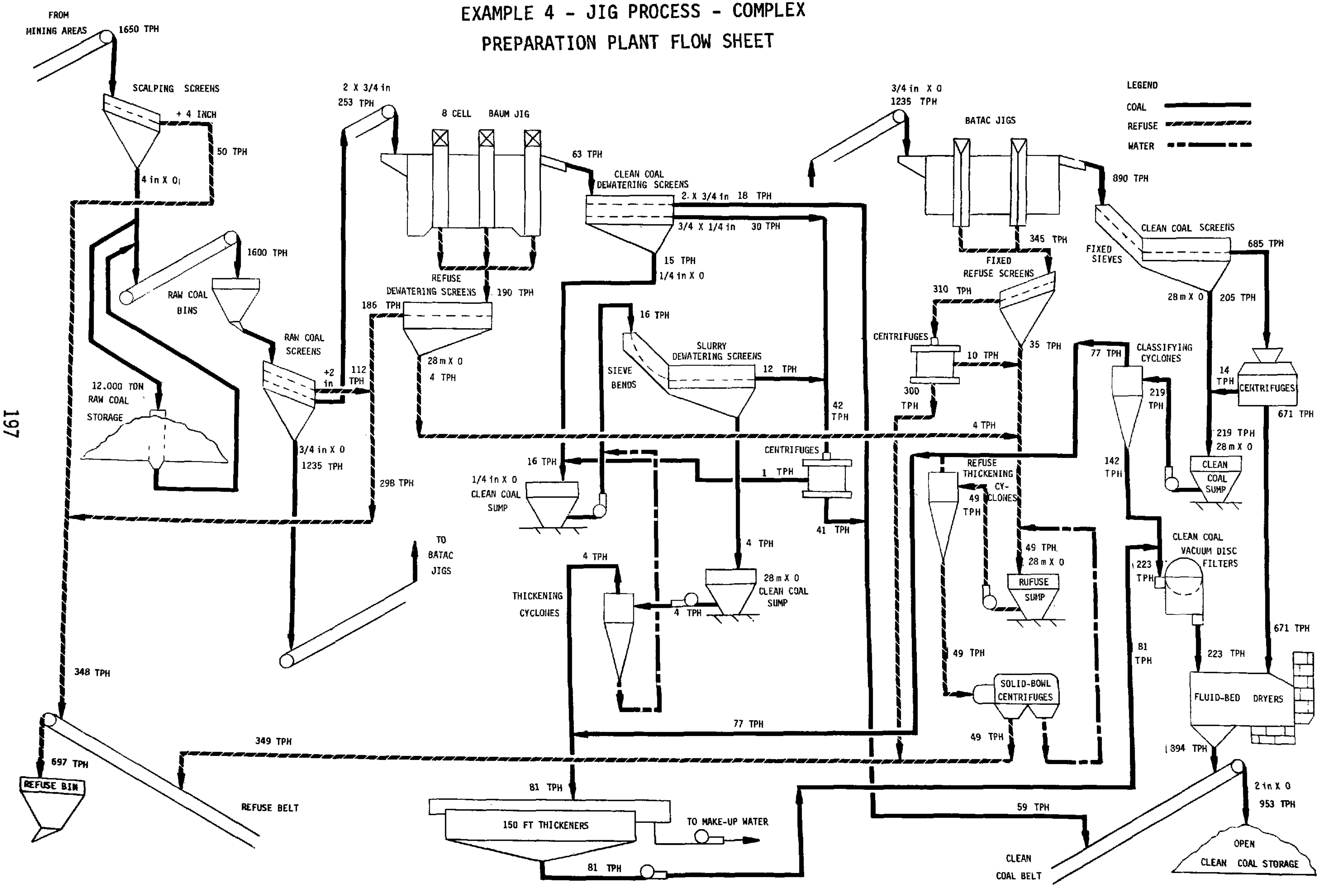
5.4.1 General Description

As indicated by the simplified flow sheet presented as Figure 5-4, this particular coal preparation process is comprised of a coarse circuit where the major separation is made by a single eight-cell Baum jig and a fine coal circuit centered around two Batac jigs. Based upon an input to the plant (following rough scalping) of 1600 tons per hour (tph), the weight yield is 59.6% and the Btu recovery is over 90%. As is indicated by these results and the sulfur reduction data given in Table 5-18,the combination of these two circuits performs an effective and efficient cleaning job on this Lower Freeport seam coal which is mined by continuous and longwall mining.

Raw coal is fed from the mining areas via 54 inch wide belts at the rate of 1650 tph to 6 x 16 foot scalping screens where the plus 4 inch material is screened off and routed to refuse. The 4 inch x 0 material passing through the scalping screens goes to surge bins ahead of 8 x 20 foot raw coal screens. When the plant is not operating, the 4 inch x 0 material goes to a 12,000 ton open coal storage area from which it is reclaimed as required.

The inclined 8 x 20 foot double deck raw coal screens separate the 1600 tph of material into three size fractions. Material of 2 inches or more passes over the top deck and goes to refuse at the rate of 112 tph. The 2 x 3/4 inch material passing over the second deck is fed to the Baum jig via a 36 inch belt at the rate of 253 tph. The 1,235 tph of 3/4 inch x 0 passing through both decks drops on a 48 inch wide belt and is fed to the two Batac jigs.

FIGURE 5-4
EXAMPLE 4 - JIG PROCESS - COMPLEX
PREPARATION PLANT FLOW SHEET



Of the 253 tph going to the jig, 63 tph "floats" and 190 tph passes out the bottom of the three compartments as refuse. The 63 tph of 2 inch and less coal goes to 6 x 16 foot double deck clean coal screens for sizing and dewatering. The top deck has screen with 3/4 inch openings and the bottom deck 1/4 inch openings. Therefore, the 2 x 3/4 inch material with a surface moisture of approximately 2.4% passes over the top deck and is fed directly to the clean coal collection belt. The 3/4 x 1/4 inch material passing over the second deck goes to centrifuges for further dewatering before going to the clean coal belt. The 1/4 inch x 0 material passing through both decks goes to a sump from which it is pumped as a slurry to sieve bends ahead of 7 x 16 foot single deck dewatering screens. All plus 28 mesh material passing over the screens goes to centrifuges and onto the clean coal belt. The 28 mesh x 0 material passing through the screens goes to a sump from which it is pumped to 10 inch rubber lined thickening cyclones for further dewatering. The overflow (all measurable material) from these cyclones goes to the two 150 foot diameter concrete thickeners.

The 190 tph of refuse from the Baum jig goes to 6 x 16 foot single deck screens for sizing and partial dewatering. The 2 inch x 28 mesh material passing over the screens has a surface moisture of around 3% and goes direct to the refuse belt. The small amount (4 tph) of 28 mesh x 0 material passing through the screens goes to a sump from which it is pumped to thickening cyclones and then to solid bowl centrifuges to get the surface moisture down to 18% before going to the refuse belt.

Returning to the fine coal cleaning portion of the plant, the two Batac jigs are fed 3/4 inch x 0 material at the rate of 1235 tph (roughly 600 tph each). Batac jigs come in 3, 4, and 5 meter widths. As a general sizing philosophy, each meter of width equates to 100 tph of feed capacity. However, this may be exceeded to some degree, as is the case of this plant, without significant degradation in performance. Of the total feed to the Batac jigs, 890 tph separate out as clean coal and 345 tph are refuse. The clean coal is fed to fixed sieves ahead of 7 x 16 foot single deck screens for sizing and partial dewatering. The 685 tph of 3/4 inch x 28 mesh material passing over the screens goes to fine coal centrifuges where the surface moisture is brought down from 25% to 6.5% before going to the fluid-bed thermal dryers. The 205 tph of 28 mesh x 0 material passing through the screens goes to a sump from which it is pumped to classifying cyclones (14 inch ceramic lined). The 100 mesh x 0 overflow from these cyclones go to the static thickeners. From the thickeners, it is pumped to vacuum disc filters for dewatering before going to the thermal dryers. The 28 mesh X 0 underflow goes directly to the disc filters and then on to thermal drying. In this circuit there is a total of four 12 disc vacuum filters. Each disc is 12 feet 6 inches in diameter. The total feed to these filters is 223 tph. These filters have been sized on the basis of 50 pounds per hour per square foot of disc surface. Therefore, the following calculation applies:

Weight Being Processed:

223 tons/hour = 446,000 pounds/hour

Surface Required:

$$\frac{446{,}000 \text{ pounds/hour}}{50 \text{ pounds/hour/ft}^2} = 8{,}920 \text{ ft}^2$$

Available Surface:

$$4 \text{ filter} \times 2736 \text{ ft}^2 = \underline{\underline{10,944}} \text{ ft}^2$$

This additional 2,000 ft^2 of available filtering surface allows for substantial fluctuations in feed without overburdening the equipment.

A total of 894 tph of 3/4 inch x 0 material is fed to the two thermal dryers each having a capacity of 550 tph. The surface moisture is reduced from over 11% to around 6% by the dryers.

The 300 tph of refuse from the Batac jigs goes to inclined single deck fixed screens which the majority of the material (310 tph) passes over before being further dewatered by centrifugal dryers. The effluent from these dryers and the 28 mesh x 0 material passing through the refuse screens go to a sump from which they are pumped to thickening cyclones (14 inch rubber lined) where they are partially dewatered. All measurable solids report to the underflow of these cyclones and go to solid-bowl centrifuges for further dewatering before going to the refuse belt. Overall plant performance is summarized by Table 5-18.

This plant is operated and maintained by the staff set forth in Table 5-22. In addition to a high degree of semi-automated electronic controls, smooth operation of the plant is aided by a closed-circuit television monitoring system.

TABLE 5-18

EXAMPLE 4 - JIG PROCESS - COMPLEX

PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	Tph	% of Feed	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
4 X 2 inch	112	7.0	-	1,250	85.32	0.27
2 X 3/4 inch	253	15.8	-	4,444	66.21	0.51
3/4 inch x 0	1,235	77.2	-	10,700	28.98	1.16
Total	1,600	100.0	5.0	9,050	38.81	1.0

Clean Coal Product From Plant:

Size Fraction	Tph	% of Feed	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
2 X 1/4 inch	59		3.0	13,401	13.35	1.14
3/4 inch x 0	894		6.0	14,300	7.9	0.91
	953		5.8	14,244	8.24	0.92

Net Performance:

Weight Yield 59.6% Btu Recovery 93.7% Btu of Clean Coal with 5.8% Moisture 13,418 Btu/lb

*Btu, Ash, and Sulfur Presented On Dry Basis

TABLE 5-19

EXAMPLE 4 - JIG PROCESS - COMPLEX

COMPOSITION OF ASSUMED PLANT FEED BY SIZE FRACTION

Size Fraction	Weight %	Cumulative Wt.%
+ 3 Inch	4.43	4.43
3 X 2 Inch	2.66	7.09
2 X 1½ Inch	3.49	10.58
1½ X 1 Inch	5.72	16.30
1 X 3/4 Inch	6.50	22.80
3/4 X 5/8 Inch	4.48	27.28
5/8 X 1/2 Inch	4.00	31.28
1/2 X 3/8 Inch	9.09	40.37
3/8 Inch X 28 Mesh	49.03	89.40
28 X 100 Mesh	7.02	96.42
100 Mesh X 0	3.58	100.00

TABLE 5-20

EXAMPLE 4 - JIG PROCESS - COMPLEX

COMPOSITION OF ASSUMED FEED TO BATAC JIGS BY SIZE FRACTION

Size Fraction	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %	Weight %	Cumulative Wt.%
3/4 Inch X 1/2 Inch	6,602	52.85	0.45	0.65	13.71	13.71
1/2 Inch X 3/8 Inch	9,809	34.69	0.48	0.88	9.36	23.07
3/8 Inch X 1/4 Inch	10,683	29.39	0.78	1.06	11.31	34.38
1/4 Inch X 8 Mesh	11,519	24.45	0.82	1.27	31.76	66.14
8 Mesh X 14 Mesh	12,159	20.65	0.91	1.37	11.15	77.29
14 Mesh X 28 Mesh	11,806	22.52	1.06	1.55	6.37	83.66
28 Mesh X 48 Mesh	12,211	19.02	1.04	1.51	4.85	88.51
48 Mesh X 100 Mesh	12,736	15.73	0.95	1.43	3.52	92.03
100 Mesh X 200 Mesh	12,445	16.98	1.09	1.61	2.39	94.42
200 Mesh X 0	10,115	31.89	0.72	1.07	5.58	100.00

TABLE 5-21

EXAMPLE 4 - JIG PROCESS - COMPLEX

CUMULATIVE WASHABILITY DATA OF ASSUMED FEED TO BATAC JIGS

Composite of 3/4 Inch X 200 Mesh Fraction - 94.42% of Feed*

Specific Gravity of Separation	Recovery % Weight	Recovery % Btu	Btu/lb	Ash %	Pyritic Sulfur %	Total Sulfur %
FLOAT 1.30	35.48	49.8	15,068	3.69	0.22	0.68
1.30- 1.35	60.03	82.6	14,769	5.42	0.31	0.78
1.35- 1.40	65.34	89.3	14,666	6.01	0.35	0.82
1.40- 1.50	69.10	93.6	14,539	6.73	0.39	0.86
1.50- 1.60	71.08	95.6	14,435	7.34	0.41	0.89
1.60- 1.70	72.37	96.7	14,344	7.86	o.43	0.91
1.70- 1.80	73.32	97.4	14,262	8.33	0.45	0.93
1.80- 2.00	74.94	98.3	14,085	9.35	0.48	0.96
SINK- 2.00	100.00	100.0	10,734	28.81	0.78	1.17

*5.58% is 200 Mesh X 0 Containing 10,115 Btu Per pound, 31.89% Ash, 0.72% Pyritic Sulfur, and 1.07% Total Sulfur

TABLE 5-22

EXAMPLE 4 - JIG PROCESS - COMPLEX

PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Plant Superintendent		1

Operating Shift (1st)

Title	Union Classification	Quantity
Shift Foreman	NU*	1
Electrical Maintenance Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	2
Mechanic	4-C	3
Stationary Equipment Operator - (Includes two thermal dryer operators)	3-C	4
Mobile Equipment Operator	3-A	5
Dozer & Truck Drivers		
Utility Man (Screenman)	1-H	1
Laborer	1-J	2
	Total	20

Operating Shift (2nd)

Title	Union Classification	Quantity
Shift Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	2
Mechanic	4-C	3
Stationary Equipment Operator	3-C	4
Mobile Equipment Operator	3-A	4
Railroad Car Loader Operator	3-E	1
Utility Man (Screenman)	1-H	1
Laborer	1-J	2
	Total	19

Maintenance Shift

Shift Foreman	NU*	2
Electrician	4-A	2
Mechanic	4-C	6
Electrician Helper	2-C	3
Mechanic Helper	2-E	3
	Total	16

Personnel Summary

General Management		1
Operating Shifts		39
Maintenance Shift		16
	Total	56

*NU-Non-Union

TABLE 5-23

EXAMPLE 4 - JIG PROCESS - COMPLEX

PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:	
Scalping Tower	
Including Two 6 X 16 Foot Single Deck	
Vibrating Screens having 15 hp each	$ 300,000
Raw Coal Storage Area	
12,000 Ton Capacity with Stacking Tube,	
Reclaiming Feeds, and Tunnel	250,000
Raw Coal Belt To Raw Coal Bins	
54 Inch Wide - 300 feet at $600 per foot	180,000
Raw Coal Bins	
1,200 Ton Capacity - 5 at $50,000 each	250,000
Raw Coal Screens	
8 X 20 Foot Double Deck Vibrating having 30 hp	
5 @ $30,000 each plus installation	300,000
Raw Coal Belt To Baum Jig	
36 Inch Wide - 250 feet at $480 per foot	120,000
Tramp Iron Magnet Over Baum Jig Belt	
Explosion Proof - Self Cleaning Type	20,000
Raw Coal Belt To Batac Jigs	
48 Inch Wide - 250 feet at $560 per foot	140,000
Total Raw Coal Storage & Handling Cost	$1,560,000

PREPARATION PLANT:

Equipment Cost -

Eight Cell Baum Jig	
1 @ $176,000	$176,000
6 X 16 Foot Double Deck Vibrating	
Clean Coal Dewatering Screens having 20 hp	
2 @ $23,000 each	46,000
6 X 16 Foot Single Deck Vibrating Refuse	
Dewatering Screens having 15 hp	
2 @ $19,000 each	38,000
Sump - 1/4 Inch X 0 Clean Coal	
1 @ $10,000	10,000
Sieve Bends	
6 Foot Wide - 5 Foot Radius	
4 @ $4,800 each	19,200
7 X 16 Foot Single Deck Vibrating Slurry	
Dewatering Screens having 15 hp	
2 @ $21,500 each	43,000
Centrifugal Dryers	
2 @ $28,200 each	56,400
Thickening Cyclones	
14 Inch Diameter w/Rubber Liner	
12 @ $1,300 each	15,600
Batac Jigs - 5 Meter Width	
2 @ $610,000 each	1,220,000

Fixed Sieves	
5 Feet Wide - 3/4 mm openings	
8 @ $4,000 each	$ 32,000
7 X 16 Foot Single Deck Vibrating Clean Coal Screens having 15 hp	
8 @ $21,500 each	172,000
Centrifugal Dryers - Bird 1300	
4 @ $50,000 each	200,000
Fixed Single Deck Refuse Screens	
2 @ $15,000 each	30,000
Centrifugal Dryers	
2 @ $28,200 each	56,400
Sump - 28 mesh X 0 Clean Coal	
5 @ $10,000 each	50,000
Classifying Cyclones	
14 Inch Diameter w/Ceramic Liners	
20 @ $3,000 each	60,000
Sump - 28 mesh X 0 Refuse	
2 @ $10,000 each	20,000
Thickening Cyclones	
14 Inch Diameter w/Ceramic Liner	
4 @ $3,000 each	12,000
Vacuum Disc Filters	
12 Feet 6 Inch Diameter - 12 Disc	
4 @ $125,000 each	500,000

Centrifugal Dryers		
Bird Solid Bowl - 36 X 72 Inch		
2 @ $110,000 each	$ 220,000	
Pumps	200,000	
Total Preparation Plant Equipment Cost	$3,176,600	
Total Cost of Preparation Plant		
Including Site Preparation, Construction of		
Building, Electrical Service, Piping, etc.		
$3,176,600 X 3.0		$9,530,000
OTHER FACILITIES & EQUIPMENT:		
Fluid-Bed Thermal Dryers - 2		
Complete with structural steel, motors, motor		
controls, wiring, piping, field erection, and		
start-up service		$6,000,000
Static Thickeners - 2		
150 Ft Diameter @ $2,000 per foot		600,000
Refuse Belt		
36 Inch Wide - 200 feet @ $480 per foot		96,000
Refuse Bin - 200 Ton Capacity		
Fabricated Part		50,000
Refuse Handling Equipment		
2 - Dozers @ $150,000 each		300,000
3 - Trucks @ $ 75,000 each		225,000
Clean Coal Belt From Dryer To Storage		
48 Inch Wide - 400 feet @ $600 per foot		240,000

Clean Coal Storage Area	
100,000 Ton Capacity With Reclaiming Feeders and Tunnel	$ 500,000
Coal Sampling System	300,000
Unit-Train Loading Facility	500,000
Total Other Facilities & Equipment	$ 8,811,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 1,560,000
Preparation Plant	9,530,000
Other Facilities and Equipment	8,811,000
Contingency (Interest during construction, etc.)	2,985,000
Total Capital Requirement	$22,886,000

BASED UPON THE 1600 TONS PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $14,300 PER TON HOUR INPUT

5.4.2 Capital Amortization

Based upon the rationale developed in Section 4.0 , the capital amortization for Example 4 is as follows:

Total Capital Required: $22.9 Million

Capacity:

Raw Coal Input - 1600 tph

Clean Coal Output - 953 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	40%
10 Year Period Per Ton of Raw Coal	$0.84	$0.62
Per Ton of Clean Coal	$1.40	$1.04
15 Year Period Per Ton of Raw Coal	$0.67	$0.50
Per Ton of Clean Coal	$1.12	$0.84

5.4.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-24 are based upon:

- o Raw Coal Input of 1600 Tons Per Hour
- o Clean Coal Output of 953 Tons Per Hour
- o Btu Recovery of 93.7%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-24

EXAMPLE 4 - JIG PROCESS - COMPLEX
OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.030	$0.050
Operating & Maintenance (Union)	0.387	0.650
Overhead -		
Includes Payroll Taxes, Insurance, Welfare Fund, Vacations, Holidays, etc. for all Preparation Plant Employees	0.250	0.420
Supplies		
Operating	0.137	0.230
Maintenance - Repair Parts and Materials Associated with Routine Maintenance	0.273	0.458
Thermal Dryer Fuel - Based upon 17 Tons/Hr Coal Consumption and Cost of Coal $20/Ton	0.213	0.357
Electricity	0.387	0.650
Other Expenses	0.084	0.141
O & M Cost - Not Including Capital Amortization	$1.76	$2.96
Capital Amortization - 10 Yrs. - 30% Utilization	0.84	1.40
Total Operating & Maintenance Cost	$2.60	$4.36
Cost Per Million Btu (13,418 Btu/lb)		$0.162

5.4.4 Discussion of Performance and Cost

The Example 4 plant is a good illustration of using coarse and fine coal jigging to produce a clean coal product low in ash and sulfur at a reasonable cost. Although when treating this particular coal the process discards over 40% of the plant feed as refuse, it recovers 93.7% of the Btu content of the raw coal.

The effectiveness of this process lies in the initial sizing of the feed to insure its consistency with the individual equipment capabilities. That is to say, the coarser material (2 X 3/4 inch) is handled by the Baum jig and the finer material (3/4 inch X 0) material is fed to the Batac jigs. By restricting the amount of fines getting into the Baum jig, a more efficient and accurate separation is accomplished. The Baum jig effects a separation at approximately 1.60 specific gravity and recovers less than 25% of the total material it processes. This low recovery is not unexpected since the feed to the Baum jig is over 66% ash.

As noted, the fine coal portion of this plant centers around two Batac jigs which treat the 3/4 inch X 0 fraction constituting nearly 80% of the plant feed. These jigs effect a separation at between 1.70 and 1.80 specific gravity. Although this means rejecting nearly 30% as refuse, the high Btu product from the Batacs is significantly lower in ash and sulfur.

The number of personnel required to operate and maintain this plant is somewhat higher than might be expected. However, the incremental increase in cost over having a more austere staff is not significant when put on a per ton basis.

As would be expected, the capital amortization of a larger plant of this type becomes a sizeable cost factor when it is utilized only 30% of the time. Unfortunately, this plant is operated only two shifts per day, five days per week with one shift reserved for maintenance. If the plant could be operated an additional 10% of the time, the capital amortization per ton of clean coal could be reduced by $0.36. Greater utilization would also favorably impact other fixed charges such as supervisory salaries and various overhead items.

Another significant cost in the operation of this plant is the thermal dryer which handles 94% of the clean coal produced. The cost of such extensive drying is reflected not only in fuel expense but particularly in higher electricity consumption due to the large horsepower requirements of the two fluid-bed thermal dryers. However, these high drying costs are more than justified by lower transportation and handling expense.

Looking at the overall performance of the process in terms of the cost, this plant performs cost effectively when treating this particular coal. The material discarded as refuse carried with it only 6.3% of the original heat content of the feed. This is a fair "price" to pay for a significantly higher Btu product with nearly 80% less ash and reasonable reduction in pyritic sulfur. If a cost was applied for these lost Btu's as discussed in Section 4.4, the total cost of preparation would increase by $0.056 per million Btu to $0.219. Although the total cost of producing the clean coal is $4.36 per ton without considering any Btu loss, the net cost would be less if consideration was given to the economic benefits attributable to preparation such as lower transportation, boiler maintenance, particulate and other emission controls, etc. As noted previously, these are not quantified since their full impact can only be appreciated on a site specific basis where such things as transportation distance and emission regulations are known.

5.5 Example 5 - Heavy Media Process - Simple

5.5.1 General Description

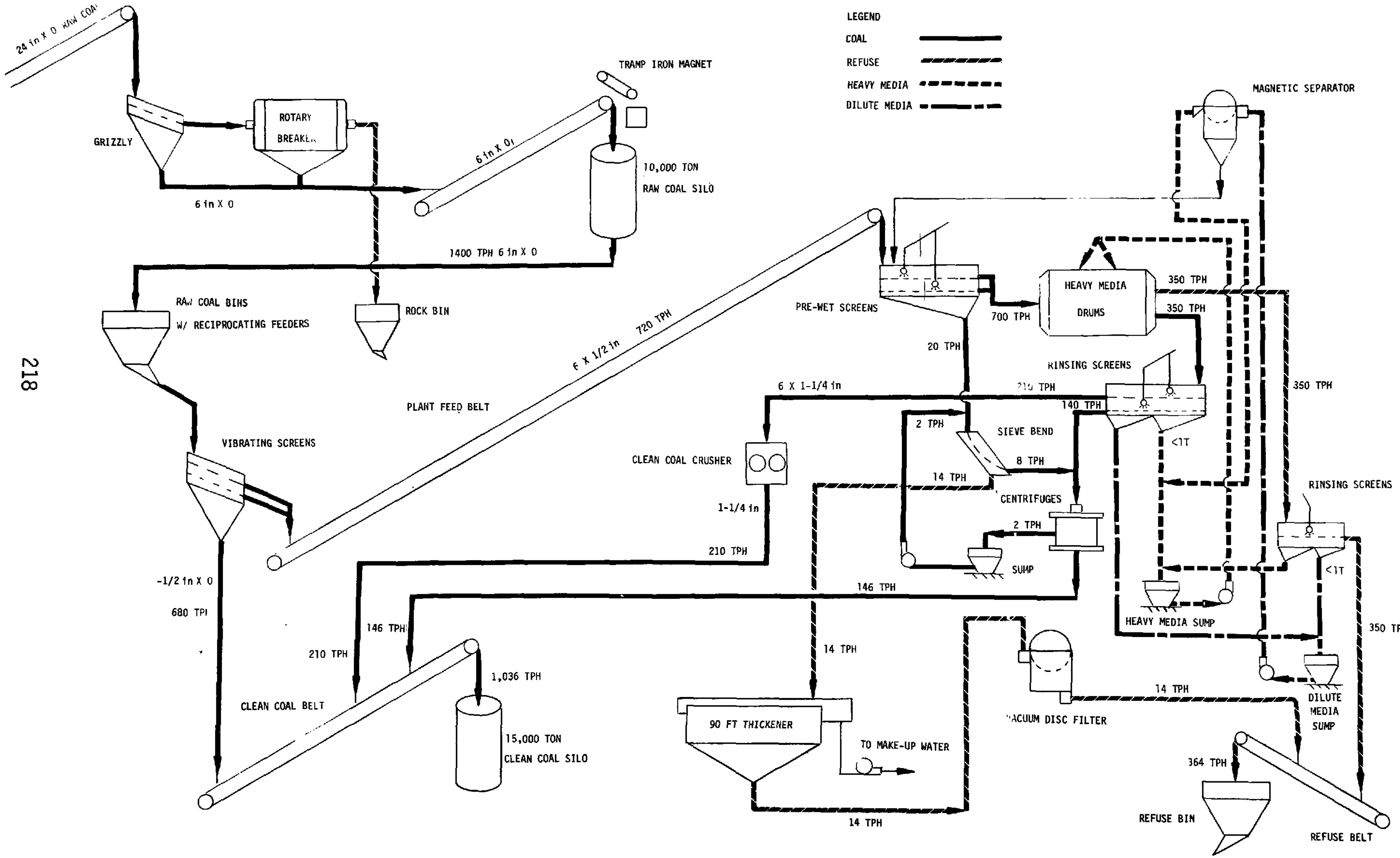
As noted previously, the term heavy media is applied to any process which uses a medium having a specific gravity approaching the specific gravity of separation. In coal preparation, the most widely accepted method for establishing the higher specific gravity medium is to suspend magnetite in water. The process is based on the theory that as the crushed material passes through such a medium, the coal will float and the refuse will sink as predicted by laboratory specific gravity analysis.

There are many levels of sophistication which a coal preparation circuit based principally on heavy media can reach. Example 5, discussed herein, is a relatively simple approach which can be quite effective with certain coals and end product requirements. A simplified flow sheet appears as Figure 5-5 on the following page.

In this particular circuit, the 24 inch X 0 run-of-mine coal, mined by conventional and continuous mining, is conveyed to a grizzly where a coarse scalping of the 6 inch X 0 material takes place. The plus 6 inch material passes over the grizzly to a rotary breaker with 6 inch opening grid plates. All material which is broken down to 6 inches or less passes through the grid plates with the oversized material going out the refuse end of the breaker to a rock bin where it is trucked away to the disposal site. Now, the 6 inch X 0 material from the grizzly and the breaker passes under a tramp iron magnet as it is conveyed to a 10,000 ton concrete silo. The magnet is intended to remove scrap

FIGURE 5-5

EXAMPLE 5 - HEAVY MEDIA PROCESS - SIMPLE PREPARATION PLANT FLOW SHEET



steel material such as mining bits, tin cans, and roof bolts which could be damaging to equipment in other portions of the plant. From the raw coal storage silo, the 6 inch X 0 coal is fed at the rate of 1400 tons per hour to five bins each feeding an 8 X 20 foot double deck vibrating screen. The top screen has openings of approximately 1-1/4 inch with the bottom deck 1/2 inch. By subjecting the coal to a double screening at this point, better definition is given to the desired sizing function by not overloading the surface of the deck. The 1/2 inch or less material passing through the bottom deck is considered clean coal and goes directly to the product collection belts at the rate of 680 tph.

The material passing over the first and second decks of the raw coal sizing screen is conveyed at the rate of 720 tph into the main portion of the preparation plant. Here it is put onto five 8 X 20 foot double deck pre-wet screens. The purpose of this wet screening operation is to further remove any fines prior to the material entering the two heavy media drums. The limited amount of additional fines passing through the bottom deck goes to a fixed sieve bend for partial de-watering with the overflow of the sieve bend going to the centrifuges for final moisture reduction before going to the clean coal belt. The underflow of the sieve bend is considered refuse and goes to the 90 foot diameter thickener.

Approximately 700 tph pass over the pre-wet screens and enter the two heavy media drums. The heavy media drums effect approximately a 50-50 separation at around 1.6 specific gravity. Floats, at the rate of 350 tph, go to two 8 X 16 foot double deck drain and rinse screens.

The major purpose of this screening operation is to rinse off the magnetite carried along with the coal from the heavy media drums. The top decks have a 1-1/4 inch opening and the bottom 1 mm. The 210 tph of 6 X 1-1/4 inch material passing over the top decks is then reduced to 1-1/4 inch by a flextooth crusher to minimize the fines and is conveyed to the 15,000 ton concrete clean coal silo. The 120 tph of 1-1/4 inch and less material passing over the lower decks of the 8 X 16 foot rinsing screens goes to centrigugal dryers before being conveyed to the clean coal silo.

The 350 tph of sinks from the heavy media drums pass over two 8 X 16 foot single deck drain and rinse screens. This not only helps to dewater the material but also salvages some of the magnetite clinging to the refuse.

Refuse from the thickener is pumped at the rate of 14 tph to a 10 foot 6 inch diameter 9 disc vacuum filter where it is dewatered and hauled away for disposal. This filter is sized according to the sizing philosophy of 20 pounds of refuse per hour per square foot of disc area (a 10' X 6" diameter unit with 9 discs, has approximately 1,395 square feet of surface; 14 ton = 28,000 lb; 28,000 lb ÷ 20 lb/sq ft = 1,400 sq ft). As observed in some of the other examples considered under this section, vacuum filters are sized in a range as high as 50 pounds per hour per square foot depending upon the nature of the material to be dewatered. In this particular case, the design was deliberately kept on the conservative side to produce a filter cake which would be sufficiently low in moisture to permit immediate disposal.

On a plant wide basis, of the 1400 tph fed from the raw coal silo, 1,036 tph are considered clean and 364 tph refuse for a weight yield of 74%. However, this is somewhat misleading in that nearly 50% of the raw coal feed is screened off as clean coal in the initial preparation operation. Therefore, a more relevant indicator of this circuit's effectiveness is the Btu recovery which approaches 95%.

Adequate operation and maintenance of the plant is achieved by a staff of forty union and non-union personnel. A listing of these individuals by job classification appears as Table 5-26. Based upon mid-1977 costs, the capital investment required to construct a plant of this configuration is approximately 10 million dollars. A breakdown of this capital cost by major component appears as Table 5-27. A summary of the operating and maintenance costs is presented in Table 5-28. Although these costs will vary somewhat due to site specific conditions such as operating approach, current quality of the raw coal, local labor problems/availability, etc., they are representative of the O & M cost level one might anticipate for an operation of this type.

TABLE 5-25

EXAMPLE 5 - HEAVY MEDIA PROCESS - SIMPLE

PREPARATION PLANT PERFORMANCE[1]

Raw Coal Feed To Plant:[2]

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
6 Inch X 0	1400	8.0	8,600	29.4	4.56

Clean Coal Product From Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
1-1/4 Inch X 0	1036	7.5	10,992	22.13	4.17

Moisture & Ash Free Btu -- 14,115 Btu/lb

Net Performance:

Weight Yield 74.0% Btu Recovery 94.6% Btu of Clean Coal with 7.5% Moisture 10,168 Btu/lb

1] Btu, Ash, & Sulfur Presented on Dry Basis

2] This is somewhat of a misnomer since nearly half (680 tph) of the total raw coal being processed never enters the plant.

TABLE 5-26

EXAMPLE 5 - HEAVY MEDIA PROCESS - SIMPLE

PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management			Quantity
Preparation Superintendent	-		1
General Foreman	-		1

Operating Shift (Two per day)

Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Stationary Equipment Operator - (Vacuum filter, thickener, media system)	3-C	1
Electrician	4-A	1
Screenman (cleaner)	1-H	2
Utility Man	1-H	1
Repairman (Belt Mechanic)	3-B	1
Mobile Equipment Operator (Refuse Handling)		
Truck Driver	3-A	3
Dozer Operator	3-A	2
	Total	13

Maintenance Shift (One per day)

Title	Union Classification	Quantity
Foreman	NU*	1
Mechanic	4-C	7
Repairman	3-B	1
Utility Man	1-H	1
Mobile Equipment Operator		
Dozer Operator	3-A	2
	Total	12

Personnel Summary

General Management		2
Operating Shifts		26
Maintenance Shift		12
	Total	40

*NU-Non-Union

TABLE 5-27

EXAMPLE 5 - HEAVY MEDIA PROCESS - SIMPLE PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:	
Scalping Tower	
Including Single Deck Vibrating Screens, Rock Bin, and Structural Work for Rotary Breaker	$ 350,000
Rotary Breaker	
10 Foot Diameter - 12 Feet Long	150,000
Raw Coal Belt To Silo	
48 Inch Wide - 200 Feet @ $560 per foot	112,000
Tramp Iron Magnet	
Explosion Proof - Self Cleaning Type	20,000
Raw Coal Silo (Concrete)	
10,000 Ton Capacity @ $110 per ton	1,100,000
Raw Coal Belt To Raw Coal Bins	
54 Inch Wide - 150 Feet @ $600 per foot	90,000
Raw Coal Bins	
100 Ton Capacity w/Feeders	
5 @ $30,000 each	150,000
Raw Coal Screens	
8 X 20 Foot Double Deck Vibrating having 30 hp	
5 @ $30,000 each plus installation	300,000

Raw Coal Belt To Plant			
48 Inch Wide - 250 Feet @ $560 per foot			$ 140,000
	Total Raw Storage & Handling Cost		$2,412,000

PREPARATION PLANT:

Equipment Cost -

8 X 20 Foot Double Deck Vibrating	
Pre-Wet Screens	
4 @ $30,000 each	$120,000
Heavy Media Drums	
Wemco - 12 Foot Diameter, 21 Feet Long	
2 @ $125,000 each	250,000
8 X 16 Foot Double Deck Vibrating	
Drain and Rinse Screens having 25 hp	
4 @ $36,000 each	144,000
8 X 16 Foot Single Deck Vibrating	
Drain and Rinse Screens	
2 @ $32,000 each	64,000
Sieve Bends - 6 Feet Wide	
4 @ $4,800 each	19,200
Sumps - Heavy & Dilute Media	
2 @ $14,000 each	28,000
Magnetic Separators	
30 Inch Diameter - 10 Feet Long	
4 @ $8,500 each	34,000

Crusher		
2 @ $12,100 each	$ 24,200	
Centrifugal Dryers		
2 @ $28,200 each	56,400	
Sump - Dryer Effluent		
1 @ $10,000	10,000	
Vacuum Disc Filter		
10 Foot 6 Inch Diameter - 7 Disc		
1 @ $90,000	90,000	
Pumps	75,000	
Total Preparation Plant Equipment Cost	$ 914,800	
Total Cost of Preparation Plant		
Including Site Preparation, Construction of		
Building, Electrical Service, Piping, etc.		
$914,800 X 3.0		$2,744,400
OTHER FACILITIES & EQUIPMENT:		
Static Thickener		
90 Ft. Diameter @ $2,000 per foot		180,000
Refuse Bin - 450 Ton Capacity		
Fabricated Part		75,000
Refuse Belt		
36 Inch Wide - 200 feet @ $480 per foot		96,000
Refuse Handling Equipment		
3 - Trucks @ $ 75,000 each		225,000
2 - Dozers @ $150,000 each		300,000

Coal Sampling System	$ 300,000
Clean Coal Belt	
54 Inch Wide - 300 Feet @ $600 per foot	180,000
Clean Coal Silo	
15,000 Ton Capacity @ $110 per ton	1,650,000
Unit-Train Load Facility	500,000
Total Other Facilities & Equipment	$3,506,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$2,412,000
Preparation Plant	2,744,000
Other Facilities and Equipment	3,506,000
Contingency (Interest during construction, etc.)	1,300,000
Total Capital Requirement	$9,962,000

BASED UPON THE 1400 TONS PER HOUR OF RAW COAL BEING PROCESSED BY THIS PLANT, THE CAPITAL COST PER TON HOUR INPUT IS QUITE LOW - $7,116. HOWEVER, SINCE ONLY 720 TPH IS RECEIVING ANY SIGNIFICANT DEGREE OF CLEANING, THE CAPITAL COST SHOULD BE BASED UPON THE INPUT TO THE PREPARATION PLANT PROPER WHICH TRANSLATES TO APPROXIMATELY $13,800 PER TON HOUR INPUT.

5.5.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 5 is as follows:

Total Capital Required: $10.0 Million

Capacity:

Raw Coal Input - 1400 tph

Clean Coal Output - 1036 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	% Utilization 40%
10 Year Period		
Per Ton of Raw Coal	$0.42	$0.31
Per Ton of Clean Coal	$0.56	$0.42
15 Year Period		
Per Ton of Raw Coal	$0.33	$0.25
Per Ton of Clean Coal	$0.45	$0.34

5.5.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-28 are based upon:

- o Raw Coal Input of 1400 Tons Per Hour
- o Clean Coal Output of 1036 Tons Per Hour
- o Btu Recovery of 94.6%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-28

EXAMPLE 5 - HEAVY MEDIA PROCESS - SIMPLE

OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non Union)	$0.148	$0.200
Operating (Union)	0.360	0.487
Maintenance (Union)	0.254	0.343
Overhead -		
Non-Union Benefits - Includes Payroll Taxes, Group Life & Medical Insurance, Pension Fund, etc.	0.030	0.040
Union Benefits - Includes Payroll Taxes, Welfare Fund, Vacations, Holidays, Clothing Allowance, etc.	0.184	0.249
Other	0.112	0.152
Supplies		
Operating - Magnetite, Flocculants, and clay settler accounts for 22%.*	0.610	0.824
Maintenance - Equipment Repair, etc.	0.504	0.681
Electricity	0.165	0.223
O & M Cost-		
Not Including Capital Amortization	$2.37	$3.20
Capital Amortization 10 years - 30% Utilization	0.42	0.56
Total Operating & Maintenance Cost	$2.79	$3.76
Cost Per Million Btu (10,168 Btu/lb)		$0.185

*Consumption of these major additives on each ton of clean coal is: Magnetite 1 to 1.5 lb; Flocculant 0.015 lb; and clay settler 0.15 lb. When the coal is damp and muddy, consumption is much higher. On an annual basis, their cost averages $0.18 to $0.20 per ton of product.

5.5.4 Discussion of Performance and Cost

Based upon the performance of the Example 5 plant as summarized on Table 5-25, one has to search for "Why?" the plant is even in existence. The answer is found in the fact that the current feed to the plant is substantially different from that around which the plant was designed. As originally conceived, approximately one-third of the raw coal was to be less than 1/2 inch and be fairly low in ash and sulfur. However, recent feed to the plant has been such that nearly half falls below 1/2 inch and contains a much larger percentage of the undesireable constituents (ash and sulfur). As a result, the total performance of the plant is far from impressive and cannot be improved by simply reducing the openings of the sizing screens since the plant equipment selection was predicated upon coarser material. To cope with these changed conditions, an extensive plant modification is being planned which will include Deister tables treating the 1/2 inch X 0 fraction. Although the anticipated results from this modification will be a reduction in weight yield to around 63% it will more than be justified by the quality of the final product.

Obviously, this process is not recommended for treating the particular coal now being run. However, a process of this type could very well show merit when handling a coal having a physical consistency similar to that around which the plant was designed. Therefore, the purpose of including this example is not only to fill out the spectrum of heavy media processes currently being utilized, but also show the capital and O & M costs of a potentially successful process of this general make-up and capacity. Since this plant as currently being operated performs very little actual cleaning, the costs of preparation per ton of clean product, as presented in the preceeding Table 5-28, are only appropriate if it is assumed that better operating results will be achieved at a 74% weight yield with another coal. However, the costs presented on a raw ton can be used as the basis for projecting product costs for whatever weight yield the reader feels is proper for another coal.

5.6 Example 6 - Heavy Media Process - Complex

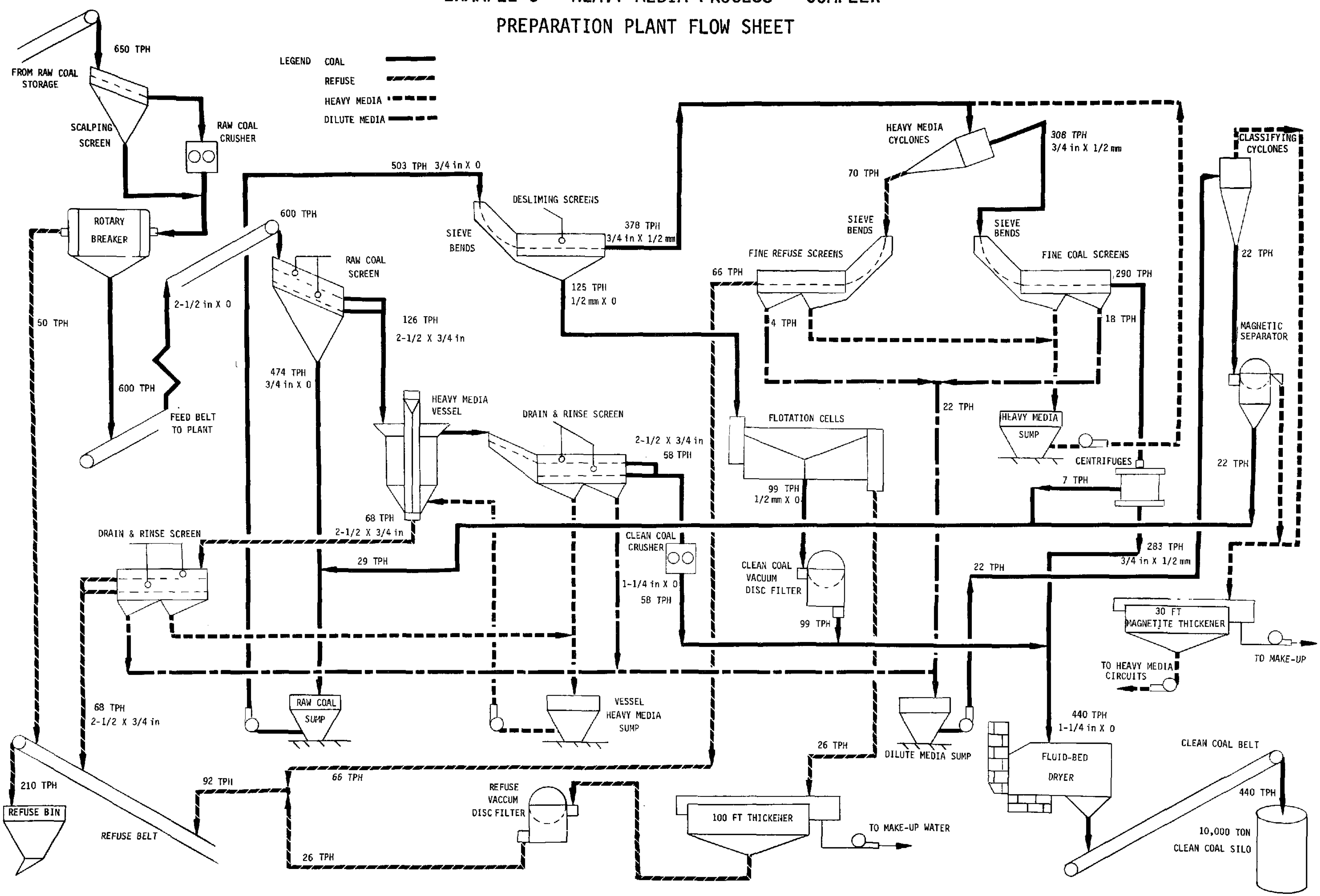
5.6.1 General Description

As shown on the plant flow sheet, Figure 5-6, the major emphasis of this preparation process is on the material of less than 3/4 inch top size which constitutes nearly 80% of the feed to the plant. This high concentration of finer material is the result of the continuous and longwall mining methods used in combination with the friable nature of the raw coal.

From the open raw coal storage area, the material is conveyed via a 42 inch belt to a fixed screen which passes coal of 8 inches or less. That material greater than 8 inches passes over the screen and is reduced to 8 inch X 0 by a crusher before going to a rotary breaker. In the rotary breaker, that material reduced to 2-1/2 inches or less passes through the screen plates and drops onto the 42 inch wide plant feed belt. Any larger size material passes through the refuse end of the breaker and reports to the refuse bin.

Raw coal 2-1/2 inch X 0 is conveyed at the rate of 600 tph to two inclined 7 X 16 foot double deck vibrating screens. The 126 tph of 2-1/2 X 3/4 inch material passing over both decks goes to the Barvoy heavy media vessel. The 474 tph of 3/4 inch X 0 passing through the screens reports to sumps from where it is pumped to the finer cleaning portion of the circuit. Of the 126 tph entering the heavy media vessel, 58 tph are recovered as clean coal. The balance (68 tph) sinks as refuse and goes to a 4 X 16 foot double deck drain and rinse screen for partial dewatering and media recovery before dropping onto the refuse belt. The 58 tph of 2-1/2 X 3/4 inch "float" from the vessel passes over a 4 X 16 foot double deck drain and rinse screen whose major purpose is media recovery. From this screen the material goes to a crusher where the clean coal is reduced to 1-1/4 inch X 0 before being conveyed to the thermal dryer.

FIGURE 5-6
EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX
PREPARATION PLANT FLOW SHEET



Returning to the finer portion of the circuit, the 3/4 inch X 0 material is pumped from the raw coal sumps to sieve bend ahead of six 8 X 16 foot single deck desliming screens at the rate of 503 tph. Passing over these screens is 378 tph of 3/4 inch X 1/2 mm (approximately 28 mesh) material which goes to heavy media cyclones. The 125 tph of 1/2 mm X 0 material passing through the desliming screens goes to two banks of four froth flotation cells. Of this total, all but 26 tph is recovered as clean coal and is partially dewatered by two vacuum disc filters before being conveyed to the thermal dryer. The refuse from the froth cells reports to the 100 foot diameter concrete static thickener from which it is pumped at the rate of 26 tph to a vacuum disc filter for partial dewatering before being conveyed to the refuse bin.

The 378 tph of 3/4 inch X 1/2 mm material passing over the desliming screens is handled by six 24-inch diameter heavy media cyclones having Nihard liners. These cyclones recover 308 tph as clean coal overflow which goes to sieve bends ahead of six 8 X 16 foot single deck screens for partial dewatering and media recovery. All but 18 tph passes over these screens and goes to centrifugal dryers for further dewatering before being conveyed to the thermal dryer. The 18 tph passing through these screens reports to the dilute media sump. The 70 tph of underflow from the heavy media cyclones goes to sieve bends ahead of two 6 X 16 foot single deck screens. All but 4 tph passes over these screens and goes directly to the refuse bin. The 4 tph passing through these screens reports to the dilute media sump from which it is pumped along with the 18 tph of material which passed through the 8 X 16 foot single deck screens to six 20 inch diameter classifying cyclones.

All 22 tph report as underflow in these cyclones and go to double drum magnetic separators from which the solids are pumped to the 3/4 inch X 0 raw coal sumps for reprocessing by the finer coal portion of the circuit.

The single fluid-bed thermal dryer handles 440 tph of 1-1/4 inch X 0 material. Following drying, the clean coal is conveyed via a 42 inch wide belt to a 10,000 ton concrete silo for storage pending unit-train load-out.

As shown in Table 5-29, this plant recovers approximately 73% by weight of the plant feed having a heat content of 14,336 Btu/lb. This translates to a 89.2% Btu recovery.

The staff necessary to operate and maintain this plant is listed under Table 5-32. As summarized in Table 5-33, a plant of this size and complexity could be built for around 13.5 million dollars.

TABLE 5-29

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX
PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	% of Feed	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
2-1/2 X 3/4 Inch	21.0	126		8,800	41.4	4.88
3/4 Inch X 1/2 mm (28 mesh)	58.2	349		12,600	17.2	4.24
1/2 mm X 0	20.8	125		12,544	17.7	4.27
	100.0	600	5.0	11,790	22.4	4.38

Clean Coal Product From Plant:

Size Fraction	% of Feed	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
1-1/4 Inch X 0		58		14,200	7.8	2.65
3/4 Inch X 1/2 mm		283		14,555	6.4	2.00
1/2 mm X 0		99		13,788	10.4	2.55
		440	5.0	14,336	7.48	2.21

Net Performance:

Weight Yield 73.3%   Btu Recovery 89.2%   Btu of Clean Coal with 5.0% Moisture 13,619 Btu/lb

* Btu, Ash, & Sulfur Presented on Dry Basis

TABLE 5-30

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX

WASHABILITY DATA OF ASSUMED PLANT FEED - 3/4 Inch X 1/2 mm*

Specific Gravity of Separation	Direct Float			Cumulative Float		
	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %
Float 1.30	61.3	4.0	1.21	61.3	4.0	1.21
1.30- 1.40	14.6	11.4	3.45	75.9	5.4	1.64
1.40- 1.45	2.3	17.3	6.32	78.2	5.8	1.78
1.45- 1.50	1.5	20.3	6.40	79.7	6.0	1.87
1.50- 1.60	1.7	24.2	8.36	81.4	6.4	2.00
1.60- 1.70	1.6	31.1	8.82	83.0	6.9	2.13
1.70- 1.90	1.7	42.0	9.56	84.7	7.6	2.28
SINK- 1.90	15.3	70.1	15.07	100.0	17.2	4.24

* 58.2% of Total Feed

TABLE 5-31

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX

WASHABILITY DATA OF ASSUMED PLANT FEED - 2-1/2 X 3/4 INCH FRACTION*

Specific Gravity of Separation	Direct Float			Cumulative Float		
	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %
Float 1.30	21.5	3.6	1.35	21.5	3.6	1.35
1.30- 1.40	20.8	10.1	3.20	42.3	6.8	2.26
1.40- 1.45	2.2	15.7	5.90	44.5	7.2	2.44
1.45- 1.50	2.1	19.4	7.19	46.6	7.8	2.65
1.50- 1.60	2.4	24.5	7.73	49.0	8.6	2.90
1.60- 1.70	2.6	32.9	7.55	51.6	9.8	3.14
SINK- 1.70	48.4	75.1	6.74	100.0	41.4	4.88

* 21.0% of Total Feed

TABLE 5-32

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX
PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Superintendent (1/2 time)		1
General Foreman		1
	Total	2

Operating Shift (2 per day)

Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	1
Mechanic	4-C	2
Mobile Equipment Operator (Refuse Hauling & Compacting)	3-A	2
Repairman·Helper (Greaser)	2-F	1
Stationary Equipment Operator (Thermal Dryer, Media, etc.)	3-C	2
Utility Man	1-H	2
	Total	12

Maintenance Shift (1 per day)

Foreman	NU*	1
Electrician	4-A	1
Mechanic	4-C	3
Repairman	3-B	2
Repairman Helper	2-F	2
	Total	9

Personnel Summary

General Management		2
Operating Shifts		24
Maintenance Shift		9
	Total	35

*NU-Non-Union

TABLE 5-33

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Storage Area		
20,000 ton capacity with reclaiming feeders and tunnel		$ 300,000
Raw Coal Belt To Scalping Tower		
42 Inch Wide - 200 feet @ $520 per foot		104,000
Tramp Iron Magnet Over Raw Coal Belt		
Explosion Proof, Self-Cleaning Type		20,000
Scalping Tower		
Including Fixed Screen and Structural Work For Crusher and Rotary Breaker		250,000
Raw Coal Crusher - 1		65,400
Rotary Breaker		
9 Ft. Diameter - 17 Feet Long		150,000
Raw Coal Belt To Plant		
42 Inch Wide - 250 feet @ $520 per foot		130,000
Total Raw Coal Storage & Handling Cost		$1,019,400
PREPARATION PLANT:		
Equipment Cost -		
7 X 16 Foot Double Deck Vibrating Raw Coal Screens		
2 @ $21,000 each	$ 42,000	
Heavy Media Vessel		
Barvoy Deep Bath Type	35,000	

4 X 16 Foot Double Deck Vibrating	
Drain & Rinse Screens	
2 @ $20,500	$ 41,000
Crusher - 1	9,000
Sump - Raw Coal 3/4 Inch X 0	
2 @ $10,000 each	20,000
Sieve Bends	
6 Feet Wide - 80 Inch Radius	
6 @ $4,800 each	28,800
8 X 16 Foot Single Deck Vibrating	
Desliming Screens	
6 @ $27,000 each	162,000
Heavy Media Cyclones	
24 Inch Diameter w/NiHard Liner	
6 @ $3,000 each	18,000
Sump - Heavy and Dilute Media	
5 @ $14,000 each	70,000
Froth Flotation Cells	
2 Banks of Four Cells	76,000
Sieve Bends	
5 Feet Wide - 80 Inch Radius	
2 @ $4,000 each	8,000
6 X 16 Foot Single Deck Vibrating	
Fine Refuse Screens	
2 @ $19,000 each	38,000

Sieve Bends	
7 Feet Wide - 40 Inch Radius	
6 @ $5,600 each	33,600
8 X 16 Foot Single Deck Vibrating	
Fine Clean Coal Screens	
6 @ $30,000 each	180,000
Centrifugal Dryers	
Bird Model 1150 D	
2 @ $48,000 each	96,000
Vacuum Disc Filters	
2 - 12 Ft. 6 Inch Diameter 10 Disc	
$120,000 each	240,000
1 - 10 Ft. 6 Inch Diameter 9 Disc	100,000
Classifying Cyclones	
20 Inch Diameter	
6 @ $2,400 each	14,400
Magnetic Separators	
Double Drum - 30 Inch Diameter -	
6 Ft. Long	
3 @ $17,000 each	51,000
Pumps	150,000
Total Preparation Plant Equipment Cost	1,412,800

Total Cost of Preparation Plant

Including Site Preparation, Construction of

Building, Electrical Service, Piping, etc.

$1,412,800 X 3.0 $4,238,400

OTHER FACILITIES & EQUIPMENT:

Static Thickener	
100 Ft. Diameter @ $2,000 per foot	$ 200,000
Fluid-Bed Thermal Dryer	
Complete with structural steel, motors, motor controls, wiring, piping, field erection, and start-up service	3,500,000
Clean Coal Belt To Silo	
42 Inch Wide - 300 feet @ $520 per foot	156,000
Clean Coal Silo	
10,000 ton capacity @ $110 per ton	1,100,000
Coal Sampling System	300,000
Unit-Train Loading Facility	500,000
Magnetite Thickener	
30 Ft. Diameter @ $2,500 per foot	75,000
Refuse Belt	
36 Inch Wide - 200 feet @ $480 per foot	96,000
Refuse Bin	
300 Ton Capacity - Fabricated Part	60,000
Refuse Handling Equipment	
2 - Trucks @ $ 75,000 each	150,000
2 - Dozers @ $150,000 each	300,000
Total Other Facilities & Equipment	$6,437,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 1,019,400
Preparation Plant	4,238,400
Other Facilities and Equipment	6,437,000
Contingency (Interest during construction, etc.)	1,754,200
Total Capital Requirement	$13,449,000

BASED UPON THE 600 TONS PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $22,400 PER TON HOUR INPUT

5.6.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 6 is as follows:

Total Capital Required: $13.5 Million

Capacity:

Raw Coal Input - 600 tph

Clean Coal Output - 440 tph

CAPITAL AMORTIZATION

	% Utilization	
Amortization Period & Basis	30%	40%
10 Year Period Per Ton of Raw Coal	$1.31	$0.97
Per Ton of Clean Coal	$1.79	$1.33
15 Year Period Per Ton of Raw Coal	$1.05	$0.78
Per Ton of Clean Coal	$1.43	$1.06

5.6.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-34 are based upon:

- o Raw Coal Input of 600 Tons Per Hour
- o Clean Coal Output of 440 Tons Per Hour
- o Btu Recovery of 89.2%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year.

TABLE 5-34

EXAMPLE 6 - HEAVY MEDIA PROCESS - COMPLEX

OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non Union)	$0.099	$0.135
Operating & Maintenance (Union)	0.638	0.870
Overhead -		
Fringe Benefits - 25% Non-Union	0.025	0.034
- 20% Union	0.128	0.174
Other - Includes Workmens' Compensation Insurance, Payroll Taxes, Welfare Fund, etc.	0.213	0.291
Supplies -		
Operating	0.169	0.23
Maintenance & Other	0.242	0.33
Thermal Dryer Fuel -		
Based Upon 7.0 Tons/Hr Coal Consumption & Cost of Coal $20/Ton	0.233	0.318
Cleaning Plant Repair Parts	0.147	0.20
Electricity (Large Thermal Dryer)	0.334	0.456
O & M Cost - Not Including Capital Amortization	$2.23	$3.04
Capital Amortization - 10 years - 30% Utilization	1.31	1.79
Total Operating & Maintenance Cost	$3.54	$4.83
Cost Per Million Btu (13,619 Btu/lb)		$0.177

5.6.4 Discussion of Performance and Cost

The Example 6 plant performs a reasonably good job of reducing ash and sulfur while recovering nearly 90% of the heat content in the raw coal feed. This is accomplished by treating the coarser size fractions (+3/4 inch) in a heavy media vessel and the finer sizes with heavy media cyclones and froth flotation. The heavy media vessel effects a separation at 1.6 specific gravity giving a clean coal yield consistent with the washability data from Table 5-31. Due to the high percentage of 3/4 inch X 0 material in the raw feed, the majority of the plant is devoted to finer cleaning equipment. The heavy media cyclones operate at 1.60 specific gravity treating the 3/4 inch X 1/2 mm (28 mesh) material with the 1/2mm X 0 handled by flotation cells. These cyclones recover over 80% of their feed as predicted by the washability data from Table 5-30. The froth cells also recover nearly 80% of their feed while significantly reducing the ash and sulfur content of the 1/2mm X 0 size fraction.

As presented in Table 5-33, this is an expensive plant to build. One of the major factors contributing to this high capital cost is the large thermal dryer necessary to handle all of the 440 tons per hour of clean coal produced by the plant. This one item accounts for 30% of the total cost of the preparation facility. In spite of the high cost, drying is necessary to meet their contract specification and can be further justified on the basis of lower transportation and handling costs. Since the capital cost is so high and current utilization is only 30%, there is substantial room for reducing the effect of capital amortization on total cost. If this plant was operated 40% of the time, the capital cost would be brought down by $0.46 on each ton of clean coal. Greater plant utilization would also have a favorable impact on other fixed expenses such as supervisory salaries and certain overhead items.

Since the Example 6 process when treating this particular coal loses approximately 10% of the heat content in the raw feed, a cost might be applied to account for these "lost" Btu's. If applied, the total cost of preparation would increase by $0.077 to $0.254 per million Btu. The application of this "cost" is based upon the assumption that the raw coal was saleable in its original form and therefore had value associated with its heat content. Even if one accepts this assumption, the validity of applying this "cost" is subject to question since the material discarded, which carried with it these "lost" Btu's, also carried large quantities of the undesireable raw coal constituents such as ash and sulfur whose removal was the very purpose of the cleaning process. Therefore, an argument might be made that if the cleaning process was performing its design function efficiently (i.e. to the Btu recovery limits consistent with its design objective), no cost should be applied for the "lost" heat content. However, a cost "penalty" would be assessed if the process did not function close to the maximum Btu recovery consistent with the desired sulfur and ash reduction. Since there are differing views on how this subject should be treated, we have identified this cost item separately above, to permit the reader complete latitude in it's application.

Although this is an expensive plant to build, the overall operating and maintenance costs are quite reasonable considering the results achieved.

Even with the low plant utilization noted above, the price per ton is less than $5.00 for a product having one-third the ash and half the sulfur of the raw coal. This expense is more than recovered by the producer in the market place who now has a far more valuable and readily saleable product. Part of the increased value of the cleaned coal is related to the benefits derived by the user. These include the obvious savings in transportation and ash disposal as well as the more subtle and sometimes greater economic benefits reflected in reduced particulate and FGD emission control capacity. When these benefits are quantified based upon the particular user's situation, they can significantly reduce the effective cost of coal preparation. In this particular case, the reduction in sulfur would substantially reduce the SO_2 emission control equipment and expense at the combustion location. Since the purpose of this study is to look at coal preparation cost at the producer's level, we have not attempted to quantify any of these benefits which our other studies have shown vary on a case by case basis.

5.7 Example 7 - Heavy Media Process - Complex

5.7.1 General Description

This plant was designed to process coal with a large percentage (40-50%) of finer material in the range of 1/4 inch X 0. The presence of so much fine material in the raw plant feed is related to the nature of the coal and the continuous mining methods used. Although such mining machinery is quite efficient from a production standpoint, the as-mined product can be more difficult to handle and process. Therefore, such a condition should be a major consideration in the design of a coal preparation plant.

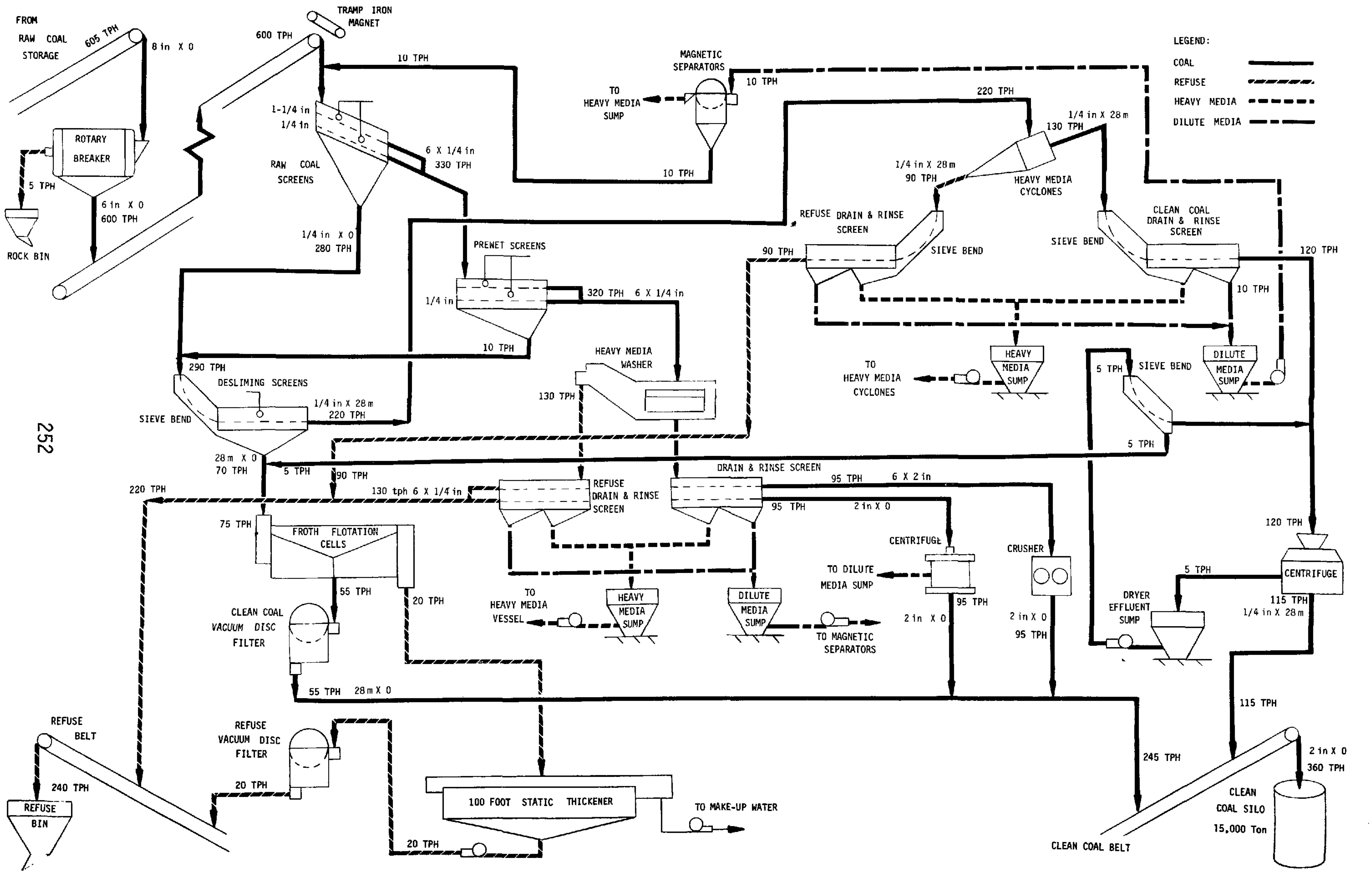
From the open raw coal storage area, 8 inch X 0 material is fed via a 42 inch wide belt to a rotary breaker at just over 600 tons per hour (tph). That material which reduces to 6 inches or less in the breaker passes through the screen plates and drops onto the 42 inch wide plant feed belt. That material which does not fracture to 6 inches or less passes out the refuse end of the breaker and reports to a rock bin.

As the raw coal moves into the plant, it passes under a tramp iron magnet to remove any stray ferrous material such as broken mining bits which may have been carried along with the coal. From the plant feed belt the 6 inch X 0 coal drops at the rate of 600 tph onto two 8 X 20 foot inclined vibrating double deck screens having 1-1/4 inch top deck and 1/4 inch lower deck openings. The actual feed to these screens is 610 tph due to an additional 10 tph from the magnetite recovery units which is recycled back through the circuit. Of the total feed to these screens, 330 tph of 6 X 1/4 inch material passes over and goes to two 6 X 16 foot double deck prewet screens having 1/4 inch lower deck openings. All but

FIGURE 5-7

EXAMPLE 7 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT FLOW SHEET



10 tph passes over both decks of these screens and goes to the heavy media vessel. Of the 320 tph of 6 X 1/4 inch material entering the vessel, 190 tph "floats" as clean product and passes to two 6 X 16 foot double deck drain and rinse screens. These screens provide the multiple functions of sizing, partial dewatering, and media recovery. Passing over the top decks is 95 tph of 6 X 2 inch clean coal which goes to a crusher where it is reduced to 2 inch X 0 before it drops onto the clean coal belt. The 95 tph of 2 inch X 0 clean coal passing over the bottom deck of the 6 X 16 foot drain and rinse screens goes to two centrifugal dryers which further dewater the material before it drops onto the clean coal belt.

Of the total feed to the heavy media washer, 130 tph reports as refuse and goes to one 6 X 16 foot double deck drain and rinse screen for media recovery and partial dewatering. All 130 tph passes over both decks of these screens and goes to the refuse belt.

Returning to the 8 X 20 foot raw coal screens, 280 tph of 1/4 inch X 0 material (46% of the total plant feed) passes through these screens and is fed with the 10 tph underflow from the 6 X 16 foot prewet screens to sieve bends ahead of four 6 X 16 foot single deck desliming screens. Of the 290 tph fed to these screens, 220 tph of 1/4 inch X 28 mesh material passes over and is fed to four 24 inch diameter heavy media cyclones. The overflow from these cyclones is 130 tph of 1/4 inch X 28 mesh material which goes to sieve bends ahead of four 6 X 16 foot single deck drain and rinse screens. All but 10 tph passes over these screens and goes to four centrifugal dryers for further dewatering. Of the 120 tph fed to these centrifuges, 115 tph is recovered and drops onto the clean coal belt. The 5 tph of effluent reports to a sump from which it is pumped over a sieve bend on to the froth flotation cells. The 10 tph passing through the 6 X 16 foot clean coal drain and rinse screens reports to the dilute media sump from which it is pumped to magnetic separators. As mentioned earlier, the magnetic separators recover the 10 tph and send it back to the beginning of the circuit.

The underflow from the heavy media cyclones is 90 tph of 1/4 inch X 28 mesh material which is fed to a sieve bend ahead of a 6 X 16 foot single deck vibrating refuse drain and rinse screen. All 90 tph passes over this screen and reports to the refuse belt.

Returning to the 6 X 16 foot desliming screens, 70 tph of 28 mesh X 0 material passes through and is fed to froth flotation cells along with the 5 tph of fine dryer effluent material which was recovered through a sieve bend as mentioned above. The 75 tph of 28 mesh X 0 material is fed to two banks of three froth cells which recover over 70% as clean coal. The 55 tph of clean product from the froth cells goes to a 10 foot six inch diameter vacuum disc filter having 14 discs for dewatering before dropping onto the clean coal belt. The 20 tph of refuse from the cells goes to the 100 foot diameter concrete static thickener. Settled material is pumped from this thickener at the rate of 20 tph to a 10 foot 6 inch diameter vaccum disc filter having 12 discs where it is dewatered sufficiently to permit disposal.

Of the 600 tph of 6 inch X 0 raw coal feed to the plant, 360 tph of 2 inch X 0 winds up on the 36 inch wide clean coal belt and is fed to a 15,000 ton capacity concrete silo to await unit-train load-out. This plant is efficiently operated and maintained by a minimum of personnel as set forth in Table 5-36. Such a small staff is made possible by the aid of a sophisticated electronic control center.

As presented in Table 5-37, a plant of this size and general make-up can currently be constructed for a price of $8.4 million.

TABLE 5-35

EXAMPLE 7 - HEAVY MEDIA PROCESS - COMPLEX
PREPARATION PLANT PERFORMANCE*

Raw Coal Feed To Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
6 Inch X 0	600	5.0	8,600	40.0	1.0

Clean Coal Product From Plant:

2 Inch X 0	360	4.88	13,348	11.67	1.14

Moisture & Ash Free Btu = 15,112 Btu/lb

Net Performance:

Weight Yield 60.0 %   Btu Recovery 93.1%   Btu of Clean Coal with 4.9% Moisture 12,697 Btu/lb

* Btu, Ash, and Sulfur Presented on Dry Basis

TABLE 5-36

EXAMPLE 7 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Manager		1
Operating Shift (Two per day)		
Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Electrician/Mechanic	4-A	1
Mobile Equipment Operator (Refuse Spreading & Compacting and Pushing Raw Coal Into Feeders)	3-A	2
Repairman Helper	2-F	1
General Outside Laborer	1-J	1
	Total	7
Maintenance Shift		
Foreman	NU*	1
Electrician/Mechanic	4-A	1
Repairman	3-B	3
Repairman Helper	2-F	1
	Total	6
Personnel Summary		
General Management		1
Operating Shifts		14
Maintenance Shift		6
	Total	21

*NU - Non-Union

TABLE 5-37

EXAMPLE 7 - HEAVY MEDIA PROCESS - COMPLEX PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Storage Area		
10,000 Ton Capacity with Stacking Tube, Reclaiming Feeders, and Tunnel		$250,000
Raw Coal Belt To Rotary Breaker		
42 Inch Wide - 200 Feet @ $520 per foot		104,000
Tramp Iron Magnet		
Explosion Proof - Self Cleaning Type		20,000
Rotary Breaker		180,000
Raw Coal Belt To Plant		
42 Inch Wide - 250 Feet @ $520 per foot		130,000
Total Raw Coal Storage & Handling Cost		$684,000
PREPARATION PLANT:		
Equipment Cost -		
8 X 20 Foot Double Deck Vibrating Raw Coal Screens		
2 @ $30,000 each	$60,000	
6 X 16 Foot Double Deck Prewet Screens		
2 @ $24,000 each	48,000	
Heavy Media Washer	45,000	
6 X 16 Foot Double Deck Clean Coal Drain & Rinse Screens		
2 @ $23,000 each	46,000	

6 X 16 Foot Double Deck Refuse Drain &	
Rinse Screen	
1 @ $26,000	$26,000
Crusher - Clean Coal	12,100
Centrifugal Dryers	
2 @ $28,200 each	56,400
Sieve Bends - 5 Feet Wide	
5 Ft. Radius - 1/2 mm openings	
4 @ $4,000 each	16,000
6 X 16 Foot Single Deck Desliming Screens	
4 @ $16,000 each	64,000
Heavy Media Cyclones	
24 Inch Diameter - Ceramic Liners	
4 @ $4,000 each	16,000
Sieve Bends - 5 Feet Wide	
30 Inch Radius - 1/2 mm openings	
6 @ $4,000 each	24,000
6 X 16 Foot Single Deck	
Drain & Rinse Screens	
5 @ $19,000 each	95,000
Centrifugal Dryer	
4 @ $23,200 each	92,800
Froth Flotation Cells	
2 Banks of Three Cells	68,000

Magnetic Separators - Single Drum		
30 Inch Diameter - 6 Feet Long		
5 @ $6,500 each	$ 32,500	
Vacuum Disc Filters		
Clean Coal - 10 Ft. 6 Inch Diameter -		
14 Disc	128,000	
Refuse - 10 Ft. 6 Inch Diameter -		
12 Disc	120,000	
Sumps - Heavy & Dilute Media		
4 @ $14,000 each	56,000	
Sump - Dryer Effluent		
1 @ $10,000	10,000	
Pumps	100,000	
Total Preparation Plant Equipment Cost	$1,115,800	
Total Cost of Preparation Plant		
Including Site Preparation, Construction of		
Building, Electrical Service, Piping, etc.		
$1,115,800 X 3.0		$3,347,400
OTHER FACILITIES & EQUIPMENT:		
Static Thickener		
100 Feet @ $2,000 per foot		200,000
Refuse Belt		
36 Inch Wide - 200 Feet @ $480 per foot		96,000
Refuse Bin		50,000

Refuse Handling Equipment	
2 - Dozers @ $150,000 each	$ 300,000
1 - Front-End Loader	50,000
Clean Coal Belt To Silo	
36 Inch Wide - 300 Feet @ $480 per foot	144,000
Clean Coal Silo - Concrete	
15,000 Ton Capacity @ $110 per ton	1,650,000
Automatic Coal Sampling System	300,000
Unit-Train Loading Facility	500,000
Total Other Facilities & Equipment	$3,290,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 684,000
Preparation Plant	3,347,400
Other Facilities and Equipment	3,290,000
Contingency (Interest during construction, etc.)	1,098,200
Total Capital Requirement	$8,419,600

BASED UPON THE 600 TON PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $14,000 PER TON HOUR INPUT

5.7.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 7 is as follows:

Total Capital Required: $8.4 million

Capacity:

Raw Coal Input - 600 tph

Clean Coal Output - 360 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	40%
10 Year Period		
Per Ton of Raw Coal	$0.82	0.61
Per Ton of Clean Coal	$1.36	1.01
15 Year Period		
Per Ton of Raw Coal	$0.66	0.49
Per Ton of Clean Coal	$1.09	0.81

5.7.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-38 are based upon:

- o Raw Coal Input of 600 Tons Per Hour
- o Clean Coal Output of 360 Tons Per Hour
- o Btu Recovery of 93.1%
- o 10 Year Amortization Period
- o 30% Utilization 2,600 Operating Hours Per Year out of a Possible 8,760 Hours or 13 Hours Per Day for 200 Days Per Year. (Although this is low, this rate is applied in order to be more consistent with the actual experience during the period over which the cost data was collected.)

TABLE 5-38

EXAMPLE 7 - HEAVY MEDIA PROCESS - COMPLEX
OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.058	$0.096
Operating & Maintenance (Union)	0.211	0.352
Overhead -		
Fringe Benefits - 25% Non-Union	0.014	0.024
- 21% Union	0.044	0.074
Other - Includes Welfare Fund, Payroll Taxes, Property Taxes, Insurance, etc.	0.060	0.100
Supplies -		
Operating - Magnetite	0.055	0.091
- Other	0.307	0.511
Maintenance	0.092	0.154
Major Maintenance - Scheduled repairs and plant improvements	0.051	0.085
Electricity -	0.090	0.150
Subcontract Services For Major Equipment Repairs & Miscellaneous Expenses	0.289	0.482
O & M Cost - Not Including Capital Amortization	$1.27	$2.12
Capital Amortization - 10 Yrs. - 30% Utilization	0.82	1.36
Total Operating & Maintenance Cost	$2.09	$3.48
Cost Per Million Btu (12,697 Btu/lb)		$0.137

5.7.4 Discussion of Performance and Cost

With the coal currently being handled by the Example 7 plant, the major thrust of the preparation process is the reduction in ash. As summarized by Table 5-35, this objective is accomplished at a loss of only 7% of the total heat content in the raw coal feed. Looking at the increase in sulfur content in the final product over that of the raw coal, one might think there was a typographical error. However, this phenomenon occurs because the sulfur content of the raw coal is mostly organic in nature and is not affected by physically cleaning. Therefore, as 40% of the raw feed is discarded as refuse, the organic sulfur bonded to the clean coal becomes a higher proportionate share of the final product. Although this result is expected with this particular coal, it should not be assumed that this process is incapable of removing sulfur. To the contrary, as demonstrated by Example 6, given a coal having a higher pyritic sulfur content, processes of this type are quite successful at effecting significant sulfur reductions.

The capital cost of this plant is quite reasonable considering its demonstrated ability to reduce over 70% of the raw coal ash. Although this plant's equipment make-up is much the same as Example 6, its capital cost is over 35% less. The principal reason for this lower capital cost over comparable capacity heavy media plants is the elimination of thermal drying. This also has a significant impact on reducing operating and maintenance costs. Through centrifugal drying methods and vacuum filters the moisture is reduced to an acceptable level. Although this is somewhat difficult to accept, it is supported by actual product data showing less than 16% of the final product is smaller than 28 mesh which is the most trouble to mechanically dewater. In spite of this lower capital requirement, the capital amortization per ton of clean coal is still $1.36 due to only a 30% utilization factor. Certainly, there is room for improvement as demonstrated by the fact that a savings of $0.35 per ton could be realized by operating merely an additional 10% of the time.

Regardless of the low plant utilization, the overall cost of producing clean coal is quite low in view of quality of the product and limited Btu loss. Besides the absence of thermal drying, the O & M cost is kept low by having a minimum staff and closely monitoring the consumption of magnetite, flocculants, and other expensive materials. As noted previously, Table 5-38, gives the producer's cost to clean a given coal by a particular process. Certainly, the clean product results in savings at the user level which go to reduce the effective cost of coal cleaning. Since these benefits are most accurately quantified on a site specific basis, no estimate is given here of their impact on the total economics of coal preparation.

If a cost is applied to account for the 7% loss in heat content of the raw feed, the cost of preparation increases by $0.066 to $0.203 per million Btu. As mentioned at several other points in this study, it is debatable whether or not it is appropriate to assess such a "penalty" when the material containing this heat content was essentially composed of the undesirable material (ash and some sulfur) which the cleaning process was designed to eliminate. This being the case, the reader is left with the prerogative to treat this matter as seen fit.

5.8 Example 8 - Heavy Media Process - Complex

5.8.1 General Description

Although not shown on the flow sheet (Figure 5-8), the raw coal is sized and most of the debris removed by a rotary breaker before being conveyed to the raw coal storage area. The 4 inch X 0 raw coal, mined by continuous and longwall mining, is fed to the breaker which has approximately 2 inch screen plate openings thereby permitting 1-1/4-inch X 0 material to pass through.

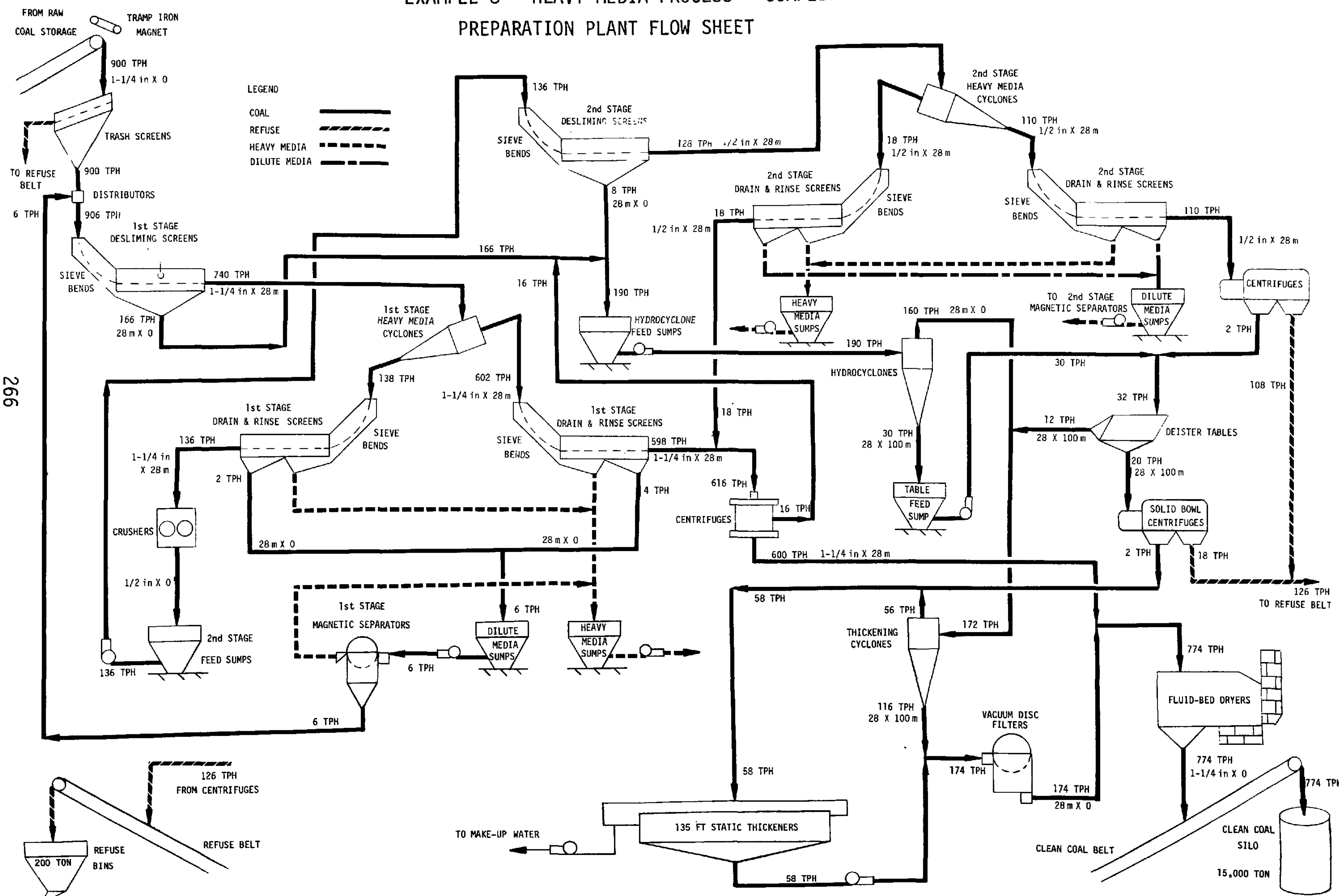
From the raw coal storage area, the 1-1/4 inch X 0 material is fed to the plant at the rate of 900 tons per hour (tph). On its way into the plant, the raw coal passes under a tramp iron magnet to remove any ferrous matter and passes through two 6 X 16 foot single deck trash screens having two inch openings to remove any larger foreign material not previously captured. The 1-1/4 inch X 0 raw coal passes over sieve bends onto twelve 6 X 16 foot single deck desliming screens. These screens with 1/2 mm openings pass the 28 mesh X 0 material at the rate of 166 tph and the 1-1/4 inch X 28 mesh material flows over at the rate of 740 tph. This 740 tph goes to twelve 24 inch first stage heavy media cyclones operating at 1.8 specific gravity. The 602 tph of overflow from these cyclones goes to sieve bends ahead of twelve 6 X 16 foot single deck drain and rinse screens whose primary function is the recovery of media. All but 4 tph pass over these screens on the way to centrifuges for partial dewatering before going to the thermal dryers. The 4 tph passing through these screens reports to the dilute media sumps.

The 138 tph of 1-1/4 inch X 28 mesh underflow from the first stage heavy media cyclones goes to sieve bends ahead of four 5 X 16 foot single deck

FIGURE 5-8

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT FLOW SHEET



drain and rinse screens for the purpose of media recovery. Of the total feed to these screens, 136 tph passes over and is reduced to 1/2 inch X 0 by two double roll crushers. This material reports to the second stage feed sumps from which it is pumped to sieve bends ahead of the four second stage 5 X 16 foot single deck desliming screens. The 2 tph of 28 mesh X 0 passing through the first stage 5 X 16 foot drain and rinse screens reports to the first stage dilute media sumps where it is pumped to the eight first stage magnetic separators and recovered for further processing.

Of the 136 tph of 1/2 inch X 0 material fed to the second stage desliming screens, 128 tph of 1/2 inch X 28 mesh passes over and is fed to the four 24 inch second stage heavy media cyclones operating at 1.8 specific gravity. Only 8 tph of 28 mesh X 0 material passes through these desliming screens and reports to the hydrocyclone feed sumps. The second stage heavy media cyclones recover 18 tph of 1/2 inch X 28 mesh clean coal which passes over two 5 X 16 foot second stage drain and rinse screens on the way to centrifuges before going to the thermal dryers. The underflow from the second stage heavy media cyclones is 110 tph of 1/2 inch X 28 mesh refuse which goes to sieve bends ahead of two 7 X 16 foot second stage drain and rinse screens for media recovery. All 110 tph passes over these screens and goes to two horizontal centrifuges where the surface moisture is reduced from 20% to around 7% before being conveyed to the refuse bin.

Now, returning to the hydrocyclone feed sumps, which receive 28 mesh X 0 material from the first and second stage desliming screens and the effluent from the clean coal centrifuges, a slurry containing 190 tph is fed to thirty-two hydrocyclones. The overflow from these cyclones is 160 tph of 28 mesh X 0. The underflow is 30 tph of 28 X 100 mesh material which reports to sumps from which it is pumped to four Deister tables for final clean coal and refuse separation. Also feeding the tables is 2 tph from the refuse centrifuge effluent sumps. The 12 tph of 28 X 100 mesh clean product from the tables joins the 160 tph of 28 mesh X 0 overflow from the hydrocyclones to feed thirty 14 inch thickening cyclones. The 56 tph of 100 mesh X 0 overflow from these cyclones goes to the two 135 foot diameter concrete static thickeners. The 116 tph of 28 X 100 mesh underflow from the thickening cyclones is joined by 58 tph of 100 mesh X 0 material pumped from the thickeners before going to the vacuum filters.

The total of 174 tph is partially dewatered by four vacuum disc filters each having ten discs 12 feet 6 inches in diameter. This gives an effective filtering surface area of 2,280 square feet per filter or a total of 9,120 square feet. Based upon a load factor of 40 pounds per hour per square foot of filtering surface gives the following minimum surface area required:

Weight Being Processed:

174 tons/hour = 348,000 pounds/hour

Surface Area Required (Minimum):

$$\frac{348{,}000 \text{ pounds/hour}}{40 \text{ pounds/hour/ft}^2} = 8{,}700 \text{ ft}^2$$

The 420 ft^2 of excess filtering capacity permits slight fluctuations in the feed without degrading performance. These filters produce a cake of approximately 25% surface moisture which goes on to the thermal dryers.

The two fluid-bed thermal dryers receive 774 tph of 1-1/4 inch X 0 material with a surface moisture of around 12%. During the drying process, the moisture is reduced to 5% or less. The dried product is conveyed to a 15,000 ton concrete silo for storage pending unit-train loadout.

Plant Operation -

The equipment in this preparation plant is arranged in two parallel circuits. This permits the plant to operate at full capacity for two shifts per day and at half capacity for the third shift while one circuit is shut down for maintenance. Based upon working five days per week, the plant can operate on an annual basis 4,160 hours at full capacity and 2,080 hours at half capacity for a total possible plant utilization of 5,200 hours per year. This would be equivalent to over 59% of the time (5,200 Hrs ÷ 8,760 Hrs). However, this is under ideal conditions and in practice the actual utilization is closer to 50%. For the purpose of allocating the capital cost of this plant, this latter utilization factor was used.

TABLE 5-39

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT PERFORMANCE

Raw Coal Feed To Plant:

Size Fraction	Tph	Surface Moisture %	Btu/lb	Ash %	Total Sulfur %
1-1/4 X 3/8 Inch	215			31.2	2.75
3/8 X 1/8 Inch	281			20.7	2.65
1/8 Inch X 0	404			13.4	2.20
	900	5.0	11,970	19.9	2.45

Clean Coal Product From Plant:

1-1/4 X 28 Mesh	600				
28 Mesh X 0	174				
	774	5.0	13,130	14.7	1.8

Net Performance:

Weight Yield 86.0% Btu Recovery 94.3% Btu of Clean Coal with 5.0% Moisture 12,473 Btu/lb

TABLE 5-40

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

WASHABILITY DATA OF ASSUMED PLANT FEED - 1-1/4 X 3/8 INCH FRACTION*

Specific	Direct Float			Cumulative Float			Cumulative Sink		
Gravity of	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %
FLOAT 1.40	41.8	9.4	1.50	41.8	9.4	1.50	58.2	46.8	3.65
1.40- 1.50	11.6	19.6	2.50	53.4	11.6	1.70	46.6	53.6	3.95
1.50- 1.60	7.4	28.4	3.30	60.8	13.7	1.90	39.2	58.3	4.05
1.60- 1.70	7.0	36.9	3.35	67.8	16.1	2.05	32.2	63.0	4.20
1.70- 1.80	6.2	44.1	3.35	74.0	18.4	2.15	26.0	67.5	4.40
SINK- 1.80	26.0	67.5	4.40	100.0	31.2	2.75			

* 23.9% of Total Feed

TABLE 5-41

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

WASHABILITY DATA OF ASSUMED PLANT FEED - 3/8 X 1/8 INCH FRACTION*

Specific Gravity of	Direct Float			Cumulative Float			Cumulative Sink		
	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %
FLOAT 1.40	67.0	7.5	1.30	67.0	7.5	1.30	33.0	47.5	5.45
1.40- 1.50	5.3	20.7	2.65	72.3	8.5	1.40	27.7	52.6	6.00
1.50- 1.60	5.3	29.7	3.50	77.6	9.9	1.55	22.4	58.0	6.60
1.60- 1.70	3.6	36.2	3.40	81.2	11.1	1.60	18.8	62.2	7.20
1.70- 1.80	3.0	43.7	3.70	84.2	12.2	1.70	15.8	65.7	7.85
SINK- 1.80	15.8	65.7	7.85	100.0	20.7	2.65			

* 31.2% of Total Feed

TABLE 5-42

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

WASHABILITY DATA OF ASSUMED PLANT FEED - 1/8 X 0 INCH FRACTION*

Specific Gravity of	Direct Float			Cumulative Float			Cumulative Sink		
	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %	Weight %	Ash %	Sulfur %
FLOAT 1.40	81.2	5.7	1.00	81.2	5.7	1.00	18.8	46.7	7.55
1.40- 1.50	2.4	22.6	2.20	83.6	6.2	1.05	16.4	50.2	8.35
1.50- 1.60	3.3	28.1	2.20	86.9	7.0	1.10	13.1	55.8	9.85
1.60- 1.70	2.2	34.2	3.50	89.1	7.7	1.15	10.9	60.1	11.15
1.70- 1.80	1.5	40.9	3.05	90.6	8.2	1.15	9.4	63.2	12.45
SINK- 1.80	9.4	63.2	12.45	100.0	13.4	2.25			

* 44.9% of Total Feed

TABLE 5-43

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX

PREPARATION PLANT OPERATING & MAINTENANCE PERSONNEL

General Non-Union Management		Quantity
Preparation Manager (1/2 time)		1
General Foreman		1
	Total	2

Operating Shift - Full (2 per day)

Title	Union Classification	Quantity
Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	1
Mechanic	4-C	2
Mobile Equipment Operator (Refuse Hauling & Compacting)	3-A	2
Stationary Equipment Operator (Thermal Dryer & Media Operators)	3-C	2
Repairman Helper (Greaser)	2-F	1
Utility Man	1-H	3
	Total	13

Operating/Maintenance Shift - Partial (1 per day)

Foreman	NU*	1
Plant Operator	4-E	1
Electrician	4-A	1
Mechanic	4-C	4
Mobile Equipment Operator	3-A	2

Stationary Equipment Operator	3-C	2
Repairman	3-B	1
Repairman Helper (Greaser)	2-F	1
Utility Man	1-H	3
	Total	16

Personnel Summary

General Management		2
Operating Shifts - Full		26
Operating/Maintenance Shift - Partial		16
	Total	44

*NU-Non-Union

TABLE 5-44

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX
PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Belt to Rotary Breaker		
48 Inch Wide 350 feet at $560 per foot		$ 196,000
Rotary Breaker		
10 Ft diameter - 16 ft. long		
Includes structural work and rock bin to		
receive debris from breaker		330,000
Raw Coal Belt to Storage Area		
48 Inch Wide 300 feet at $560 per foot		168,000
Raw Coal Storage Area		
20,000 ton capacity with reclaiming feeders		
and tunnel		300,000
Raw Coal Belt to Plant		
48 Inch Wide 350 feet at $560 per foot		196,000
Total Raw Coal Storage & Handling Cost		$1,190,000
PREPARATION PLANT:		
Equipment Cost -		
6 X 16 Foot Single Deck Trash Screens		
2 @ $15,000 each	$ 30,000	
Sieve Bends		
6 Ft Wide, 2 Ft 6 Inch Radius		
14 @ $4,800 each	67,200	

7 X 16 Foot Single Deck Vibrating	
Desliming Screens	
12 @ $21,500 each	$258,000
7 X 16 Foot Single Deck Vibrating	
Drain & Rinse Screens	
2 @ $21,500 each	43,000
Sieve Bends	
4 Ft Wide, 2 Ft 6 Inch Radius	
4 - 1st Stage, 6 - 2nd Stage	
10 @ $3,200 each	32,000
5 X 16 Foot Single Deck Vibrating	
Drain & Rinse Screens	
6 @ $18,500 each	111,000
5 X 16 Foot Single Deck Vibrating	
Desliming Screens	
4 @ $18,500 each	74,000
Sieve Bends	
5 Ft Wide, 2 Ft 6 Inch Radius	
12 @ $4,000 each	48,000
6 X 16 Foot Single Deck Vibrating	
Drain & Rinse Screens	
12 @ $19,000 each	228,000
Heavy Media Cyclones	
24 Inch Diameter w/Ni-Hard Liner	
16 @ $3,000 each	48,000

Centrifugal Dryers	
6 @ $28,200 each	$169,200
Crushers - 2 @ $33,100 each	66,200
Magnetic Separators	
30 Inch Diameter - 10 Feet Long	
10 @ $8,500 each	85,000
Centrifugal Dryers - Solid Bowl	
2 @ $110,000 each	220,000
Centrifugal Dryers - Horizontal Refuse	
2 @ $25,000 each	50,000
Hydrocyclones - 14 Inch Diameter w/Ni-Hard	
Liner & Refrax Underflow	
32 @ $2,000 each	64,000
Deister Tables	
2 Double Deck @ $21,000 each	42,000
Thickening Cyclones	
14 Inch Diameter w/Rubber Liner	
30 @ $1,300 each	39,000
Vacuum Disc Filters	
12 Ft 6 Inch Diameter - 10 Disc	
4 @ $120,000 each	480,000
Sumps - 1st Stage Heavy Media	
8,000 gallon - 1/4 Inch Steel	
2 @ $14,000 each	28,000

Sumps - 1st Stage Dilute Media	
7,000 gallon - 1/4 Inch Steel	
2 @ $14,000 each	$ 28,000
Sumps - 2nd Stage Feed	
4,000 gallon - 1/4 Inch Steel	
2 @ $10,000 each	20,000
Sumps - 2nd Stage Heavy Media	
4,000 gallon - 1/4 Inch Steel	
2 @ $14,000 each	28,000
Sumps - 2nd Stage Dilute Media	
3,000 gallon - 1/4 Inch Steel	
2 @ $14,000 each	28,000
Sumps - Hydrocyclone Feed Sumps	
9,000 gallon - 1/4 Inch Steel	
2 @ $10,000 each	20,000
Sumps - Refuse Centrifuge Effluent Sumps	
2,500 gallon - 1/4 Inch Steel	
2 @ $10,000 each	20,000
Sumps - Table Feed	
3,000 gallon - 1/4 Inch Steel	
2 @ $10,000 each	20,000
Sumps - Other	
7 @ $10,000 each	70,000
Pumps	200,000
Total Preparation Plant Equipment Cost	$2,616,600

Total Cost of Preparation Plant	
Including Site Preparation, Construction of Building, Electrical Service, Piping, etc.	
$2,616,600 X 3.0	$7,849,800
OTHER FACILITIES & EQUIPMENT:	
Fluid-Bed Thermal Dryers - 2	
Complete with structural steel, motors, motor controls, wiring, piping, field erection, and start-up service	5,400,000
Static Thickeners - 2	
Each 135 feet in diameter @ $2,000 per foot	540,000
Refuse Belt	
36 Inch Wide - 200 feet @ $480 per foot	96,000
Refuse Bins	
2 - 100 ton capacity - fabricated part	100,000
Refuse Handling Equipment	
2 - Trucks @ $ 75,000 each	150,000
2 - Dozers @ $150,000 each	300,000
Coal Sampling System	300,000
Clean Coal Belt to Silo	
48 Inch Wide - 200 feet @ $560 per foot	112,000
Clean Coal Silo	
15,000 ton capacity @ $110 per ton	1,650,000
Unit-Train Loading Facility	500,000
Total Other Facilities & Equipment	$9,148,000

SUMMARY OF CAPITAL COST:

Raw Coal Storage and Handling	$ 1,190,000
Preparation Plant	7,850,000
Other Facilities and Equipment	9,148,000
Contingency (Interest during construction, etc.)	2,728,000
Total Capital Requirement	$20,916,000

BASED UPON THE 900 TONS PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO APPROXIMATELY $23,200 PER TON HOUR INPUT

5.8.2 Capital Amortization

Based upon the rationale developed in Section 4.0, the capital amortization for Example 8 is as follows:

Total Capital Required: $20.9 Million

Capacity:

Raw Coal Input - 900 tph

Clean Coal Output - 774 tph

CAPITAL AMORTIZATION

Amortization Period & Basis	% Utilization 30%	40%	50%
10 Year Period			
Per Ton of Raw Coal	$1.36	$1.01	$0.81
Per Ton of Clean Coal	$1.58	$1.17	$0.94
15 Year Period			
Per Ton of Raw Coal	$1.09	$0.81	$0.65
Per Ton of Clean Coal	$1.26	$0.94	$0.75

5.8.3 Operating and Maintenance Costs

The operating and maintenance costs summarized in the following Table 5-45 are based upon:

- o Raw Coal Input of 900 Tons Per Hour
- o Clean Coal Output of 774 Tons Per Hour
- o Btu Recovery of 94.3%
- o 10 Year Amortization Period
- o 50% Utilization 4,380 Operating Hours Per Year out of a Possible 8,760 Hours or 17.5 Hours Per Day for 250 Days Per Year.

TABLE 5-45

EXAMPLE 8 - HEAVY MEDIA PROCESS - COMPLEX
OPERATING AND MAINTENANCE COSTS

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$0.035	$0.041
Operating & Maintenance (Union)	0.267	0.310
Overhead -		
Includes Payroll Taxes, Vacation and Holiday Pay, Welfare Fund, Taxes, Insurance, etc.	0.196	0.228
Supplies -		
Operating	0.249	0.290
Maintenance - Includes Scheduled Major Repair and Replacements	0.529	0.615
Thermal Dryer Fuel - Based upon 12.5 Tons/Hr Coal Consumption and Cost of Coal $20/Ton	0.278	0.323
Electricity	0.456	0.53
Other	0.087	0.101
O & M Cost - Not Including Capital Amortization	$2.10	$2.44
Capital Amortization - 10 Yrs. - 50% Utilization	0.81	0.94
Total Operating & Maintenance Cost	$2.91	$3.38
Cost Per Million Btu (12,473 Btu/lb)		$0.135

5.8.4 Discussion of Performance and Cost

The Example 8 plant is simply a two stage heavy media cyclone process with limited use of Deister tables. As indicated by the performance data summarized in Table 5-39, it has the potential for high Btu recovery by crushing the underflow from the first stage cyclones and subjecting it to another round of cleaning.

Of the heavy media processes presented in this study, others show more dramatic reductions in ash and sulfur than occurs with the coal currently being treated by the Example 8 plant. However, as we know, the results achieved by a given preparation process vary with the feed to the plant and this raw coal is not particularly high in ash or sulfur. Therefore, the purpose of presenting this plant is to give further understanding of capital and operating and maintenance costs for a larger heavy media plant which is capable of achieving significant reductions in both ash and sulfur. A further reason for presenting this plant is to show the favorable cost impact of increasing utilization to 50%. This plant is capable of operating over 50% of the time by virtue of its parallel circuit design. Although this increases the initial capital requirement, it is justified by the greater output which permits a lower per unit allocation of fixed charges.

Besides the parallel circuitry, necessitating redundant equipment, the thermal drying of all clean coal produced increases this plant's capital cost. However, due to the high percentage of fines, thermal drying is required.

Looking at the total producer's cost of preparation summarized on the preceding Table, it is clear that, in spite of the high capital requirement, the cost per ton of clean product is substantially less than some smaller heavy media plants. This lower cost is directly attributable to the plant capacity and greater utilization mentioned above. For example, if this plant was operated only 30% of the time there would be nearly a 20% increase ($0.64) in the cost of each clean ton resulting from higher capital amortization alone, not to mention the impact on other fixed charges.

With the raw coal currently being handled by this plant, the process yields a 94.3% Btu recovery. Therefore, it would seem inappropriate to apply an additional cost to cover these "lost" Btu's. However, if such a charge is applied, the total cost of cleaning increases by $0.039 to $0.174 per million Btu.

In conclusion, the reader is reminded that the operating and maintenance costs presented herein are those experienced by the producer. As stated earlier, the clean product carries with it various benefits which are reflected in lower costs to the user which go to reduce the overall net cost of coal preparation.

5.9 SUMMARY OF PREPARATION PROCESS EXAMPLES

Table 5-46 on the following page gives a tabular summary of the major performance and cost elements from the eight actual operating preparation plants examined in Section 5.0.

TABLE 5-46

SUMMARY OF PREPARATION PROCESS EXAMPLES[1)]

Example	Process/Level	Input Capacity	Capital Cost Per Ton Per Hr. Input	Clean Coal Output	Btu Recovery	Operating and Maintenance Cost[2)]		
						Per Ton Raw Coal	Per Ton Clean Coal	Per Million Btu[3)]
1	Jig/Simple	600 tph	$ 6,600	354 tph	91.6%	$1.97	$3.35	$0.138
2	Jig/Intermediate	1000 tph	$ 13,700	714 tph	96.4%	$2.62	$3.67	$0.152
3	Jig/Intermediate	1000 tph	$ 12,100	566 tph	83.0%	$2.22	$3.92	$0.157
4	Jig/Complex	1600 tph	$ 14,300	953 tph	93.7%	$2.60	$4.36	$0.162
5	Heavy Media/Simple	1400 tph	$ 13,800	1,036 tph	94.6%	$2.79	$3.76	$0.185
6	Heavy Media/Complex	600 tph	$ 22,400	440 tph	89.2%	$3.54	$4.83	$0.177
7	Heavy Media/Complex	600 tph	$ 14,000	360 tph	93.1%	$2.09	$3.48	$0.137
8	Heavy Media/Complex	900 tph	$ 23,200	774 tph	94.3%	$2.91	$3.38	$0.135

1) All cost figures as of mid-1977

2) Includes capital amortization

3) Does not include allowance for Btu loss of Process

SECTION 6.0

FUTURE PROSPECTS FOR COAL PREPARATION

6.0 FUTURE PROSPECTS FOR COAL PREPARATION

It is the opinion of the author, that there is a significant potential for larger centralized preparation plants fed by more than one mine thereby capable of operating almost continuously. To accomplish this in some areas would necessitate cooperative agreements between smaller producers to assure round-the-clock availability of plant feed. Additionally, the plant would have to be laid out in such a manner to permit parallel circuits or at least redundancy of higher maintenance equipment. Due to union restrictions, overtime would be a recurring cost factor. However, such a cost would more than be covered by the increased output and efficiency of such an arrangement.

As expressed in a recent EPRI report, "The technological factors that will contribute to the increasing use of preparation for power coals are the advance of nonselective and continuous types of mining equipment; problems associated with the use of high ash, high sulfur, and alkali content coal in the boilers; and the expensive and uncertain performance of flue gas desulfurizers".*

Indications are clear that an increasing percentage of utility coals will be cleaned. This is being brought about by such factors as:

1) Emission Standards - Getting Tougher
   Coal Prep Can Eliminate or Reduce FGD costs and Associated Operational Problems
2) Economic Pressures -
   Greater Heat Content Per Unit Weight
   Reduced Boiler Maintenance
   Price of Higher Quality Coal

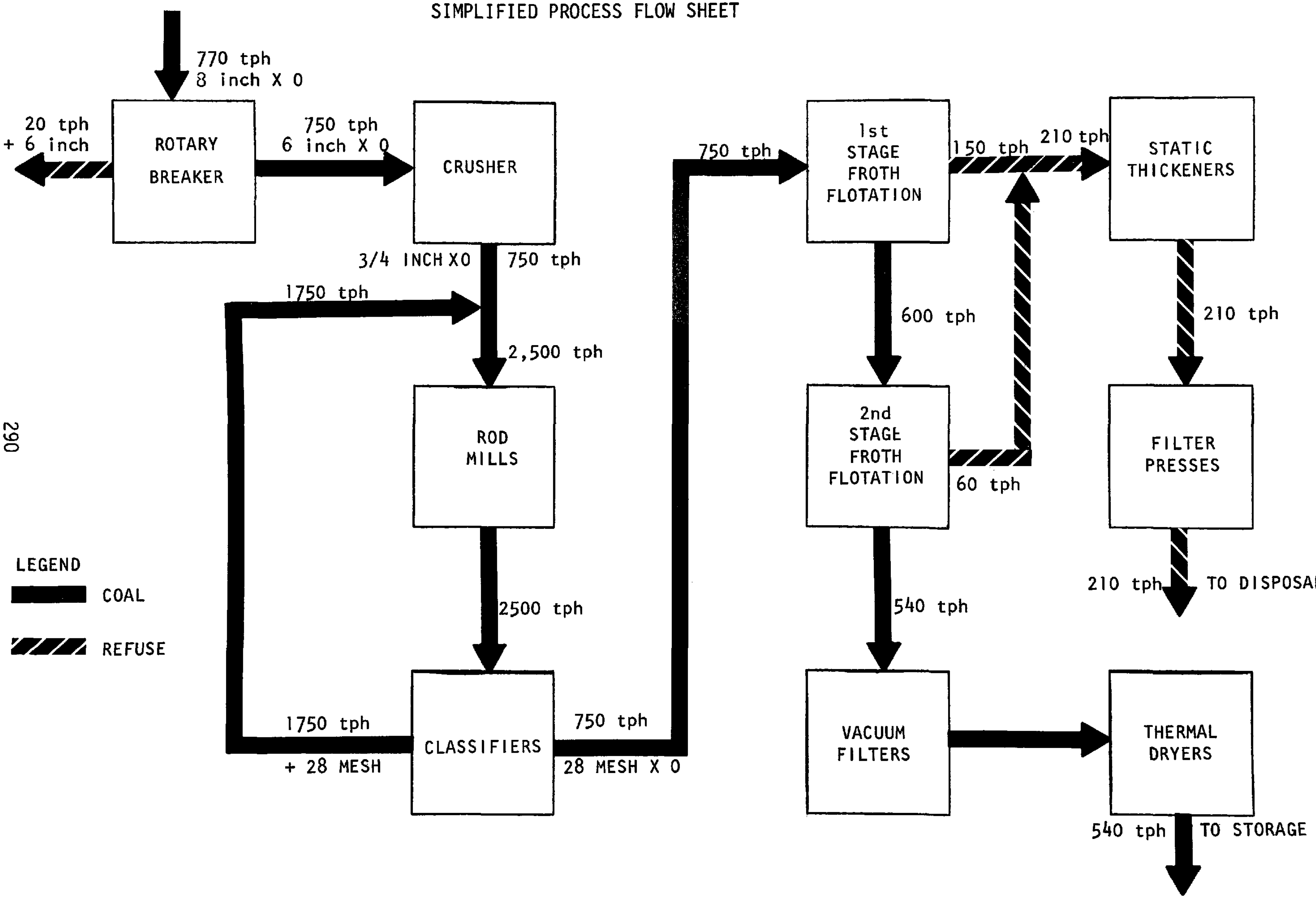
*From: Physical Coal Preparation, EPRI FP-314, May 1977, page 3-1

In order to cost-effectively meet this increase in demand brought on by these tougher emission standards and increasing economic pressures, coal preparation processes will have to be designed around maximizing Btu recovery while substantially reducing the ash and pyritic sulfur contents. One approach to meeting this design objective might be an all flotation process of the general configuration presented in Figure 6-1. In this hypothetical approach, the 8 inch X 0 run-of-mine coal would be fed to a rotary breaker where the initial size reduction and removal of harder refuse would occur. From the rotary breaker, the 6 inch X 0 raw coal would go to a crusher for reduction to 3/4 inch X 0 before going to a rod mill for final reduction to 28 mesh or less. To minimize the creation of fines, the rod mill would be operated in such a manner to avoid over-grinding. This being the case, a significant portion of the product from the rod mill would be plus 28 mesh. By using a classifier and re-circulating the oversize product, as shown in Figure 6-1, only 28 mesh X 0 would be fed to the first stage froth flotation cells. The froth collected from the first stage flotation would be fed to second stage froth flotation cells, where further cleaning would occur. The reject from both stages of flotation would go to static thickeners. Since the underflow from the static thickeners would be comprised of a high percentage of very fine particles, it would have to be pumped to filter presses for dewatering before disposal. The product from the second stage flotation cells would be partially dewatered by vacuum disc filters and then further dried by a disc or other indirect type thermal dryer. A fluid-bed thermal dryer could not be used under these conditions due to the fine nature of the clean coal. Currently, most of the indirect type thermal dryers available are constructed on a small scale and

FIGURE 6-1

HYPOTHETICAL FLOTATION PLANT WITH FINE REFUSE DISPOSAL

SIMPLIFIED PROCESS FLOW SHEET



use oil as the heat source. However, as high volume drying operations of the type required by this hypothetical plant become more common, larger scale units using coal fired boilers should become available. Although the capital cost will not be influenced to any significant degree, the fuel consumption cost should be cut in half.

Based upon late-1977 equipment and construction prices, a plant of this general make-up and capacity would require an initial capital investment of approximately $38 million dollars. A rough breakdown of this estimated capital cost is presented in Table 6-1. The personnel necessary to operate and maintain a plant of this type would not vary substantially from that required in a comparable capacity heavy media facility with thermal drying. Assuming this 750 tph input plant, producing 540 tph of clean coal, was utilized at least 40% of the time and achieved a 96% Btu recovery, the operating and maintenance cost including capital amortization would be just under $8.00 per ton of clean product. Based upon a clean coal (10-12% moisture) having a thermal content of 13,500 Btu per pound, this equates to approximately $0.30 per million Btu. The major components of this estimated O & M cost are listed in Table 6-2. This total O & M cost is greatly influenced by the high capital and power costs of the fine clean coal and refuse dewatering equipment. Additionally, the fine grinding of the entire plant feed contributes significantly to the overall cost of such a plant.

Since all the clean coal produced by this process would be of a fine size, transportation and handling would present problems. Therefore, a fine cleaning plant of this type might be most appropriately located adjacent to the using power plant or the clean coal transported pneumatically.

TABLE 6-1

HYPOTHETICAL FLOTATION PLANT
WITH FINE REFUSE DISPOSAL
PREPARATION PLANT CAPITAL REQUIREMENTS

RAW COAL STORAGE AND HANDLING:		
Raw Coal Storage Area		$ 300,000
Raw Coal Belt To Breaker		
42 Inch Wide - 200 Feet @ $520 per foot		104,000
Tramp Iron Magnet		20,000
Rotary Breaker including structural work		250,000
Raw Coal Belt To Plant		
42 Inch Wide - 300 Feet @ $520 per foot		156,000
Total Raw Coal Storage & Handling Cost		$ 830,000
PREPARATION PLANT:		
Crusher -	$ 90,000	
Rod Mills		
4 @ $395,000	1,580,000	
Classifiers		
4 @ 40,000	160,000	
Conditioning Tanks	150,000	
1st Stage Froth Flotation Cells		
10 Banks of 5 cells		
10 @ $65,000	650,000	
2nd Stage Froth Flotation Cells		
8 Banks of 5 cells		
8 @ $65,000	520,000	

Vacuum Filters		
12 feet 6 inch diameter, 15 discs		
7 @ $150,000	$ 1,050,000	
Pumps	200,000	
Total Preparation Plant Equipment Cost	$ 4,400,000	
Total Cost of Preparation Plant		
Including Site Preparation, Construction of		
Building, Electrical Service, Piping, etc.		
$4,400,000 X 3.0		$13,200,000
OTHER FACILITIES		
Static Thickeners		
200 Foot diameter - concrete		
2 @ $2,000 per foot of diameter		800,000
Filter Presses		
7 @ $275,000 (basic equip. Cost)		
7 X 3 X $275,000		5,775,000
Thermal Dryers		
Indirect Disc Type		
(60 tph $1,200,000 full price)		
9 X $1,200,000		10,800,000
Clean Coal Silo		
10,000 Ton Capacity @ $110 per ton		1,100,000
Clean Coal Belt To Silo		
42 Inch Wide - 200 feet @ $520/ft		104,000
Total Other Facilities & Equipment		$18,579,000

SUMMARY OF CAPITAL COST

Raw Coal Storage and Handling	$ 830,000
Preparation Plant	13,200,000
Other Facilities and Equipment	18,579,000
Contingency (Interest during construction, etc.)	4,891,000
Total Capital Requirement	$37,500,000

BASED UPON THE 750 TONS PER HOUR INPUT TO THIS PLANT THE CAPITAL REQUIREMENT TRANSLATES TO $50,000 PER TON HOUR INPUT

TABLE 6-2

HYPOTHETICAL FLOTATION PLANT WITH FINE REFUSE DISPOSAL OPERATING AND MAINTENANCE COSTS*

COST CATEGORY	Per Ton Raw Coal	Per Ton Clean Coal
Labor -		
Supervisory (Non-Union)	$ 0.04	$ 0.06
Operating & Maintenance (Union)	0.27	0.38
Overhead -		
Includes Payroll Taxes, Insurance, Welfare Fund, Vacations, Holidays, etc. for all Preparation Plant Employees	0.20	0.28
Supplies		
Operating	0.25	0.35
Maintenance - Repair Parts and Materials Associated with Routine Maintenance	0.60	0.83
Thermal Dryer Fuel -		
Based upon 2600 gal/hr Fuel Oil Consumption and Cost of Oil @ $0.32/gal	1.11	1.54
Electricity	1.00	1.39
Other Expenses	0.10	0.14
O & M Cost -		
Not Including Capital Amortization	$3.57	$4.97
Capital Amortization -		
10 Yrs. - 40% Utilization	2.18	3.02
Total Operating & Maintenance Cost	$5.75	$7.99
Cost Per Million Btu (13,500 Btu/lb)		$0.30

*Extrapolated from comparable capacity heavy media plant allowing for significantly greater power consumption

Another procedure, which would significantly reduce the capital and operating costs of the plant by eliminating the expensive drying capacity, might be to transport the product via slurry pipeline to the utility plant. If the product was to be transported by conventional means, it would be necessary to consolidate the coal into pellets or briquettes to improve its handling properties. Such additional processing capability would slightly increase the total cost of preparation. However, the selection of this or any other transportation approach could only be made after a careful evaluation of the overall economics of the specific situation.

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16. ABSTRACT - This report presents a discussion of the major physical coal preparation processes currently available and the equipment used by each to effect a separation of the coal from the undesirable constituents such as ash and pyritic sulfur. Further, eight specific examples of a wide range of actual preparation plants are examined from the standpoint of capital and operating and maintenance costs to develop a total cost of coal cleaning for each plant. The preparation plants examined were all operating as of mid-1977 and span a spectrum of cleaning processes from a relatively simple jig plant to rather sophisticated circuits utilizing heavy media, froth flotation, and thermal drying.

For the particular plants considered by this study, there was a range of cleaning costs from over $3.00 to nearly $5.00 per ton of clean coal produced. These costs are especially sensitive to the make-up and performance of the cleaning circuit in addition to the manner in which it is being operated. In this latter regard, plant utilization can be a significant factor since it influences the output over which the fixed costs are amortized. As evidenced by most of the preparation plants examined, many coal cleaning facilities operate only 30% of the time, thereby experiencing a relatively high capital burden per ton of clean product. To alleviate this problem, one of the example preparation plants was designed to include parallel cleaning circuitry with significant amounts of redundant equipment. Such plant configuration, permits maintenance without shutting down the entire facility.

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