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INTEGRATED COAL PREPARATION AND CWF PROCESSING PLANT

CONCEPTUAL DESIGN AND COSTING

Final Technical Report
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Edward T. McHale
Anton D. Paul
James T. Bartis

Muharrem Korkmaz
(Roberts & Schaefer Company)

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EXECUTIVE SUMMARY

At the request of the U.S. Department of Energy (DOE), Pittsburgh Energy Technology Center, a study was conducted to provide DOE with a reliable, documented estimate of the cost of producing coal-water fuel (CWF). The approach to the project was to specify a plant capacity and location, identify and analyze a suitable coal, and develop a conceptual design for an integrated coal preparation and CWF processing plant. Using this information, a definitive costing study was then conducted, on the basis of which an economic and sensitivity analysis was performed utilizing a financial evaluation model to determine a price for CWF in 1992.

The design output of the integrated plant is 200 tons of coal (dry basis) per hour. Operating at a capacity factor of 83 percent, the baseline design yields approximately 1.5 million tons per year of coal on a dry basis. This is approximately equivalent to the fuel required to continuously generate 500 MW of electric power. The design and costing are based on a battery-limit integrated plant located at or near a coal mine site. It is assumed that roads, rail lines, electric service, water access, auxiliaries, etc., are available. CWF can leave the plant by rail, barge or pipeline. Costs for off-site disposal of dewatered refuse are included in the final cost figure.

The CWF produced by the plant is intended as a replacement for heavy oil or gas in electric utility and large industrial boilers. The particle size distribution, particularly the top size, and the ash content of the coal in the CWF are specified at significantly lower levels than is commonly found in typical pulverized coal grinds. The particle top size is 125 microns (vs. typically 300mμ for pulverized coal) and the coal ash content is 3.8 percent. The lower top size is intended to promote complete carbon burnout at less derating in boilers that are not designed for coal firing. The reduced mineral matter content will produce ash of very fine particle size during combustion, which leads to less impaction and reduced fouling of tubes in convective passages.

The plant design is based on a specific eastern high volatile A bituminous coal; namely, the No. 2 Gas seam, of which there are enormous reserves. Presently, production from this seam is about 5 million tons/year. With the cooperation of Peabody Coal Company, drum quantities of run of mine (ROM) samples were obtained and screened, milled, and analyzed for float/sink and froth flotation properties. Based on these results, a highly efficient coal preparation process was designed. The coal preparation circuits involve skimming off a high quality coarsely-sized product, crushing middlings to minus 1/4 inch, and cleaning all fines using Microcel™ column flotation. Since the final product is a slurry, extensive fines processing can be accomplished at reasonable cost because dewatering requirements are minimal and coal drying is not required. Consequently, advanced coal preparation methods for cleaning coal fines integrates well with CWF production.

The CWF production portion of the plant is based on a staged milling process to efficiently produce a fluid, stable slurry. The sizing, power draws and costs of the grinding mills were provided by Allis Mineral Systems, who have experience with milling of coal under the unique conditions necessary to produce a high quality CWF. The cost for CWF additives, which represents the largest cost element in the total product price, was obtained from vendor quotes.

Following the conceptual design of the integrated plant, Roberts & Schaefer Company was engaged to provide estimates for the capital costs, labor, operating and maintenance supplies, and consumables. The Roberts & Schaefer Company is a construction and engineering firm that is highly experienced in design, costing, and construction of coal preparation facilities. A summary of the cost elements in the pricing of the CWF is tabulated below.

Item	Cost	$/hour	$/ton coal	$/MMBtu
Investment Capital	$42,200,000	-	-	-
Working Capital	$2,005,000	-	-	-
Labor	$4,760,000/yr	652	3.26	0.11
Electricity	$4,816,000/yr	660	3.30	0.11
Reagents	$12,434,000/yr	1704	8.52	0.29
Other O&M	$2,897,000/yr	397	1.99	0.07
Btu Loss	$4,962,000/yr	680	3.40	0.11

In the above listing, Other O&M includes property tax, insurance and maintenance supplies. Btu loss refers to the loss in combustible matter as a result of beneficiating the feed coal.

Based upon these cost elements, the annualized cost of CWF in 1992 dollars is estimated at $1.84 per MMBtu. This cost estimate includes a feedstock coal cost (mine mouth, pre-cleaned) of $1.00/MMBtu in 1992 dollars, and is based on a 20-year plant life, with a constant inflation rate of 4 percent per annum over the life of the plant, 100 percent equity investment (as opposed to debt financing) and a 15 percent nominal after-tax internal rate of return on investment.

Design and construction of coal preparation facilities are mature, state-of-the-art operations and represent minimal project risk. The major uncertainty is associated with the design of the CWF portion of the integrated plant, particularly the sizing of the grinding mills. Accordingly, the estimate of capital investment includes a very conservative contingency of 30 percent. An analysis of the sensitivity of the cost to variations in individual cost elements was also performed.

ACKNOWLEDGEMENT

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1.0 INTRODUCTION

This study was undertaken for the purpose of providing the U.S. Department of Energy with a reliable estimate of the cost of coal-water fuel (CWF) and of documenting the basis for the estimation. The approach to the project was to specify a plant capacity and location, identify and analyze a suitable coal, and develop a conceptual design for an integrated preparation and CWF processing plant. Using this information, a definitive costing study was then conducted by the engineering firm, Roberts & Schaefer Company. On the basis of their results, an economic and sensitivity analysis was performed utilizing a financial evaluation model to determine what CWF would cost in 1992.

The scale of the coal preparation and CWF plant design chosen for the study is 200 tons per hour coal output on a dry basis (285 tph CWF). The baseline case assumes round-the-clock operation with an annual operating capacity of 83 percent, corresponding to 166 tph dry coal average output or about 1.5 million tons per year. This is equivalent to the energy required to fuel approximately 500 MW of continuous electric generating capacity. (Other approximate equivalencies are 27,000 barrels per day of CWF or three unit trains per week of CWF delivery.) It is possible that some economy of scale could be realized if the design were based on a larger plant. This would be modest, however, and would be derived mainly from the preparation plant since the equipment specified for CWF processing is about the maximum from which economies of scale can be obtained.

The design and costing are based on a battery-limit, integrated plant located at or near a coal mine site. As such, it is assumed that roads, rail lines, electric service, water access, auxiliaries, etc., will be available. Also, no provision is made for raw coal storage, since coal storage is assumed to be part of the mining operation. CWF delivery can be by rail, barge or pipeline. The normal operating mode is assumed to be out-loading of CWF directly into unit trains made up of rail tank cars. Storage is provided for two days production of CWF.

Costs for off-site disposal of dewatered refuse are included in the final cost figure. The waste stream will contain mineral matter and a smaller amount of combustible material of the mined coal. In addition there will be minor amounts of the reagents used in the preparation process, all of which are now employed in coal beneficiation operations. There are no problems anticipated in disposing of the plant refuse by means conventionally practiced at coal mine sites.

The CWF type at which the study was directed is a boiler grade fuel intended to be burned in utility or large industrial units. The particle size distribution, particularly the top size, and the ash content of the coal in the CWF were specified at significantly lower levels than is commonly found in present pulverized coal grinds for similar application. The rationale for the lower top size of particles in the CWF is that this will promote complete carbon burnout at less derating in boilers that are not designed for coal firing. The assumption is made that atomizer technology will advance adequately to provide spray droplet sizes sufficiently small to fully take advantage of the finer coal particle size distribution. The top size of present pulverized coal grinds is about 300 microns. While it is established in the technical literature that finer coal particles require shorter residence times for burnout, there can be no definite predetermined size specification for a generic CWF as is being considered here because furnace volume and radiant characteristics will vary. Accordingly, a somewhat arbitrary top size limit was selected; namely, 125 microns.

The ash content for the cleaned coal can be specified with more certainty. The main objective of a lower ash level is to minimize deposit formation in convective tube banks. The technical literature and discussions with combustion technologists investigating this subject have revealed that there is a substantial decrease in deposits when ash levels in coal are reduced to somewhere in the 3-5 percent range[1]. The reason for the deposit drop-off with ash reduction is that the ash particle *size* decreases with decreasing quantity of ash, which in turn leads to less impaction of tubes because the finer ash particles with their lower inertia tend to follow gas flow through the convective passages.

The mechanism leading to finer ash particles at lower ash levels has been reasonably well established[2,3,4]. At moderate to high concentrations of mineral matter, each coal particle (or in the case of CWF, each droplet) gives rise, upon combustion, to a single ash particle. Most of the small mineral matter particles within the coal particle (or CWF droplet) coalesce into this single ash particle during burnout of the coal char. Accordingly, deeper cleaning of coal produces particles (or CWF droplets) with less total ash, so that the size of the final ash particle is finer. There is also a second important effect which occurs as ash levels fall to approximately 3 to 5 percent. During coalescence, higher quantities of mineral matter tend to impart mechanical integrity to char particles (cenospheres), which allows them to burn out intact as individual particles. At low ash levels this mechanism cannot operate effectively because the separation between mineral matter particles is too great; hence, char particles tend to fragment during burnout, thus producing even finer ash. It is desirable to clean coal deeply enough to reach the regime where fine ash particles are released during combustion, and accordingly the specification for the preparation plant design was set at 3-5 percent coal ash. The actual value realized in the preparation plant design is 3.7 percent.

2.0 PROJECT APPROACH

The integrated plant design is based on a high volatile A bituminous coal from an extensive seam in West Virginia. The overall approach to the study was to identify the coal, obtain samples for relevant analyses and develop quantitative, conceptual process flow diagrams. Vendor data for the size and cost of major equipment were then obtained. Finally an architectural and engineering firm (Roberts & Schaefer Company) was engaged to perform a detailed process review and definitive costing, including total capital, construction and operating and maintenance costs.

A coal-water fuel form affords the perfect opportunity to utilize advanced physical methods of beneficiation to deep clean coal. Deep cleaning requires processing relatively large amounts of coal fines, as compared to conventional coal cleaning. Normally, these coal fines would need to be dewatered and subjected to thermal drying, both of which are relatively expensive operations. However, since the final product is a CWF, the dewatering operation is minimized and thermal drying is unnecessary. Thus, by combining beneficiation and CWF formulation in a single plant, significant cost savings accrue because of the reduction or elimination of these important unit operations.

For cleaning fines, the coal preparation plant design includes column flotation circuits. Column flotation was selected since this technology allows more efficient recovery as compared to conventional methods of cleaning coal fines. Primary emphasis was given to ash reduction, since the coal chosen for the present design is fortuitously low in sulfur.

2.1 Coal Selection and Analysis

Using the Keystone Coal Industry Manual and other available sources, a review of coals of Pennsylvania, Virginia, West Virginia and eastern Kentucky was conducted. There are innumerable seams in these states with coal of acceptable cleaning and slurrying properties; however, all the data that one would like to have to make an appropriate choice are often not readily available (data such as cleanability and grindability properties). Accordingly, the initial selection was based heavily on proximate analyses and on current availability and total reserves of the coal. The coal chosen was a high volatile A bituminous from No. 2 Gas seam (*aka* Campbell Creek seam) mined by Peabody Coal Company in Montcoal, West Virginia. Total annual production of No. 2 Gas coal is close to five million tons, with about 1.4 million tpy output from the Montcoal complex. Total seam reserves are estimated at eight billion tons (original minable tonnage.) A tour of the Montcoal mine site and the cleaning facility was arranged by Peabody. This coal is typically cleaned to about 5 percent ash by physical methods, including froth flotation, and sold as steam coal, although it is of metallurgical quality. It was arranged for drum quantities of ROM coal to be sampled and shipped for analysis by Commercial Testing and Engineering (CT&E), a major coal testing laboratory.

A regimen of tests was developed involving screening, float/sink, grinding, etc., that provided the data necessary to prepare the process flow diagrams for the preparation plant and to compute mass balances. This was an interactive process in that a process flow diagram would be developed on the basis of laboratory results, from which further lab testing would be defined, the results of which produced an improved plant design, and so forth. A similar procedure was followed for the design and sizing of the column flotation circuits, which was performed with major assistance from the Virginia Center for Coal and Mineral Processing at the Virginia Polytechnic Institute and State University (VPI). The results of the CT&E and VPI analyses are collected in Appendices A and B. Listed below in Table 1. are typical proximate analyses of No. 2 Gas coal.

Table 1. Typical Proximate Analyses No. 2 Gas Coal (Dry Basis)

PROPERTY	ROM	PEABODY COMMERCIAL PRODUCT
% ASH	40.0	5.0
% VOLATILE MATTER	23.0	32.0
% FIXED CARBON	37.0	63.0
% SULFUR	0.7	0.8
HHV BTU/LB	8,830	14,800

2.2 Design Methodology

2.2.1 Preparation Plant

The methodology that was required in designing the coal preparation plant was driven by the factors listed below, some of which are common to general beneficiation processes and others of which are unique to the present CWF application:

- Product ash content of 3-5 percent (2-3 lb/MMBtu)
- High Btu recovery
- Minimum grinding of mineral matter
- Minimum coal throughput to flotation circuits
- Readily dewaterable product
- Coal Washability Characteristics

A discussion follows of each of these factors and its role in guiding the preparation plant design.

A product ash level of 3-5 percent is desirable in order that the ash resulting from coal combustion have a sufficiently fine particle size distribution. Extremely small ash particles will follow the gas flow in the convective section of a boiler, thereby minimizing tube erosion and deposition. To achieve simultaneously a low ash level and a high Btu recovery, it is necessary to subject a portion of the coal to finer grinding in order to liberate mineral matter. Coal comminution is ordinarily avoided in preparation plant operations because fines are difficult to handle and to market. However, in the present case the final product is to be a coal-water fuel in which the coal will ultimately be milled to a very fine size consist. Accordingly, it is far less disadvantageous, both operationally and economically, to introduce grinding into a beneficiation process that is an integrated precursor to CWF processing.

The ROM coal feed to the preparation plant is 40 percent ash by weight. Grinding such a high ash feed will incur operational and maintenance costs that can be avoided by first subjecting the ROM material to a high specific gravity separation. The resulting product is greatly reduced in mineral matter content. The other constraint on the preparation plant grinding is that it is considered good practice to minimize the throughput to flotation circuits, inasmuch as this type of beneficiation process is more costly than alternative gravity-based methods such as cycloning or jigging. Hence, to the greatest extent possible, conventional coal cleaning methods are utilized ahead of fine grinding and flotation.

A further consideration that imposes limitations on the grinding is that the products leaving the various cleaning circuits must be dewatered to some extent prior to being milled into CWF. Accordingly, there is a trade-off to be observed between retaining relatively coarse, more easily dewatered material and finer ground coal that has mineral matter liberated but is more difficult to dewater.

Lastly, the inherent washability characteristics of the ROM coal fractions and their separation products throughout the beneficiation process are fundamental driving factors in the design. It is apparent from the float/sink analysis for flowstreams 2 and 6 of Figure 1, summarized in Table 2, that this particular coal contains a large fraction of low gravity material, another large fraction of high gravity material and a very small amount of middlings. It is evident that initial separation at relatively high specific gravity will remove substantial amounts of mineral matter from the incoming coal. The refuse from a 1.7 sp. gr. separation will actually consist of about 86 percent mineral matter.

Table 2. Summary of Composite Float/Sink Data for Two Fractions of Incoming ROM Coal

SPECIFIC GRAVITY		2½" x ¼" FRACTION	
SINK	FLOAT	WEIGHT %	% ASH
-	1.4	19.5	4.4
1.4	1.7	2.2	22.7
1.7	-	28.1	89.0

SPECIFIC GRAVITY		¼" x 28M FRACTION	
SINK	FLOAT	WEIGHT %	% ASH
-	1.4	23.1	3.0
1.4	1.7	1.3	23.4
1.7	-	9.5	88.9

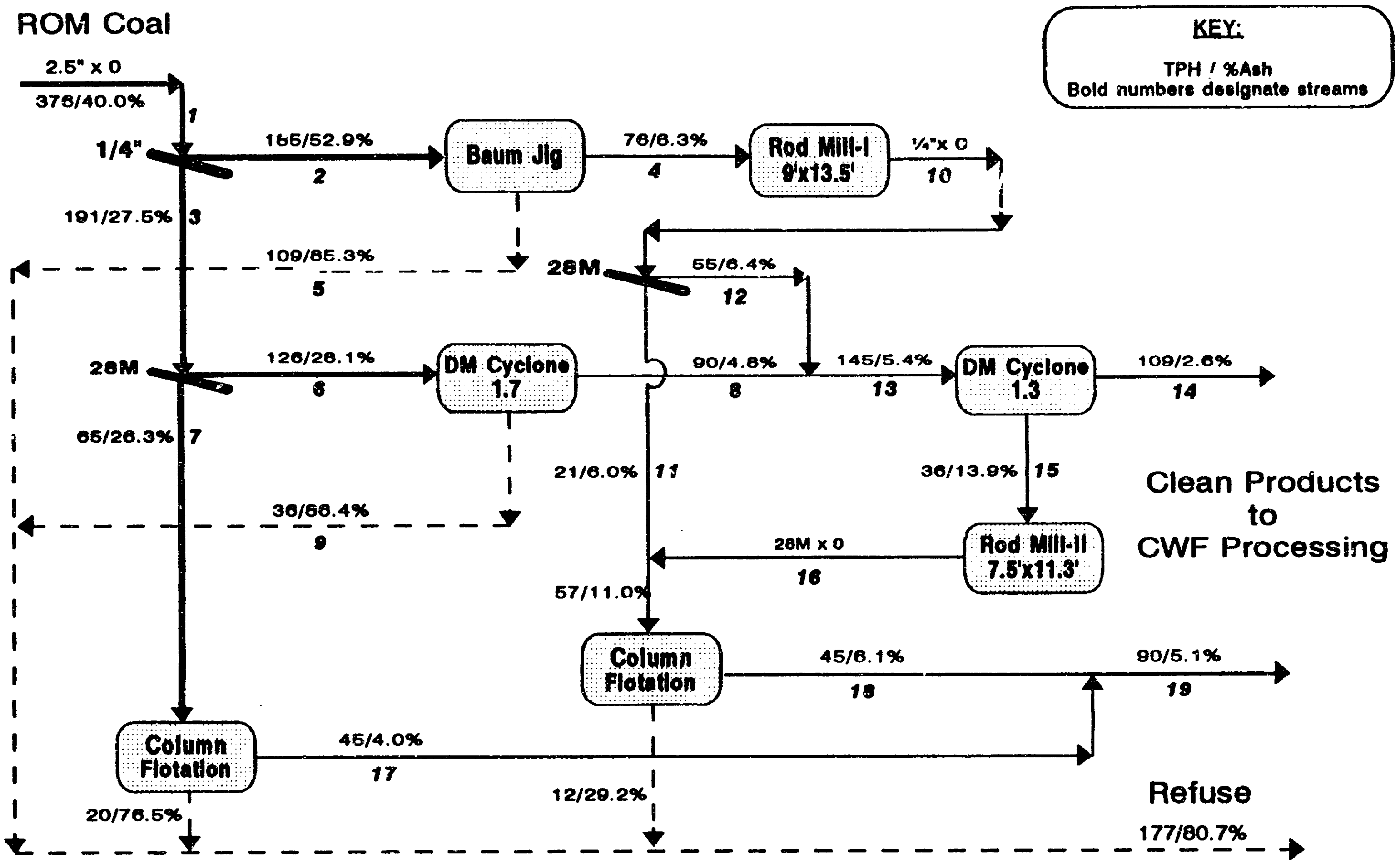

FIGURE 1. Coal Preparation Flowsheet

The foregoing principles were applied in the design of the coal preparation plant, shown conceptually in Figure 1. The mass balances shown in this schematic were developed by utilizing the laboratory analyses of the coal fractions (screening, float/sink, grinding) and a computer program that simulates coal preparation operations[5]. This computer code provides an approximation to practical plant performance for each unit operation.

Referring to Figure 1, ROM coal is first screened at ¼" and the undersize is further screened at 28 mesh (600 microns, Tyler designation). The ¼" size was selected because screening efficiency is highest when the screen size is close to the D_{50} of the material consist (see Table 3), and in combination with the 28M screen provides the same size ratio (approximately 10:1) of material to both the Baum jig and the 1.7 sp. gr. cyclone. The 28M × 0 fraction is then diverted to the flotation circuit.

Table 3. Screen Analysis of ROM Coal

PASSING	RETAINED	WEIGHT %
2½"	1"	16.6
1"	½"	16.5
½"	¼"	16.6
¼"	28M	33.9
28M	0	16.4

Following the Baum jig, the 2½" × ¼" material is milled to ¼" × 0 to liberate additional mineral matter. Float/sink tests and proximate analyses showed that this grinding operation produced a significantly lower-ash product out of the 1.3 sp. gr. cyclone, although carbon recovery was not improved. The 28M screening following the first rod mill is intended to separate fines for flotation prior to sending the larger size ¼" × 28M fraction to the 1.3 sp. gr. cyclone. The reject stream from the 1.3 sp. gr. cyclone is further milled and sent to flotation, because testing showed that additional recovery of low-ash product was achievable.

Column flotation cells were specified for processing the fine (28M × 0) coal streams in this preparation plant design. Column flotation represents an advanced method of beneficiation for fine material that is widely used in the mineral industry and is currently being introduced into the coal industry. Employing a counter-current water wash, column flotation is superior in performance to conventional froth flotation in cases where very fine particles (< 100M × 0) are to be processed. Screen analysis (Appendix B) showed that the product from the rod mill contained approximately 70 percent finer than 100 mesh. The column cells were sized by VPI based on their engineering experience with these units, and the performance determined from release data that were experimentally measured by them.

2.2.2 CWF Plant

Coal-water fuel can be produced by any of several methods: (1) "single-step," in which the exact required amounts of coal, water and additives are charged to a media mill (such as a ball mill or stirred vertical mill) and grinding is performed under viscous conditions; (2) "bimodal," in which part of the coal is milled either dry or wet (dilute or viscous) to a coarse consist, part is milled dry or wet to a fine consist, and the two blended in a mixing step; (3) a variation on the single-step method in which a minor fraction of the mill product is further milled to a finer consist and blended back into the original major fraction; (4) dry-milling of the entire amount of coal with subsequent addition of water and additives in an appropriate mixer (mills other than a media mill, e.g., bowl mill, have been used for grinding by this method); and (5) the "staged" method which was selected for the present study. In the staged process, part of the coal is milled under efficient conditions, such as dry or as a dilute water suspension, followed by viscous milling of all material in a finishing step.

In the present case, Figure 2 schematically illustrates this approach as applied to the design of the CWF production section of the plant. For the ¼" × 28M fraction coming from the coal preparation section, a centrifuge is used to reduce the moisture level to approximately 7 percent, after which this dried product is ground in rod mills. For the 28M × 0 fraction, coal dewatering is accomplished using a screen bowl centrifuge. Next,

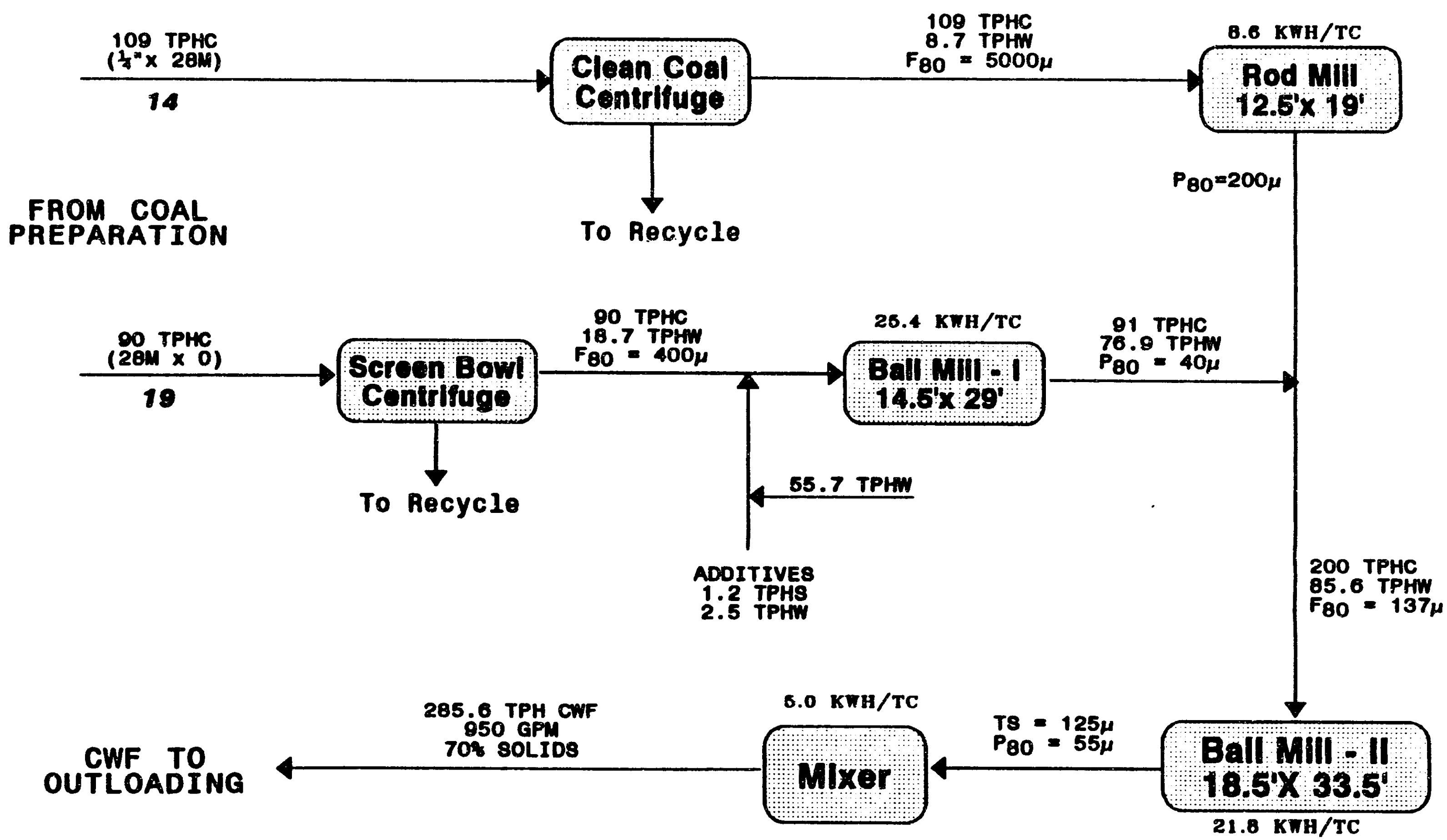

FIGURE 2. Staged CWF Process

makeup water is added to bring the water level to 46 percent by weight, and the resultant slurry is wet milled under relatively low viscosity conditions. The products from the wet and dry milling operation are combined and final milling (ball mill II in Figure 2) is accomplished under viscous conditions.

There is inherent inefficiency in all the CWF processing methods because, as is now well understood, substantial amounts of fines must be produced in a CWF in order to impart fluidity and stability[6]. Hence, it is not sufficient to simply mill coal to a specification such as is usually set for pulverized coal grinds, e.g., 75 percent less than 200 mesh; provision must be made to produce fines. There does not seem to be any published data on the comparable efficiencies of the various processes mentioned above, although the degree of inefficiency of viscous milling has been reported[7] to be a factor of four or more greater than conventional grinding.

The staged process was judged superior for the requirements of the present CWF. Since part of the cleaned coal, Figure 2, coming into the CWF plant is ¼" in size, it appeared that extensive viscous grinding would be required to insure a top size of 125 microns if a single-step method were selected. Hence this approach was ruled out. The normal bimodal process was also ruled out because of the requirement to produce what would be essentially a very fine grind of a substantial amount of coal. Ball mills are known to be very inefficient for very fine grinding; the only viable alternative is a high-speed media mill. However, contacts with a high-speed media mill vendor indicated that an impractically large number of their largest mills would be required. Dry milling with subsequent mixing with water was not selected because it is not generally known how to control such grinding to produce the required fines.

Referring to Figure 2, the staged CWF process is designed to accommodate the incoming coal streams from the preparation plant and to produce the most efficient grinding scheme practicable, consistent with the required loading of fines in the product CWF. Most efficient grinding is by dry and/or dilute wet milling; accordingly, the circuits were designed to do much of the grinding in these ways. The ¼" × 28 M stream is the more easily dewatered to a sufficiently dry condition for rod millings. Rod milling is more efficient than ball milling for the relatively coarse product and also provides better top size control. The 28M × 0 coal preparation plant stream, together with makeup water and the required additives for CWF processing, produces a fairly dilute feed for ball mill I. The ball mill I and rod mill products are then blended and sent to ball mill II for final grinding, then to high-shear mixers to improve viscosity and stability. Specific mixing energy input was specified as 5 kWh/ton of coal[8]. The sizing, power draws and costs of the mills were provided by Allis Mineral Systems, who have experience with viscous milling of coal. Some modification of their results was necessary to accommodate variations in the final specification of the plant design. The mill sizes and operating power draws (given as specific grinding energies along with throughput) are shown on Figure 2 together with a size designation for feed and products in and out of the mills. (F_{80} and P_{80} on the figure refer to feed and product sizes that 80 weight percent of the coal is finer than.) The size of the large ball mill II shown in Figure 2 is based on the Allis recommendation. Two smaller mills, approximately 14.5′ in diameter by 29′ in length[13], could serve as an alternative and would not significantly impact cost or efficiency of the plant. The total grinding energy to produce the CWF is 38 kWh/ton of coal. (Note that while the centrifuges are shown in Figure 2 as part of the CWF process, they are actually included in the costing of the preparation plant.)

3.0 INTEGRATED PLANT DESIGN

3.1 Preparation Plant

The general design approach is described in section 2.2.1. In this section, some pertinent details are presented together with descriptions of how a coal preparation plant simulator was used as a design aid. The description is based on Figure 1. A detailed process flow diagram (Figure 3) and plan views (Appendix C) of the integrated plant are shown on foldout sheets.

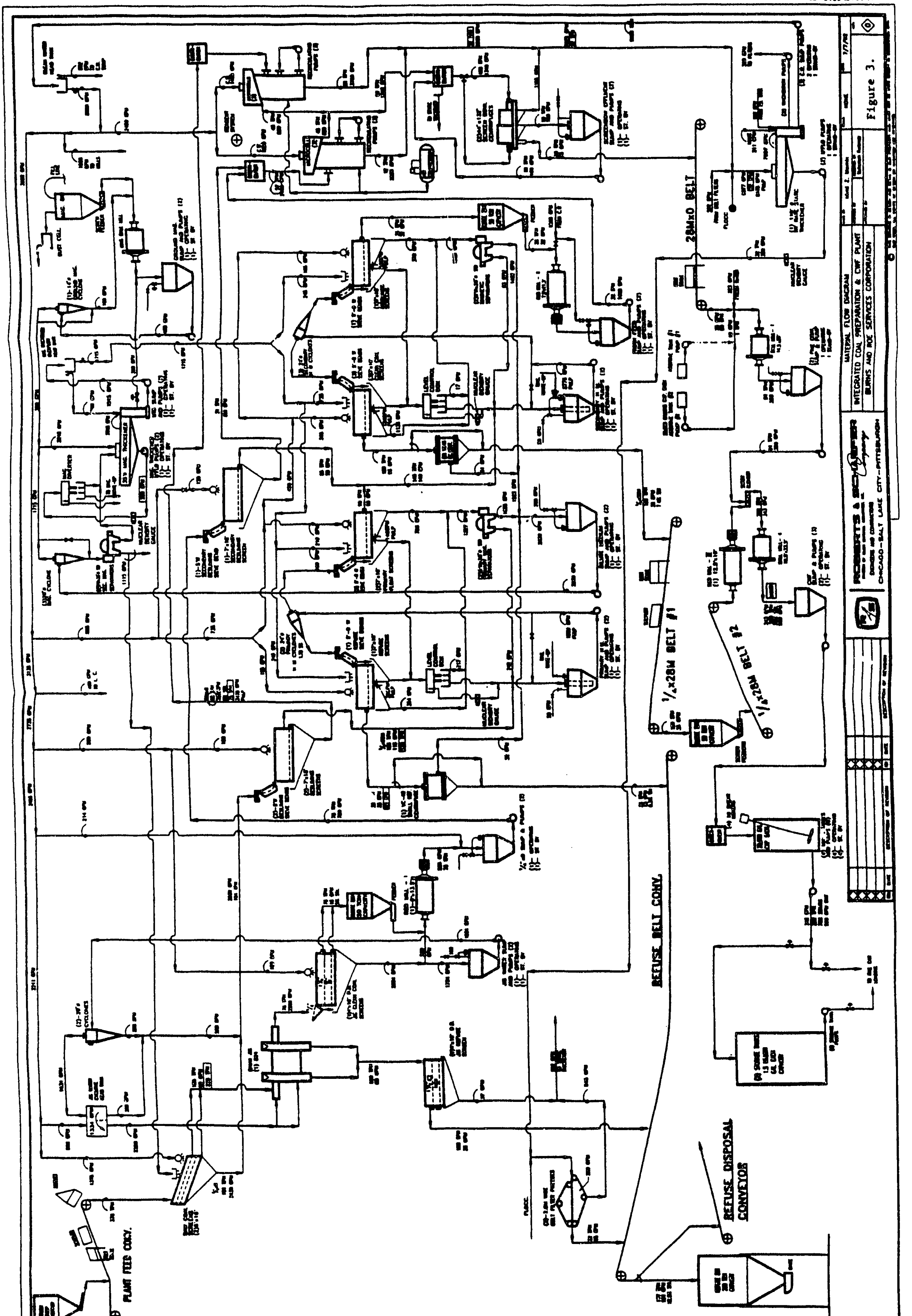
Figure 3.
MATERIAL FLOW DIAGRAM
INTEGRATED COAL PREPARATION & CWF PLANT
BURNS AND ROE SERVICES CORPORATION
ROBERTS & SCHAEFER
CHICAGO-SALT LAKE CITY-PITTSBURGH
28Mx0 BELT
1/4x28M BELT #1
1/4x28M BELT #2
REFUSE BELT CONV.
REFUSE DISPOSAL CONVEYOR
PLANT FEED CONV.

Several flowsheet configurations were evaluated for processing the ROM coal in accordance with the objectives and guidelines described in Section 2.2.1. These flowsheets utilized different processing options, such as number of streams split from the ROM coal, screen sizes and specific gravities used for separations, regrind of middlings, and proportion of material sent for flotation. A process that yielded a product with high carbon recovery and low ash content was finally selected (Figure 1).

A coal preparation plant simulator was used to predict plant performance from laboratory data. Several plant simulation programs have been developed for coal preparation applications[9]. One such simulator is that developed jointly by the U.S. Department of Energy and the Environmental Protection Agency[5]. This simulator, the "Computer Simulation of Coal Preparation Plants," was used to evaluate the flowsheet design, perform off-line optimization, and examine the effect of process variables on coal product quality.

The flowsheet contained two areas where special laboratory testing was required to develop complete material balances. First, laboratory float-sink tests were performed to predict the washability of the jig product after being crushed to ¼" × 0 in the rod mill. This washability can not be predicted since there exists no mathematical model capable of accounting for mineral liberation during grinding and, thereby, calculating new washabilities. Considering the washability of the ROM coal and the operating specific gravity of the Baum jig, the product leaving the jig closely resembles the minus 1.7 specific gravity material for the ROM coal. Consequently, laboratory tests were performed by separating the plus 1.7 specific gravity material from the ROM coal, grinding the remainder to ¼" × 0, and performing washability tests on the ground product.

Laboratory experiments were also conducted to obtain an accurate estimate of the performance of the flotation columns used to clean the minus 28M streams. These tests were conducted by the Virginia Center for Coal and Mineral Processing and involved preparing coal samples in the laboratory that were similar to those to be sent for column flotation for evaluation. An established technique, known as release analysis, was employed to evaluate the flotation behavior of these streams and obtain the optimum separation that could be obtained by froth flotation[10,11]. A floatability curve, similar to that obtained from washability analysis, is obtained from the procedure.

Column flotation tests have been shown to produce a separation approaching that of the float/sink curve[12]. Hence, the procedure consisted of obtaining release analysis curves for each stream to be processed by column flotation, selecting an optimum operating point from each curve, and designing flotation columns to replicate this behavior. For stream 7 (Figure 1), a 28M × 0 sample was obtained by screening, then subjected to release analysis; the resulting flotability curve is shown in Figure B-1 in Appendix B. The optimum point for operating the column was selected from this curve as producing a 4.0 percent ash product at 75 percent yield. For stream 16, a ¼" × 28M sample was first prepared by screening the ROM coal. From this sample the plus 1.7 sp. gr. and the minus 1.3 sp. gr. material was removed by a float-sink procedure, after which it was ground to 28M × 0. The ground sample was subjected to release analysis, and the resulting flotability curve is also shown in Figure B-1 in Appendix B. The optimum point for operating the column for the feed stream was selected from this curve as producing an 8.3 percent ash product at 80 percent yield. The column flotation performance for stream 11 was estimated using best engineering judgement as laboratory flotation data were not available for this steam. Other than above, all material balances were obtained using the computer model.

Table 4 summarizes the output characteristics of the three clean coal product streams from the coal preparation flowsheet. Computer calculated washability data of major product streams are given in Appendix D. The combined clean coal product characteristics from all three clean coal streams are obtained using a weighted average of the individual characteristics of each stream.

Table 4. Summary of Performance of Preparation Plant Based on Simulated Flow Values of Figure 3

Stream 14 (¼" × 28M)	29.0% of Input Material 2.6% Ash 15,170 Btu/lb HHV
Stream 17 (minus 28M)	12.0% of Input Material 4.0% Ash 14,760 Btu/lb HHV
Stream 18 (minus 28M)	12.0% of Input Material 6.1% Ash 14,576 Btu/lb HHV
Combined Clean Products (Streams 14 and 19)	**53.0% Total Recovery** **85.1% Carbon Recovery** **89.6% Btu Recovery** **3.7% Ash** **14,945 Btu/lb**

3.2 CWF Process Plant

The essential elements of a process design to produce high quality coal-water fuel comprise the grinding and mixing circuits and the selection of proper additives. In this section further details of these items as well as CWF storage will be given. It was not possible, as was done for the preparation plant design, to have laboratory testing performed in order to precisely define specifications and operating conditions for the CWF plant. These had to be based on published data and on prior operating experience of commercial vendors specialized in these operations.

A staged grinding process as illustrated in Figure 2 was chosen for the CWF plant design. Having selected a process scheme, the problem of designing the plant becomes one of sizing mills and specifying power requirements. In ordinary mineral processing plants where rod and ball mills are utilized, designing can be accomplished with confidence using the Bond methodology[13]. However, the experimental data of Bond were obtained under dry or dilutc wet milling conditions and cannot be applied directly to viscous milling as is required for CWF processing. The predicted difference in mill capacity between conventional and viscous grinding is in fact very large, being several times less for the latter according to published information[7]. Accordingly, it was necessary to obtain the ball mill sizes and horsepower (and costs) from an equipment manufacturer. Allis Mineral Systems was chosen because they have specific experience with ball milling of viscous coal slurries. They were provided with feed sizes, tonnage, and grindability for each stream and the desired product size. The staged CWF process shown in Figure 2 differs somewhat from several variations on which Allis based estimates, and adjustments to their data were made for the final adopted design. The rod mill (Figure 2) sizing and power draw were estimated by the Bond method, as they also were for the two rod mills specified in the preparation plant (Figure 1), because these all involve conventional grinding.

Referring to Figure 2, two clean coal product streams from the preparation section of the plant are fed to centrifuges for dewatering, with the discharged water recycled. The ¼" × 28M stream, which is the more easily dewatered, is reduced to approximately 7 percent moisture content for dry grinding in the rod mill. The exact moisture level is not critical so long as it is low enough for dry grinding. The estimated feed and product sizes in terms of the 80 percent passing points, as well as the power draw per ton per hour of coal, are shown on the figure. The rod mill product is blended with the product of ball mill I to be fed to ball mill II.

The 28M × 0 coal stream from the preparation plant is similarly dewatered and fed to ball mill I for wet grinding. Per recommended engineering practice this stream is over-dewatered and a required amount of makeup water added back in, together with a solution of the surfactant and base additives. This method eliminates the operational requirement for dewatering the coal stream to an exact water content. The wet milling in ball mill I is conducted at about 46 percent water content and with all the additives present, which yields a mill base of only moderate viscosity and provides for grinding efficiency approaching that of conventional milling. The product stream is blended with that from the rod mill for viscous milling in ball mill II. (It is noted that the F_{80} of ball mill I is lower than the P_{80} of the final product from ball mill II. This is an artifact of the staged milling process. It is required that this finer product be sent through the second ball mill in order to provide for the necessary viscous grinding which generates the fines required in a quality CWF.)

The product from ball mill II is subjected to high-speed mixing as a "finishing" step. A specific mixing energy input of 5 kWh per ton of coal is specified based on reported[8] studies that show the viscosity of CWF slurries decreases and levels off at about this point. Following the mixing operation, CWF is then pumped directly to rail tank cars for transport to users. Two insulated and heated storage tanks, each of 1.5 million gallons capacity (approximately two days production), are provided in the event of a discontinuity in the unit train operation. Outloading to barges or to pipeline is an equivalent alternative to rail transport.

Processing of CWF involves only unit operations utilizing mature technology and equipment with histories of proven reliable operation. There are no complex equipment, unit processes, or elevated temperature and pressure operations involved. Process control entails the monitoring of only a few intermediate and final product properties; specifically, coal content, particle size distribution and viscosity. With standard instrumentation these properties can be measured very rapidly in a quality control lab by periodic sampling. Viscosity and coal content could be analyzed on-line if desired, but this does not seem to be practiced for particle size distribution.

3.3 Description of Process Flow Diagram

Following is a description of the detailed process flow diagram shown in Figure 3. As mentioned earlier, the process is based on a battery-limit, integrated plant located at or near a dedicated coal mine, where necessary roads, rail lines, electric and water service, auxiliaries, etc., are available. The flow sheet description includes the entire process within the plant battery limits, but specifically excludes the following:

- Raw coal transportation from mine-mouth to preparation plant.
- Raw coal unloading and storage.
- Raw coal stockpiling and reclaiming.
- Raw coal crusher and grizzly for the 2.5" topsize control of raw feed coal.
- Mobile material handling equipment.

The above operations are generally found at a mine site, whether or not the mined coal is beneficiated. Consequently, the cost of these operations is included in the ROM coal cost and is not considered explicitly as a cost element in CWF preparation. Also, the flowsheet does not specify the final disposition of refuse. Rather the design and costing provide for all refuse to be dewatered and collected in a refuse bin, from which it is transported from the plant site by conveyor belt to a disposal location assumed to be approximately one mile away.

The Process Flow Diagram can be broadly classified into several sections, each of which is discussed below.

Raw Coal Screening Circuit

The preparation plant circuit begins with a 250 ton capacity truck dump hopper from which raw coal is removed via a vibrating feeder onto a conveyer belt. A conveyer belt scale is provided for manual monitoring of raw coal throughput. A mechanical sampler is installed on the conveyor belt for cutting samples of the raw coal entering the preparation plant. A tramp iron magnet removes any tramp iron present in the feed before it enters the preparation facility.

From the conveyor belt, the raw coal is dumped on double-deck screens where it is separated at ¼". The plus ¼" oversize is sent to a Baum jig while the undersize is deslimed at 28M using single-deck screens. The undersize from the single-deck screens is sent to the froth flotation circuit and the oversize (¼" × 28 M) is sent to the primary hydrocyclone circuit.

Baum Jig Circuit

The +¼" oversize from the double deck raw coal screens is cleaned in a Baum jig operated to provide a high specific gravity separation. The jig refuse is drained and sent to a refuse belt conveyer. The jig product is also drained and sent to a 50-ton surge bin for intermediate storage. Process water drained from the jig product is sent to a sump, from which it is pumped to two classifying cyclones for removal of entrained fine coal. The cyclone overflow is returned to the jig head tank for reuse in the jig circuit. Coal present in the cyclone underflow is combined with the raw ¼" × 0 coal prior to desliming at 28M.

Primary Grinding Circuit

The jig product is removed from the 50 ton surge storage bin via a screw feeder and fed into a rod mill (rod mill I) where it is wet milled in an open loop circuit to minus ¼" topsize. The ground product is deslimed at 28M and the ¼" × 28M stream is sent to the primary hydrocyclone circuit to be combined with the primary cyclone product. The 28M × 0 stream from the desliming operation is sent to the froth flotation circuit.

Primary Cyclone Circuit

The ¼" × 28M oversize from the raw coal screening circuit is sent to a 5,000 gallon heavy medium sump and pumped to the primary heavy medium cyclone circuit. This circuit consists of two, 24" diameter cyclones and is configured to operate at high specific gravity (≈1.70 sp.gr.). The cyclone product is drained, rinsed, and combined with the ¼" × 28M coal obtained from the primary grinding circuit. The combined stream is sent to the secondary heavy media sump. The refuse material from the cyclones is drained, rinsed, and dewatered on screens. The flowsheet includes a small centrifuge that can be used for further dewatering the refuse before it is sent to the refuse belt conveyor.

Secondary Cyclone Circuit

Material from the secondary heavy media sump is pumped to the secondary heavy media cyclone circuit. This cyclone circuit consists of three, 24" diameter cyclones and is configured to produce a low specific gravity (≈1.30 sp.gr.) separation. The low-gravity separation is achieved using fine magnetite; namely, 100 percent passing 325M and 25 percent passing 5 microns. The cyclone overflow is drained, rinsed, and dewatered on single deck screens, then further dewatered with a centrifuge. The dewatered cyclone overflow product is sent to the CWF plant via a belt conveyer. The cyclone underflow is drained, rinsed, dewatered on a single-deck screen and sent to a 50-ton surge bin prior to the secondary grinding circuit.

Secondary Grinding Circuit

The secondary cyclone circuit underflow is removed from a 50-ton surge bin via a screw feeder and fed into a rod mill (rod mill II) for further size reduction to 28M topsize, under open circuit conditions. Ground material is sent to the column flotation feed sump for intermediate storage and conditioning prior to column flotation.

Froth Flotation Circuit

Prior to flotation, the column feed material is conditioned in a sump to modify particle surface chemistry for optimum flotation performance. This circuit consists of two banks of column cells, each containing three, 10′ diameter cells. The first bank is designed to treat the raw, 28M × 0 coal obtained from the raw coal cleaning circuit. The second bank treats the 28M × 0 coal from the secondary grinding circuit. The froth products from both banks are combined and sent to a screen bowl distributor for distribution to two screen bowl centrifuges. The dewatered 28M × 0 product is transferred from the centrifuges to the CWF plant by a belt conveyer. The column refuse is pumped from each of the columns to a static thickener.

Column Refuse Dewatering

Column refuse is thickened in the static thickener and pumped to a refuse belt filter press where it is further dewatered to approximately 30-35% moisture. The dewatered refuse is directed to a refuse belt conveyor where it is combined with refuse streams from the jig and heavy medium cyclone circuits and dumped into a 250 ton refuse bin for intermediate storage prior to eventual disposition.

Magnetic Recovery and Make-Up Circuit

The magnetite recovery circuit is similar to a typical media recovery circuit, with minor modifications to accommodate the unconventional low gravity separation in the process flow sheet. Because of the requirement previously mentioned for fine magnetite for low gravity separations, a magnetite grinding mill is included in the circuit to avoid the costly purchase, storage and handling of fine magnetite. With the grinding mill in the circuit, 70 grade magnetite (68 -72% -325M) may be purchased and ground to finer sizes as needed. Provision is also made to minimize the loss of fine magnetite in the circuit by employing a magnetite thickener.

Magnetite supplied from the magnetite bin is fed into a ball mill and is ground wet in closed circuit to the required degree of fineness. The ground magnetite slurry is directed from the mill to a sump from which it is pumped to a single, ground magnetite cyclone classifier. The underflow is returned to the ball mill for further size reduction, and the overflow is directed to the magnetite thickener. The magnetite thickener overflow is sent to a sump and pumped to the magnetite thickener overflow head tank for use in the drain operations in the heavy medium cyclone circuits. Magnetite from each drain screen in the primary and secondary heavy media circuits is collected separately and returned directly to its respective heavy media sump. Magnetite from rinse screens is recovered through the primary magnetic separators in each of the circuits. The concentrate from each of the magnetite separators is returned directly to its respective heavy media sump, while the effluent containing dilute media is sent to the dilute media sump. From this sump, the dilute media is pumped to three classifying cyclones. The overflow from the classifying cyclones consisting of fine magnetite is sent to the magnetite thickener. The cyclone underflow containing relatively coarser magnetite is sent to the secondary magnetite separator, from which the recovered magnetite is sent to the magnetite thickener. The magnetite thickener underflow is pumped to the magnetite diverter with density monitored by an on-line nuclear density gauge. From the magnetite diverter, the recovered magnetite is directed as needed to the primary or secondary heavy media sumps as make-up magnetite.

CWF Processing Circuit

The products from the two clean coal centrifuges represent the feeds to the CWF grinding and mixing circuit. The centrifuge designated EB-36 discharges 109 tph of ¼" × 28M coal, containing the equivalent of 35 gpm moisture, via belt conveyor to a surge tank and into the 12.5′ diameter rod mill III for dry grinding. This mill discharge is blended with the slurry discharge from ball mill I and fed to ball mill II. The feed to ball mill I is the 28M × 0 partially dewatered product from the screen bowl centrifuge. This material is fed at 90 tph coal, slurried with the equivalent of 75 gpm water, into the 14.5′ diameter ball mill. The additives (in water solution) plus makeup water are admixed with this coal slurry feed. (Note that the additives (1.2 tph on a dry basis) are combustible materials with a heating value comparable to coal and are therefore included as fuel in the CWF.)

The combined products of ball mill I and rod mill III are fed to the 18.5′ diameter ball mill II for final milling under viscous conditions. This mill discharge is passed over a magnet to remove fugitive iron from broken or worn mill grinding media, then pumped to a 20,000 gallon high-shear mixing tank (four each), and finally to rail car loading. Two 1.5 million gallon storage tanks are available in the event of a disruption of unit train arrival or departure. These storage tanks have capacity for two days production of CWF.

4.0 EQUIPMENT SIZING AND COST ESTIMATIONS

Following the conceptual design of the integrated plant, Roberts & Schaefer Company (R&S) was engaged to review the design, develop a detailed process flow diagram, and provide estimates for the capital costs, labor, operating and maintenance supplies, and consumables (other than CWF additives and grinding energy, which were estimated by SAIC and Allis Mineral Systems). Roberts & Schaefer is a highly experienced architectural and engineering company with a specialty in design, costing and construction of coal preparation facilities. The report of their subcontract effort was provided to DOE PETC through the Burns and Roe Services Corporation[14]. The relevant information in that report is included in this section of the present report, in Appendix C, and in the attached process flow diagram.

4.1 Capital Costs

The capital costs are detailed in Table C-1 of Appendix C and were estimated by standard procedures used by R&S. A summary of these costs is shown in Table 5. The R&S procedures yield what is referred to in various engineering sources as a definitive estimate, which has an expected accuracy of ± 10 percent. Vendor prices for the major equipment were obtained by SAIC and provided to R&S. The ancillary equipment to complete the plant design was added by R&S. Also shown in Table C-1 are the number, size, capacity and connected horsepower of the equipment, obtained by SAIC from vendors or estimated by R&S. The R&S cost estimates are based on data they use for preparing proposals to their clients for turnkey projects. The installed costs of the equipment include engineering, site preparation, and piping, platework and electrical hookups for each item. The equipment costs for the CWF portion of the plant were brought to installed and operational cost figures by applying the multipliers R&S uses for its proposals.

In estimates of this kind, it is customary for R&S to apply a 10 - 15 percent contingency; however, because a substantial portion of the plant represents CWF processing which does not carry the maturity of preparation plant design and construction, an overall contingency of 30 percent was deemed appropriate for this study. The greatest uncertainty in designing a CWF plant is related to the sizing of the grinding mills. There are [illegible] data available on scaling a viscous grinding process to full-scale production. Equipment manufacturers can develop estimates based only on pilot-scale testing and analogy to conventional milling. This scaling uncertainty represents a much greater production and cost risk in construction of the first few CWF plants than in later units, and eventually the risks will decline to the level of that assigned to other major equipment by the time an n^{th} plant is designed. The large capital contingency included for the CWF portion of the integrated plant covers the uncertainty in the sizes of the grinding mills and insures that the design production capacity is adequate.

Table 5. Summary of Capital Costs for Integrated Plant (See Table C-1)

Coal Preparation	$13,967,000.
Refuse Handling	1,383,000.
Clean Coal Handling	765,000.
CWF Processing	15,725,000.
Contingency	9,560,000.
Start-Up	800,000.
TOTAL	$42,200,000.

4.2 Labor Costs

Labor costs, which represent a fixed operating and maintenance (O&M) cost, were estimated by developing a manning chart for O&M and management personnel, shown in Table C-2 of Appendix C. A chemist is included in the management category to oversee all analyses performed in the plant, particularly the monitoring of CWF properties. The total labor is based on one group of four management personnel and four shifts of operating personnel, since it is intended to run the plant 24 hours per day, seven days per week. An operating factor for the plant of 83 percent requires production during 7,300 hours per year. This would allow an average of 24 hours per week for scheduled maintenance and four hours per week for unscheduled maintenance.

An average labor rate of $70,000 per person per year, including indirect burden, was applied, for a labor expense totally $4,760,000 per year for 68 persons. The $70,000 figure was obtained by escalating to 1992 labor-rate data reported in a 1978 analysis of coal preparation costs[15]. It was found by consulting several sources that the average annual labor rate varies widely among estimators, due at least partly to locale and by what indirect costs are included. However, the $70,000 figure is consistent with an average from three other sources[16,17,18].

4.3 Variable O&M Costs

The variable O&M costs include electric energy, preparation plant consumables, CWF additives, other maintenance supplies and water. The estimation of costs for each of these categories is summarized below.

The electric power requirements are shown in Table C-1, where the connected horsepower of each piece of equipment is listed. It is noted that the grinding energy to produce CWF comprises about two-thirds of the total electric energy requirement. This power draw is related to the required fineness of grind and the viscous milling conditions. The total connected horsepower of 18,800 would require a power substation of the order of $15MW_e$. The actual operating electric power is taken to be 85 percent of connected, and, at 83 percent operating capacity, power usage would be 87×10^6 kWh/y, equivalent to a specific energy of about 60 kWh/t coal output.

The cost of electricity has been taken as 5.5¢ per kWh for industrial service in West Virginia, the design site of the integrated plant. This figure represents a highly conservative estimate, since data from 1987 through 1990 indicate industrial power rates in West Virginia at between 3.60¢ and 4.23¢ per kWh[19]. This conservative estimate also serves as a contingency in the estimate of the total operating power of the plant.

The preparation plant consumables usage and cost are based on experience of R&S and input from VPI and SAIC. Magnetite consumption is taken as 2 lbs per ton of feed to the heavy media cyclone circuits, and total feed to these circuits is 271 tph. At $125/ton for the required fine grade of magnetite, the cost of magnetite consumption is approximately $34/hr, or 17¢ per ton clean coal in the CWF. Flocculant, which is required in refuse disposal, was determined by discussions with manufactures of static thickeners and filters to be $0.75 - $1.00/ton of the 32 tph of 28M × 0 thickener feed treated. For conservatism, the higher estimate was used, yielding a flocculant cost of $32/hr, or 16¢ per ton of coal in the CWF. Fuel oil, which is employed as collector in the column flotation circuits, is used at the level of 0.75 lb/ton of column coal feed, at a nominal delivered price based on commodity quotes of about 20¢ per pound. The frother for the column flotation cells is used at the level of about 0.7 lb/ton coal feed to the column. A delivered price of 85¢/lb frother was obtained from vendors for their products. Total coal feed to the columns is 122 tph. A summary of the preparation plant reagents and costs is given in Table 6.

Table 6. Summary of Cost and Usage of Consumable Reagents for Preparation Plant

Reagent	Cost Per Operating Hour	Cost Per Ton of Coal in CWF
Magnetite	$34	$0.17
Flocculant	$32	$0.16
Collector	$18	$0.09
Frother	$72	$0.36
Total	$156/hr	$0.78/ton (2.6¢/MMBtu)

The principal additive used in the formulation of CWF is a dispersant and usually represents the single largest contributor to the incremental cost of producing the slurry. The most widely known dispersant for CWF is the ammonium salt of a naphthalene-formaldehyde sulfonate (ANS). Since this is an anionic surfactant, a base (ammonium hydroxide) is also used to control the pH of the slurry. Price quotes from vendors indicate the delivered cost would be about $0.55/lb. of active ingredient (it is sold as a solution) for the ANS. Recent published prices in the Chemical Marketing Reporter for ammonium hydroxide put the delivered price at approximately $0.14/lb. The usage level for the two CWF additives cannot be known precisely without a laboratory evaluation since it is coal-specific. Accordingly, best engineering judgment was employed, and values of 0.6 percent and 0.4 percent of the coal (dry basis) were specified for ANS and ammonium hydroxide, respectively. At these usage levels the CWF additive costs are $6.62 and $1.12 per ton of coal, or $1,324 and $224 per hour, for ANS and base, respectively.

Maintenance supplies were estimated by R&S based on their engineering judgment and on data in reference[14] to be $1.35/ton coal output, or $270 per hour. This expense on an annual basis is approximately equal to 5 percent of the estimated total capital cost. The water usage for the plant comprises the amount that goes out with the CWF (343 gpm) and also with the refuse (101 gpm). The total water usage of 26,640 gallons/hour is estimated to cost $16 per hour at 60¢/1000 gallons, or 8¢ per ton coal output.

The foregoing O&M costs estimates are summarized in Table 7 in three commonly useful forms. For this study, the fixed costs comprise the total labor, property taxes and insurance, and remain unchanged unless there is a change in the operating capacity factor; for example, if plant operation were reduced to three shifts (120 hours per week). In such a case, operating labor would be reduced appropriately, but management labor and property taxes and insurance would not change. The variable O&M costs depend on the plant operating output, and are accounted for in the CWF Production Sensitivity Analysis.

Table 7. Summary of Variable O&M Costs

Variable Cost Item	$/hour	$/ton coal	$/MMBtu
Electric Usage	660.	3.30	0.11
Preparation Plant Reagents	156.	0.78	0.026
CWF Additives	1548.	7.74	0.26
Water	16.	0.08	0.0027
Other O&M Supplies	270.	1.35	0.045

4.4 Financial Assumptions and CWF Price Estimate

In addition to the investment capital and O&M costs previously estimated there are several other cost elements that enter the pricing of CWF. Working capital is required and is taken to be one-twelfth of all annual O&M expenses. A combined federal and state tax rate of 38 percent and a property tax rate of 2 percent are assumed, both of which are consistent with recommendations in the EPRI Technical Assessment Guide[16]. The Btu loss during beneficiation is estimated from the process recoveries and the heat values of input and cleaned coal: 376 tph input at 8830 Btu/lb and 199 tph output at 14,945 Btu/lb, to yield a loss of 692 MMBtu/hr, or 10.4 percent. At the assumed feed coal cost of $1.00/MMBtu, this loss is equivalent to $692/hr, or $3.46 per ton of clean coal. The financial assumptions and a summary of cost elements used to estimate the price of CWF are presented in Tables 8 and 9, respectively.

Table 8. Financial Assumptions Used to Estimate CWF Price

Cost of Coal Feed	$1.00/MMBtu
Plant Life	20 Years
Plant Operating Factor	83.3 Percent
Inflation Rate	4 Percent
Depreciation Method	7-Year Declining Balance
Federal and State Tax Rate	38 Percent
Property Tax Rate	2 Percent
Equity Investment	100 Percent
Return on Investment	15 Percent (Nominal after Tax)

In addition to these tabulated assumptions it is also assumed in the financial analyses that all capital investment funds are expensed one year before plant operation begins.

Table 9. Summary of Cost Elements in Pricing CWF

Item	Cost	$/hour	$/ton coal	$/MMBtu
Investment Capital	$42,200,000	-	-	-
Working Capital	$2,005,000	-	-	-
Fixed O&M	$5,604,000/yr	768	3.84	0.13
Variable O&M	$19,337,000/yr	2650	13.25	0.44
Btu Loss	$5,050,000/yr	692	3.46	0.12

With these cost data and the financial assumptions of Table 8, a price was derived for CWF product using a financial evaluation model developed for use in costing products from coal preparation facilities[20]. The annualized price, free-on-board the production plant at the mine site, is $1.84/MMBtu, comprising $1/MMBtu coal feed and $0.84/MMBtu incremental cost. This price includes a 15 percent nominal after-tax return on investment, corresponding to $0.15/MMBtu.

5.0 PRICE SENSITIVITY ANALYSIS

The sensitivity of the CWF base case incremental price of $0.84/MMBtu to variations in economic and technical assumptions and parameters was examined. The results are collected in Table 10 for the main variables, where nominal variation percentages are chosen.

Variations in plant life show an inverse effect, a shorter life increasing the price because capital is applied over less of a time period. In the case of a variation in cost of coal, an increase or decrease causes the total CWF product price to increase or decrease by the amount of that variation in addition to the variation in the incremental cost shown in the table.

The variations in the plant capacity factor refer to five-day weeks of 120 hours/week, 52 weeks/year, in the case of three shifts, and 80 hours/week, 52 weeks/year, in the case of two shifts. The three-shift case assumes 100 hours/week of production and 20 hours/week of maintenance, with a capacity factor of 59.4 percent. The two-shift case assumes approximately 67 hours/week production, 13 hours/week maintenance, and a capacity factor of 39.8 percent. These show that there would be a modest price increase if the plant were run on a three-shift operation, but a significant increase if the plant were reduced to two shifts.

The variable listed as CWF Production refers to change in plant output if CWF specifications or the properties of another selected coal were different than the base case.

The properties of interest are the particle size distribution (PSD) of coal in the CWF and the ease of coal grinding as measured by the Hardgrove Grindability Index (HGI). In the first case, the baseline PSD for the CWF was set at a P_{80} of 55mμ, which was estimated to yield a top size of approximately 125mμ, as discussed earlier. (P_{80} refers to 80 weight percent of particles finer than the stated size.) If a coarser particle consist is specified; for example, a P_{80} of 70mμ, which is estimated to yield a top size in the range of 300mμ, similar to a pulverized coal grind, then a substantial reduction in price would be realized. To estimate this reduction, the increased grinding capacity of each CWF mill was determined using the Bond methodology for the coarser PSD. This estimate gave a production rate of 259 tph output for the same equipment size and power draw of the CWF section of the overall plant. However, since the preparation plant input would now be approximately 30 percent greater (487 tph), costs of all factors other than labor were increased appropriately. The result given in Table 10 shows that the incremental price would decrease about $0.13/MMBtu.

The price sensitivity to coal grindability was also examined by varying the HGI. The rationale for the range of 55 to 70 (baseline taken as 65) is that in selecting a coal for CWF production, one would not normally choose one that is harder to grind than a 55 HGI material unless there were other compelling reasons; and the selection of coals with HGI values greater than 70 becomes more limited. Again, using the Bond methodology, the CWF plant capacity was estimated as 170 tph for HGI = 55 and 214 tph for HGI = 70. As in the case with PSD sensitivity, the CWF plant size, cost and total power draw remain constant. Since the variation in output is well within ± 20%, which is the design capacity range for the preparation plant, only the O&M costs (electricity and supplies) were altered in estimating the effect of HGI on the incremental CWF cost as given in Table 10.

Table 10. Sensitivity of CWF Price to Financial and Technical Variables

Item	Variation	Base Case	Change from Base Case Incremental Price of $0.84/MMBtu + $	- $
Investment Capital	± 10%	$42,200,000	0.017	0.017
Labor	± 10%	$4,760,000/yr	0.011	0.011
Electricity	± 10%	$4,784,000/yr	0.011	0.011
Reagents and Additives	± 10%	$12,434,000/yr	0.029	0.029
Plant Life	∓ 50%	20 years	0.060	0.010
Income Tax Rate	± 20%	38%	0.016	0.004
Rate of Return (nominal after tax)	± 33%	15%	0.070	0.050
Cost of Coal	± 10%	$1.00/MMBtu	0.012	0.010
Btu Loss	± 10%	10.2%	0.011	0.011
Capacity Factor/Labor Time	59.4% (3 shifts)	83.3% (full time)	0.08	-
	39.8% (2 shifts)	83.3% (full time)	0.21	-
CWF Production*:				
PSD D_{80}/TS (259 tph)	70mμ/300mμ	55mμ/125mμ	-	0.13
HGI (170 tph)	55	65	0.13	-
HGI (214 tph)	70	65	-	0.04

*Note that the production rate varies from the 200 tph base case
PSD = particle size distribution, TS = top size, HGI= hardgrove grindability index

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Appendix A

COMMERCIAL TESTING AND ENGINEERING COMPANY

Laboratory Analysis Results

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • (312) 953-9300
NCE 1908
Member of the SGS Group (Société Générale de Surveillance)

August 19, 1991

PLEASE ADDRESS ALL CORRESPONDENCE TO:
P.O. BOX 808, CHARLESTON, WV 25323
TELEPHONE: (304) 925-6631
FAX: (304) 925-8877

EOS TECHNOLOGIES, INC.
1601 NORTH KENT STREET
SUITE 1102
ARLINGTON VA 22209
ATTENTION: EDWARD T. McHALE
BOA NO.: JM-0785

Sample identification by
EOS TECHNOLOGIES, INC.

SAMPLE I.D.: RAW COAL
MONTCOAL COMPLEX
PEABODY COAL CO.
05/15/91

Kind of sample reported to us: COAL

Sample taken at: --

Sample taken by: EOS TECHNOLOGIES, INC.

Date sampled: May 15, 1991

Date received: August 12, 1991

Analysis Report No. 61-08328

SIEVE ANALYSIS

Passing	Retained On	% Weight	CUMULATIVE RESULTS % Retained	CUMULATIVE RESULTS % Passing
-----	1" RD	16.56	16.56	83.44
1" RD	1/2" RD	16.51	33.07	66.93
1/2" RD	1/4" RD	16.61	49.68	50.32
1/4" RD	28 Mesh	33.88	83.56	16.44
28 Mesh	0	16.44	100.00	0.00

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Alla R. Seaman

Manager, Charleston Laboratory

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

SCREEN ANALYSIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
						CUMULATIVE RESULTS							
SIZE		DRY BASIS				Retained on Screen in Column 2				Passing Screen in Column 1			
Passing	Retained on	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
PLUS X 1" RD		16.6	71.26	0.60	3718.	16.6	71.26	0.60	3718.	100.0	39.97	0.77	8859.
1" RD X 1/2" RD		16.5	50.84	0.64	7091.	33.1	61.08	0.62	5400.	83.4	33.74	0.81	9882.
1/2" RD X 1/4" RD		16.6	36.50	0.80	9478.	49.7	52.87	0.68	6762.	66.9	29.53	0.85	10570.
1/4" RD X 28 MESH		33.9	27.93	0.89	10843.	83.6	42.76	0.76	8417.	50.3	27.23	0.87	10931.
28 MESH X 0		16.4	25.78	0.83	11112.	100.0	39.97	0.77	8859.	16.4	25.78	0.83	11112.

COMMERCIAL TESTING & ENGINEERING CO.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
PLUS x 1" RD = 16.60% of COAL													
-	1.40	18.7	5.30	0.65	14748.	18.7	5.30	0.65	14748.	100.0	71.26	0.60	3718.
1.40	1.70	3.4	24.45	0.67	11458.	22.1	8.25	0.65	14242.	81.3	86.43	0.59	1182.
1.70	-	77.9	89.14	0.59	733.	100.0	71.26	0.60	3718.	77.9	89.14	0.59	733.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
1" RD x 1/2" RD = 16.50% of COAL													
-	1.40	41.6	4.74	0.74	14798.	41.6	4.74	0.74	14798.	99.9	50.84	0.64	7091.
1.40	1.70	4.5	23.62	1.21	11595.	46.1	6.58	0.79	14485.	58.3	83.73	0.56	1592.
1.70	-	53.8	88.76	0.51	755.	99.9	50.84	0.64	7091.	53.8	88.76	0.51	755.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
1/2" RD x 1/4" RD = 16.60% of COAL													
-	1.30	40.5	2.32	0.80	15207.	40.5	2.32	0.80	15207.	100.0	36.50	0.80	9478.
1.30	1.40	16.4	7.68	0.98	14284.	56.9	3.86	0.85	14941.	59.5	59.77	0.80	5578.
1.40	1.50	3.7	16.99	1.55	12680.	60.6	4.67	0.89	14803.	43.1	79.59	0.73	2266.
1.50	1.70	1.6	29.71	2.57	10612.	62.2	5.31	0.94	14695.	39.4	85.47	0.65	1288.
1.70	-	37.8	87.83	0.57	893.	100.0	36.50	0.80	9478.	37.8	87.83	0.57	893.

COMMERCIAL TESTING & ENGINEERING CO.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
1/4" RD x 28 MESH = 33.90% of COAL													
-	1.30	58.3	2.02	0.85	15157.	58.3	2.02	0.85	15157.	100.0	27.93	0.89	10843.
1.30	1.40	9.7	8.82	1.29	13997.	68.0	2.99	0.91	14992.	41.7	64.15	0.94	4811.
1.40	1.50	2.5	18.39	2.05	12415.	70.5	3.54	0.95	14900.	32.0	80.92	0.83	2026.
1.50	1.70	1.4	32.31	2.52	10128.	71.9	4.10	0.98	14807.	29.5	86.21	0.73	1146.
1.70	-	28.1	88.90	0.64	698.	100.0	27.93	0.89	10843.	28.1	88.90	0.64	698.

COMMERCIAL TESTING & ENGINEERING CO.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

RAW COAL
MONTCOAL COMPLEX
PEABODY COAL COMPANY
MAY 15, 1991

LAB NO. 61-08328-3

August 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
28 MESH x 0 = 16.40% of COAL													
-	1.30	16.5	2.48	0.79	15044.	16.5	2.48	0.79	15044.	100.0	25.78	0.83	11112.
1.30	1.40	33.8	5.27	0.80	14523.	50.3	4.35	0.80	14694.	83.5	30.38	0.84	10335.
1.40	1.50	11.0	10.58	0.90	13548.	61.3	5.47	0.82	14488.	49.7	47.46	0.87	7488.
1.50	1.70	6.7	30.04	0.88	10379.	68.0	7.89	0.82	14083.	38.7	57.94	0.86	5765.
1.70	-	32.0	63.78	0.85	4799.	100.0	25.78	0.83	11112.	32.0	63.78	0.85	4799.

COMMERCIAL TESTING & ENGINEERING CO.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

PEABODY COAL COMPANY
WEST VIRGINIA DIVISION
MONTCOAL COMPLEX - 6/21/91
RAW COAL PLANT FEED 2" X 0
SCREEN ANALYSIS

LAB NO. 61-08327

November 1991

1	2	3	4	5	6	7	8	9	10	11	12	13	14
						CUMULATIVE RESULTS							
SIZE		DRY BASIS				Retained on Screen in Column 2				Passing Screen in Column 1			
Passing	Retained on	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
1/4" RD X	28 MESH	70.2	6.48	0.79	14479.	70.2	6.48	0.79	14479.	100.0	6.19	0.80	14507.
28 MESH X	0	29.8	5.51	0.82	14571.	100.0	6.19	0.80	14507.	29.8	5.51	0.82	14571.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

PEABODY COAL COMPANY
WEST VIRGINIA DIVISION.
MONTCOAL COMPLEX - 6/21/91
RAW COAL PLANT FEED 2" X 0

LAB NO. 61-08327

November 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
1/4" RD x 28 MESH = 70.20% of RAW COAL PLANT FEED													
-	1.30	67.3	2.32	0.75	15183.	67.3	2.32	0.75	15183.	100.0	6.48	0.79	14479.
1.30	1.35	15.9	7.37	0.72	14385.	83.2	3.29	0.74	15030.	32.7	15.03	0.87	13032.
1.35	1.40	7.8	11.38	0.73	13522.	91.0	3.98	0.74	14901.	16.8	22.29	1.01	11751.
1.40	1.45	3.5	17.54	0.89	12523.	94.5	4.48	0.75	14813.	9.0	31.74	1.25	10215.
1.45	1.50	1.7	20.84	1.40	12046.	96.2	4.77	0.76	14764.	5.5	40.78	1.48	8747.
1.50	1.70	2.0	31.74	1.75	10145.	98.2	5.32	0.78	14670.	3.8	49.70	1.52	7271.
1.70	-	1.8	69.65	1.26	4077.	100.0	6.48	0.79	14479.	1.8	69.65	1.26	4077.

EOS TECHNOLOGIES, INC.
ARLINGTON, VIRGINIA

PEABODY COAL COMPANY
WEST VIRGINIA DIVISION
MONTCOAL COMPLEX - 6/21/91

LAB NO. 61-08327 RAW COAL PLANT FEED 2" X 0 November 1991

FLOAT & SINK ANALYSIS
DRY BASIS

1	2	3	4	5	6	7	8	9	10	11	12	13	14
SPECIFIC GRAVITY		FRACTION ANALYSIS DRY BASIS				CUM. RECOVERY (FLOAT)				CUM. REJECT (SINK)			
SINK	FLOAT	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu	% Wt.	% Ash	% Sul.	Btu
28 MESH x 0 = 29.80% of RAW COAL PLANT FEED													
-	1.30	60.3	1.44	0.79	15306.	60.3	1.44	0.79	15306.	100.0	5.51	0.82	14571.
1.30	1.35	14.9	4.98	0.78	14711.	75.2	2.14	0.79	15188.	39.7	11.70	0.87	13454.
1.35	1.40	11.8	7.33	0.72	14032.	87.0	2.85	0.78	15031.	24.8	15.73	0.92	12698.
1.40	1.45	5.8	11.39	0.75	13571.	92.8	3.38	0.78	14940.	13.0	23.36	1.10	11488.
1.45	1.50	2.4	14.75	0.85	12919.	95.2	3.67	0.78	14889.	7.2	33.01	1.39	9809.
1.50	1.70	2.8	24.14	1.22	11343.	98.0	4.25	0.79	14788.	4.8	42.14	1.66	8255.
1.70	-	2.0	67.33	2.27	3931.	100.0	5.51	0.82	14571.	2.0	67.33	2.27	3931.

COMMERCIAL TESTING & ENGINEERING CO.

Appendix B

VIRGINIA CENTER FOR COAL AND MINERALS PROCESSING
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Laboratory Test Results

Table 1. Release Analysis Results for ROM -28 Mesh Sample

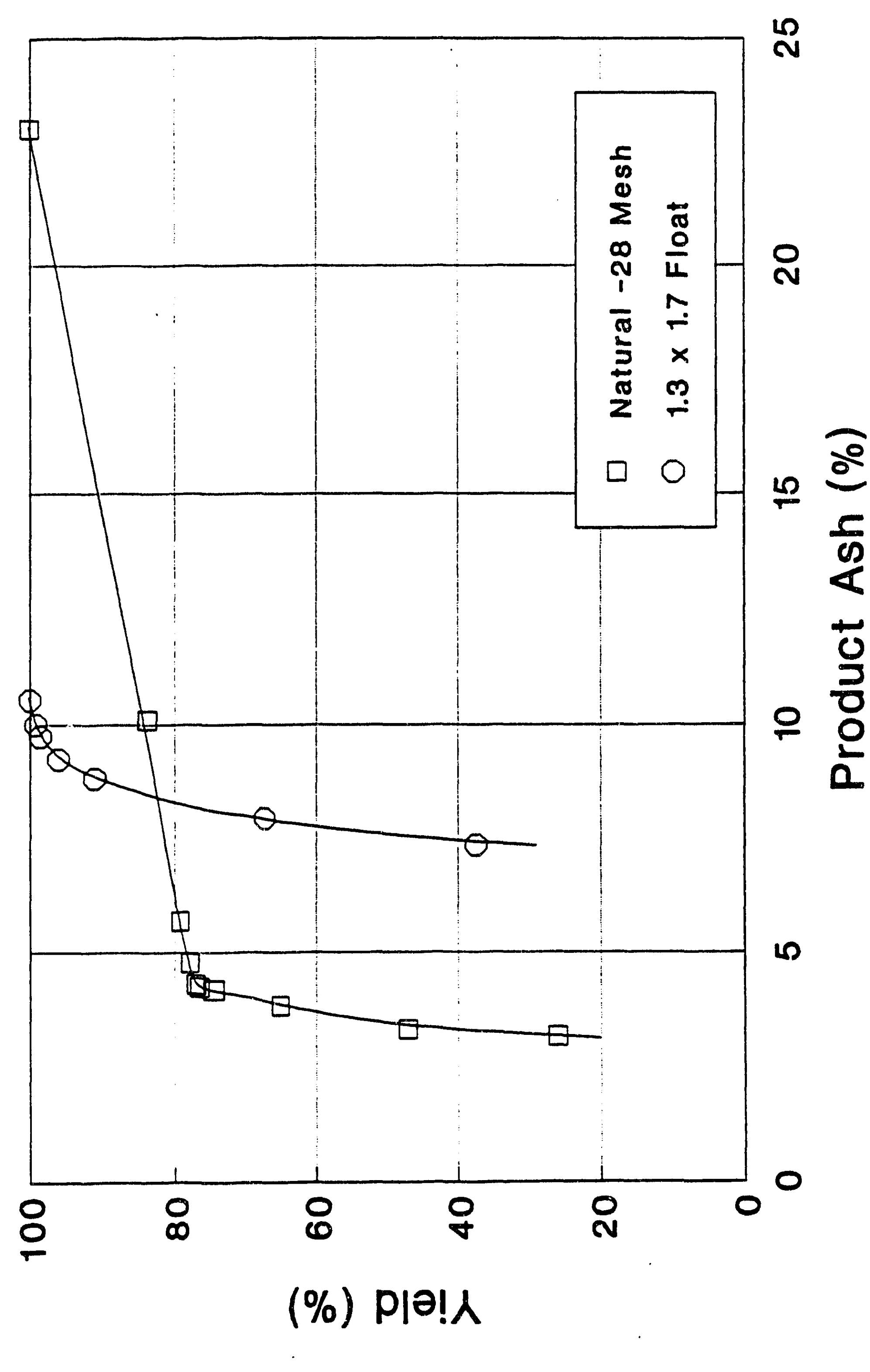
Sample	Ash (%)	Wt (g)	Wt (%)	Cum. Wt (%)	Cum. Ash (%)
Product 1	3.16	85.15	25.89	25.89	3.16
Product 2	3.51	69.57	21.15	47.04	3.32
Product 3	5.17	59.58	18.11	65.15	3.83
Product 4	6.67	30.25	9.20	74.35	4.18
Product 5	6.43	6.25	1.90	76.25	4.24
Tail 5	14.30	1.45	0.44	76.69	4.30
Tail 4	44.65	2.96	0.90	77.59	4.76
Tail 3	52.25	4.93	1.50	79.09	5.66
Tail 2	81.96	15.97	4.86	83.95	10.08
Tail 1	90.38	52.81	16.06	100.0	22.98
Total		328.92	100.0		

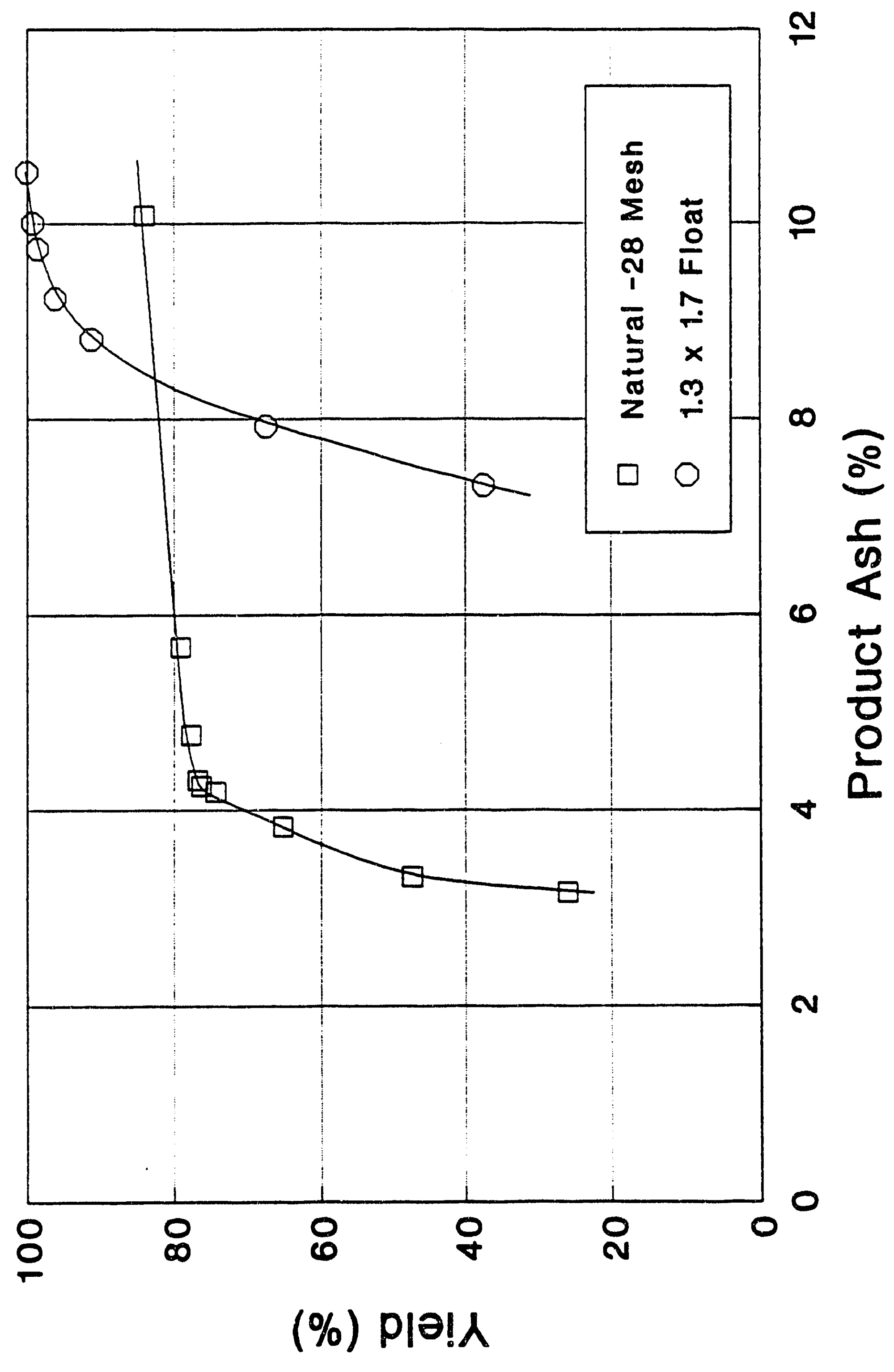
Table 2. Size Distribution for 1.3 x 1.7 Float Fraction

Size (Mesh)	Wt (%)	Cum. Wt (%)
+35	0.06	100.0
35x48	1.50	99.97
48x65	6.52	98.47
65x100	14.65	91.95
100x150	13.03	77.30
150x200	11.89	64.27
200x270	14.06	52.38
270x400	5.89	38.32
-400	32.43	32.43

Table 3. Release Analysis Results for 1.3 x 1.7 Float Fraction

Sample	Ash (%)	Wt (g)	Wt (%)	Cum. Wt (%)	Cum. Ash (%)
Product 1	7.32	73.37	37.47	37.47	7.32
Product 2	8.66	58.94	30.10	67.57	7.92
Product 3	11.39	45.89	23.43	91.0	8.81
Product 4	16.82	9.90	5.06	96.06	9.23
Tail 3	29.60	4.72	2.43	98.49	9.74
Tail 2	46.67	1.39	0.71	99.20	10.0
Tail 1	74.94	1.61	0.82	100.0	10.53
Total		195.81	100.0		


Natural -28 Mesh
1.3 x 1.7 Float
Product Ash (%)
Yield (%)
0
5
10
15
20
25
0
20
40
60
80
100


Natural -28 Mesh
1.3 x 1.7 Float
Product Ash (%)
Yield (%)
0
2
4
6
8
10
12
0
20
40
60
80
100

Appendix C

ROBERTS & SCHAEFER COMPANY

Results of Costing Study

TABLE C-1

INTEGRATED COAL PREPARATION & CWF PLANT EQUIPMENT & COST LIST

	RAW COAL CIRCUIT	NO.	SIZE	CAPACITY	HP	COST
1.01	Truck Dump Hopper	1		250 Ton	---	500,000
1.02	Raw Coal Feeder	1	36"x72"	0-450 TPH	2	18,000
1.03	Plant Feed Belt	1	36"x500'	450 TPH	100	350,000
1.04	Plant Feed Belt Scale	1	36"	450 TPH	---	10,000
1.05	Plant Feed Magnet	1	---	---	7.5	17,000
1.06	Plant Feed Sampling System	1			10	100,000
1.07	Raw Coal Screens	2	6x16 DD	400 TPH	2x15	115,000
	SUBTOTAL				149.5	1,110,000
	BAUM JIG CIRCUIT					
2.01	Baum Jig	1		225 TPH		450,000
	Elevators	2		125 TPH	2x7.5	
	Blower	1			50	
	Controls	1			15	
2.02	Jig Refuse Screen	1	4x16 DD	120 TPH	15	50,000
2.03	Jig Clean Coal Screen	1	4x16 DD	100 TPH	15	65,000
2.04	Jig Water Sump	1	---	5000G	---	In Pump U.
2.05	Jig Water Pumps	2	8"x6"	1834 GPM/EA.	125 ea.	53,000
2.06	Classifying Cyclones	2	20" Dia.	1834 GPM	---	30,000
2.07	Jig Head Tank	1		2000 GA.	---	40,000

	BAUM JIG CIRCUIT (CONTINUED)	NO.	SIZE	CAPACITY	HP	COST
2.08	Surge Bin	1	---	50 Ton	---	70,000
2.09	Feeder	1	24"x60"	0-100 TPH	2	10,000
2.10	Rod Mill No. 1	1	9'Dia. x 13.5' Lg.	76 TPH	600	750,000
	SUBTOTAL				837	1,518,000
3.01	Desliming Sieve Bends	2	6'W, 40"R, 60°	3500 GPM Slurry	---	25,000
3.02	Desliming Screens	2	7'x16' S.D.	150 TPH	2x20	130,000
3.03	Primary H.M. Sump	1	---	5000 Gal.	---	In Pump U.
3.04	Primary H.M. Pumps	2	8"x6"	1850 GPM/Ea.	125 Ea.	60,000
3.05	Primary H.M. Cyclones	2	24" Dia.	75 TPH/Ea.	---	50,000
3.06	Refuse Sieve Bend	1	5'W,40"R, 60°	860 GPM	---	12,000
3.07	Refuse Screen	1	7' x 16'	60 TPH	20	65,000
3.08	Refuse Centrifuge	1	VC 48F	60 TPH	40	90,000
3.09	Primary Float Sieve Bends	2	5'W,40"R, 60°	1720 GPM	---	24,000
3.10	Primary Float Screens	2	7'x16' SD	100 TPH	2 x 20	130,000
	SUBTOTAL				265	586,000

	SECONDARY H.M. CYCLONE CIRCUIT	NO.	SIZE	CAPACITY	HP	COST
4.01	1/4" x 0 Sump	1		2500G	---	In Pump U.
4.02	1/4" x 0 Pumps	2	6" x 4"	1000 GPM/Ea.	50 Ea.	50,000
4.03	Secondary Desliming Sieve Bend	1	5'W,40"R, 60°	860 GPM	---	12,000
4.04	Secondary Desliming Screen	1	7'x16' SD	70 TPH	20	65,000
4.05	Secondary H.M. Sump	1		7000 Gal.	---	In Pump U.
4.06	Secondary H.M. Pumps	2	10" x 8"	2775 GPM/Ea.	150 Ea.	70,000
4.07	Secondary H.M. Cyclones	3	24" Dia.	50 TPH/Ea.	---	75,000
4.08	Clean Coal Sieve Bends	3	5'W,40"R, 60°	860 GPM/Ea.	---	36,000
4.09	Clean Coal Screens	3	7'x16' SD	145 TPH	3 x 20	195,000
4.10	Clean Coal Centrifuges	2	VC-48	180 TPH	2 x 41	175,000
4.11	Middling Sieve Bend	1	5'W,40"R, 60°	860 GPM	---	12,000
4.12	Middling Screen	1	7'x16' SD	55 TPH	20	65,000
	SUBTOTAL				382	755,000

	MAGNETITE RECOVERY & MAKE-UP CIRCUIT	NO.	SIZE	CAPACITY	HP	COST
5.01	Primary Magnetic Separators	4	8'W,36" Dia. S.D.	715 GPM/Ea.	4 x 5	80,000
5.02	Dilute Medium Sump	1		7000G		In Pump U.
5.03	Dilute Medium Pumps	2	10" x 8"	2830 GPM/Ea.	200 Ea.	70,000
5.04	Magnetite Cyclones	3	20" Dia.	950 GPM/Ea.	---	50,000
5.05	Secondary Magnetic Separators	2	8'W, 36" Dia. D.D.	560 GPM/Ea.	4 x 5	140,000
5.06	Magnetite Thickener	1	35" Dia.	2015 GPM	6	350,000
5.07	Underflow Pumps	2	4" x 3"	250 GPM	10 Ea.	40,000
5.08	Magnetite Diverter	1	---	---	---	15,000
5.09	MTO Sump	1	---	4000G	---	In Pump U.
5.10	MTO Pumps	2	8" x 10"	1915 GPM	60 Ea.	30,000
5.11	MTO Head Tank	1	---	---	---	15,000
5.12	Magnetite Bin	1	---	60 Ton	---	40,000
5.13	Dust Filter		---	---	2	10,000
5.14	Magnetite Feeder		---	---	2	10,000
5.15	Magnetite Ball Mill		3' Dia. 5' Lg.	1500 Lbs/Hr.	20	130,000
5.16	Ground Magnetite Sump	1		1000 G		In Pump U.

	MAGNETITE RECOVERY & MAKE-UP CIRCUIT (Continued)	NO.	SIZE	CAPACITY	HP	COST
5.17	Pumps	2	4" x 3"	400 GPM	15 Ea.	40,000
5.18	Ground Magnetite Cyclone	1	14" Dia.	400 GPM	---	15,000
5.19	H.M. Density Controls	4	---	---	---	40,000
5.20	Level Control Boxes	2	---	---	---	30,000
5.21	Recorder Controllers	4	---	---	---	20,000
5.22	Level Controls	10	---	---	---	20,000
	SUBTOTAL				355	1,145,000
	FROTH FLOTATION CIRCUIT					
6.01	Surge Bin	1	---	50 Ton	---	70,000
6.02	Feeder	1	---	0-50 TPH	2	20,000
6.03	Rod Mill #2	1	7.5'x11'-4	36 TPH	500	460,000
6.04	Froth Feed Sump	1	---	4000 Gal.		In Pump U.
6.05	Froth Feed Pumps	2	8' x 6'	1700 GPM @	50 Ea.	50,000
6.06	Froth Cell Distributors	2	---	---	---	12,000
6.07	Microçells	6	10' x 25'	15 TPH CC/Ea.		1,100,000
	Recirculation Pumps	6	10" x 8"	2400 GPM/Ea.	6x75	In Cell U.
	Air Compressors	2	---	750 CFM	2x200	80,000

	FROTH FLOTATION CIRCUIT (Continued)	NO.	SIZE	CAPACITY	HP	COST
6.09	Reagent System	1			5	100,000
6.10	Screen Bowl Distributor	1	---	---	---	25,000
6.11	Screen Bowls	2	44 x 132	50 TPH/Ea.	2 x 450	1,000,000
6.12	Screen Bowl Effluent Sump	1		1000 Gal.		In Pump U.
6.13	Screen Bowl Effluent Pumps	2	---	150 GPM/Ea.	5 Ea.	30,000
	SUBTOTAL				2312	2,947,000
	WATER CLARIFICATION SYSTEM					
7.01	Static Thickener	1	110' Dia. Hi-Rate	8500 GPM	7.5	750,000
7.02	Underflow Pumps	2	6 X 4	450 GPM/Ea.	10 Ea.	30,000
7.03	Belt Filter Presses	2	2M Wide	17 TPH/Ea.	2 x 7.5	325,000
7.04	Filter Washdown Pumps	3	1.5 x 1	100 GPM @ 100 PSI	3 x10	25,000
7.05	C.W. Sump	1		20000 GA		In Pump U.
7.06	C.W. Pump	3		4500 GPM/Ea.	2 x 200	80,000
7.07	C.W. Head Tank	1	---	---	---	50,000
7.08	Flocculation Facilities		---	---	5	150,000
7.09	Fresh Water Make-Up Facilities	---		450 GPM	50	156,000
	SUBTOTAL				517.5	1,566,000

		NO.	SIZE	CAPACITY	HP	COST
	MISCELLANEOUS PLANT EQUIPMENT					
8.01	Magnetite Clean-Up Pump	1	2-1/2" Vert.	150 GPM	7.5	25,000
8.02	Clean Up Sieve Bend	1	4'W, 40"R, 60°	---	---	10,000
8.03	Plant Clean-Up Pump	1	2-1/2" Vert.	150 GPM	7.5	25,000
8.04	Plant Clean-Up Sieve	1	4'W; 40"R, 60°	---	---	10,000
8.05	Plant Air System	1		200 CFM-100 PSI	50	70,000
8.06	Washdown System	---	---	---	---	20,000
8.07	Machinery Hoist & Trolleys	Lot	---	---	10	100,000
8.08	Gland Water System	---	---	---	5	30,000
8.09	Laboratory Equipment	Lot	---	---		150,000
	SUBTOTAL				80	440,000
	STRUCTURES					3,900,000
	PREPARATION PLANT TOTAL				4548	13,967,000
	REFUSE HANDLING SYSTEM					
9.01	Refuse Belt Conveyor	1	30" x 250	250 TPH	30	220,000
9.02	Refuse Bin	1		250 Ton		600,000
9.03	Refuse Bin Gate	1	---	---	5	30,000
9.04	Refuse Disposal Belt	1	30"	250 TPH	75	533,000
	SUBTOTAL				110	1,383,000

		NO.	SIZE	CAPACITY	HP	COST
	CLEAN COAL HANDLING SYSTEM					
10.01	1/4" x 28M Belts No. 1 & 2		30"	150 TPH Each	2 x 25	450,000
10.02	1/4" x 28M Belt Scale			150 TPH		10,000
10.03	Surge Bin			50 Ton		70,000
10.04	28M x 0 Belt		30"	150 TPH	25	225,000
10.05	Belt Scale			150 TPH		10,000
	SUBTOTAL				75	765,000
	GRINDING & CWF SLURRY SYSTEM					
11.01	Feeder	1	4' X 6'	150 TPH	2	10,000
11.02	Rod Mill No. III	1	12.5 x 19'	110 TPH	1500	1,900,000
11.03	Ball Mill #1	1	14.5 x 29'	90 TPH	3600	3,200,000
11.04	Screw Blender	1		200 TPH	25	50,000
11.05	Fine Coal Sump					In Pump U.
11.07	Fine Coal Pumps	2	10" x 10"	600 GPM	60 Ea.	150,000
11.07	Ball Mill #2	1	18.5 x 33.5'	201 TPH	7000	5,000,000
11.08	Magnet	1			10	25,000
11.09	Coal Water Fuel Sump	1		3000 Gal.		In Pump U.
11.10	CWF Pumps	3	10" x 10"	480 GPM/Ea.	2 x 50	150,000
11.11	Mixing Tank Distributors	2	---	---	---	25,000
11.12	Mixing Tanks	4		4 x 20000 Gal.	---	110,000

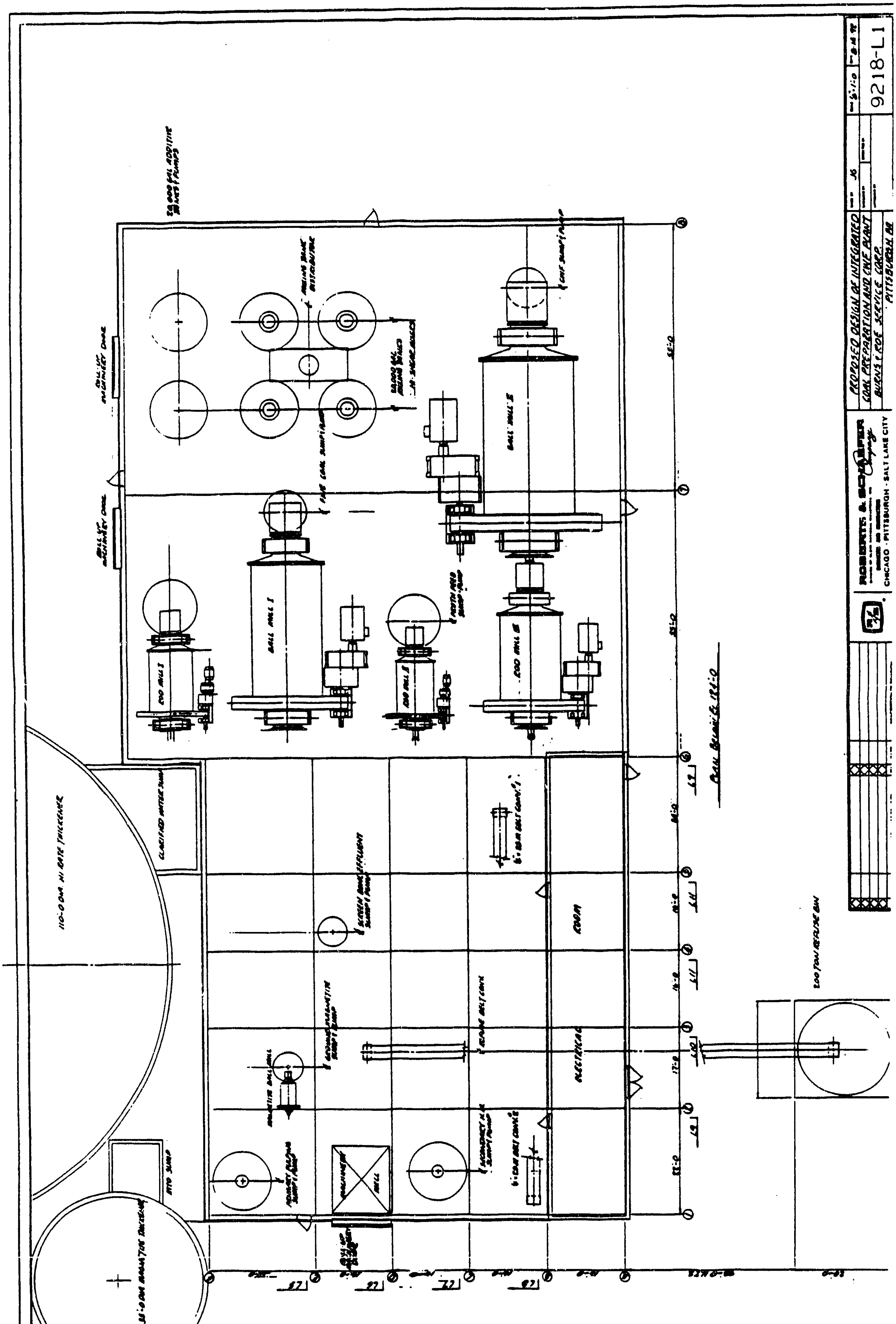
		NO.	SIZE	CAPACITY	HP	COST
	GRINDING & CWF SLURRY SYSTEM					
11.13	Hi-Shear Mixers	4			4x300	500,000
11.14	Mixing Tank Pumps	8		960 GPM/Ea.	4x30 Ea.	300,000
11.15	Storage Tanks	2		2 x 1.5 Mil. Gal.	---	2,000,000
11.16	Storage Tank Pumps	2	10" x 10"	480 GPM	2x50	150,000
11.17	Additive Tanks	2		20000 Ga. Ea.		In Pump U.
11.18	Additive Pumps	2		2 GPM Ea.		55,000
	SUBTOTAL				13717	13,625,000
	Structures					2,100,000
	CWF PLANT TOTAL					15,725,000

SUMMARY

	HP	Cost
PREPARATION PLANT -	4898	$ 13,967,000
REFUSE HANDLING -	110	$ 1,383,000
C.C. HANDLING -	75	$ 765,000
CWF PLANT -	13717	$ 15,725,000
CONTINGENGY (~30%)-		$ 9,560,000
TOTAL	18800	$ 41,400,000

Table C-2. Plant Manning Table and Labor Cost Estimate

Management		No.
Plant Manager		1
General Foreman		1
Chemist		1
Clerk		1
Total		4
Operating		
Shift Foreman		1
Plant Operator		1
Electrician		1
Mechanic		2
Welder		1
Thickener & Presses		1
Repairman Helper		1
Utility Man		2
Grinding Plant		4
Quality Control		2
Total		16
Summary		
Management		4
Operating Shifts (4)	4 × 16 =	64
		68
At average $70,000/man/year		$4,760,000/year
Per Ton of CWF Coal Solids		$3.26/ton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COAL PREPARATION AND CWF PLANT
BURNS & ROE SERVICE CORP.
PITTSBURGH PA
ROBERTS & SCHAEFER
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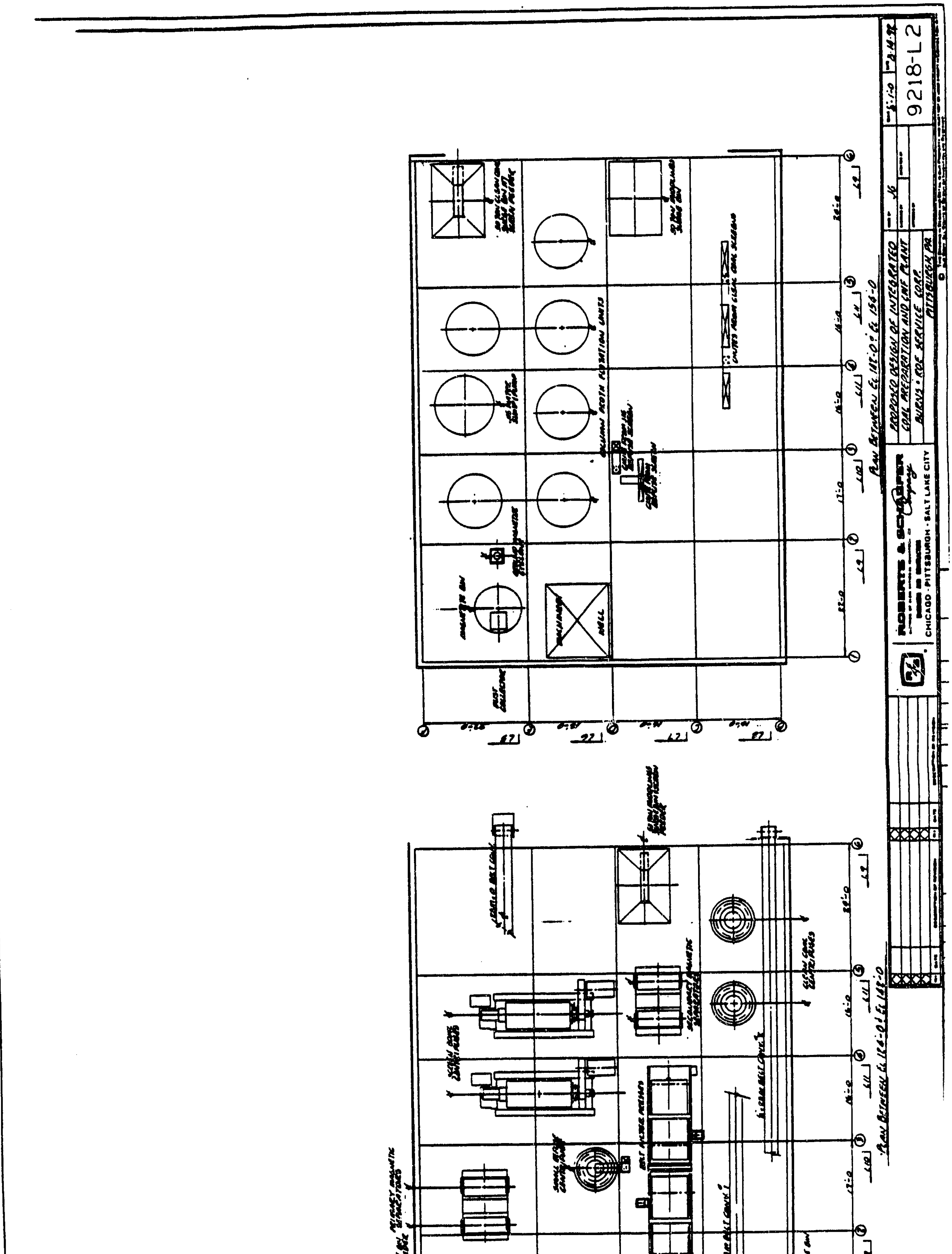
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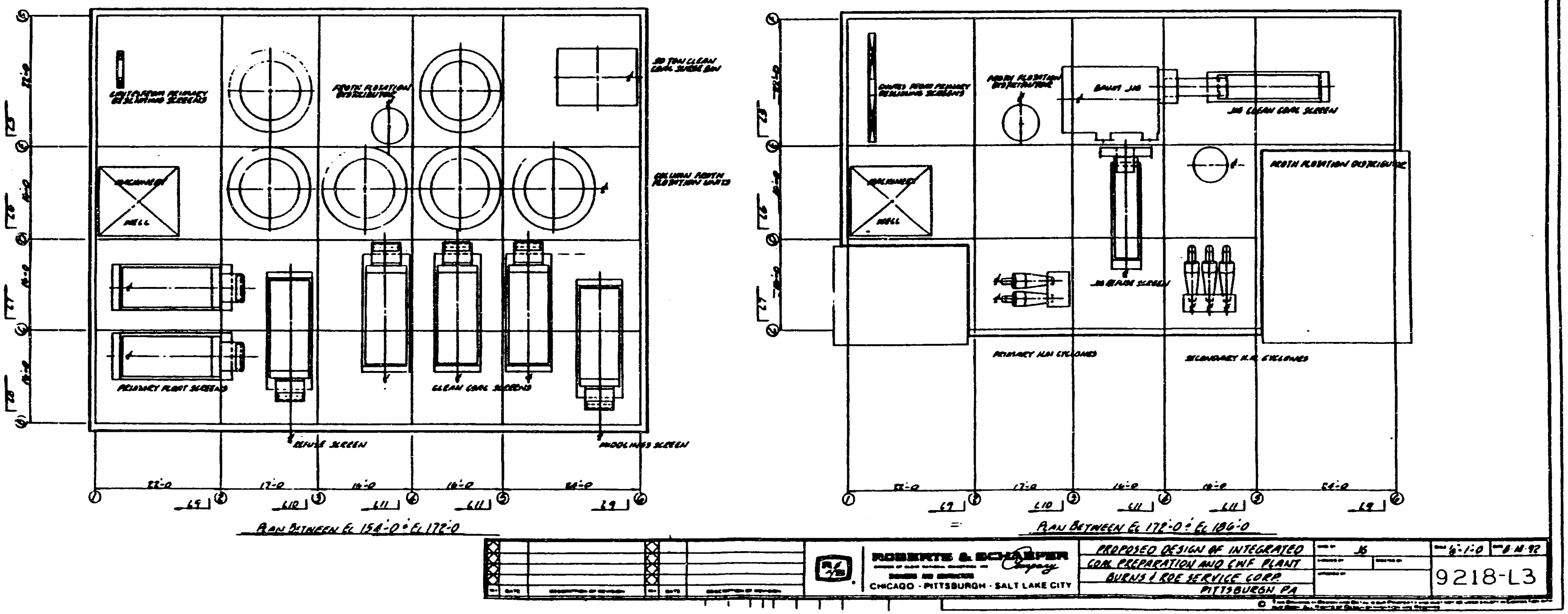

PRIMARY PLANT SCREENS
REFUSE SCREEN
CLEAN COAL SCREENS
MIDDLINGS SCREEN
FROTH FLOTATION DISTRIBUTOR
COLUMN FROTH FLOTATION UNITS
WELL
PLAN BETWEEN EL 154'-0" & EL 172'-0
BAUM JIG
JIG CLEAN COAL SCREEN
FROTH FLOTATION DISTRIBUTOR
PRIMARY H.M. CYCLONES
SECONDARY H.M. CYCLONES
PLAN BETWEEN EL 172'-0" & EL 186'-0
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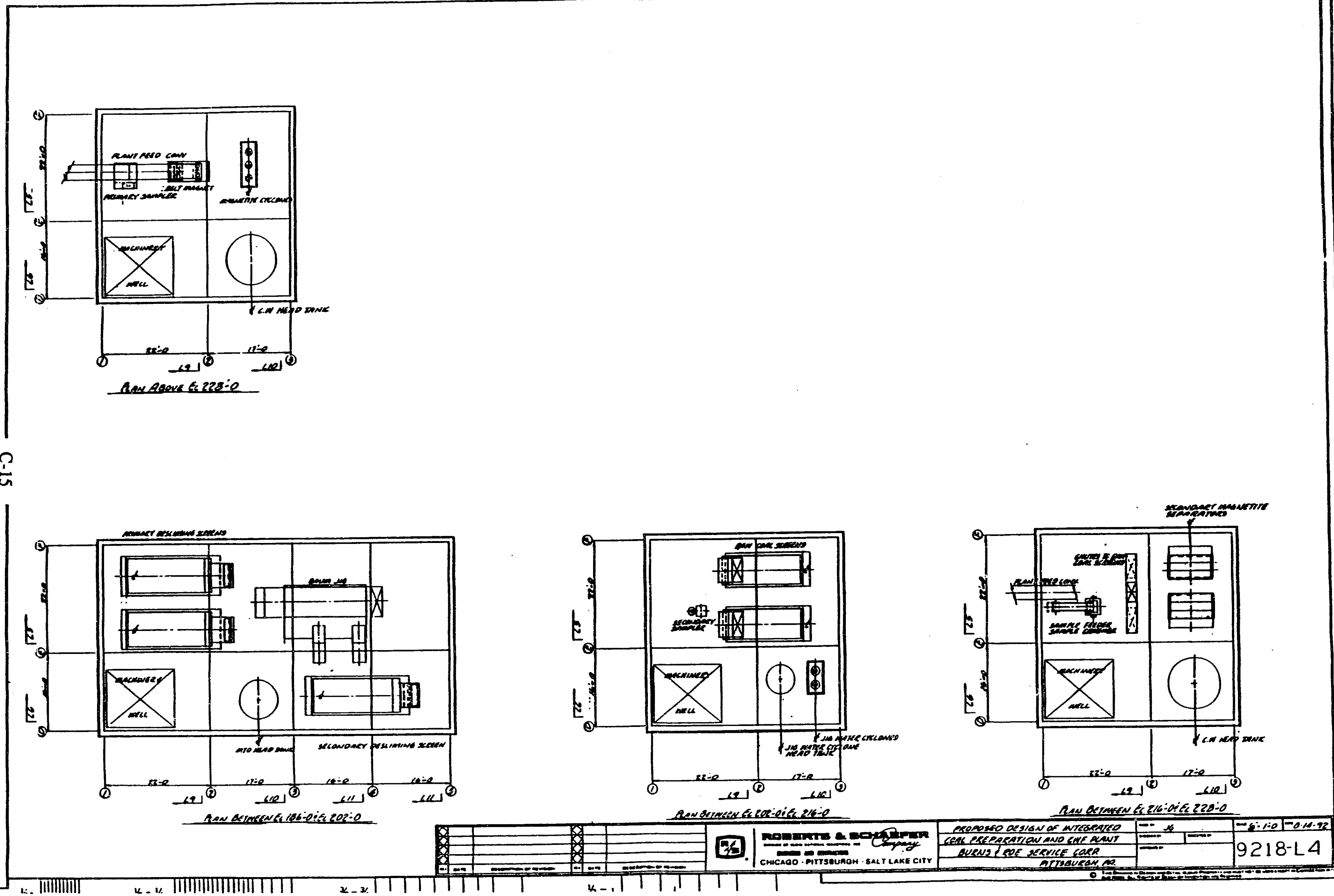
PLANT FEED CONV
BELT MAGNET
PRIMARY SAMPLER
MAGNETITE CYCLONES
MACHINERY WELL
℄ C.M HEAD TANK
PLAN ABOVE EL 228'-0
PRIMARY DESLIMING SCREENS
BAUM JIG
MTO HEAD TANK
SECONDARY DESLIMING SCREEN
PLAN BETWEEN EL 186'-0" & EL 202'-0
RAW COAL SCREENS
SECONDARY SAMPLER
℄ JIG WATER CYCLONES
℄ JIG WATER CYCLONE HEAD TANK
PLAN BETWEEN EL 202'-0" & EL 216'-0
SECONDARY MAGNETITE SEPARATORS
PLANT FEED CONV
SAMPLE FEEDER SAMPLE CRUSHER
PLAN BETWEEN EL 216'-0" & EL 228'-0
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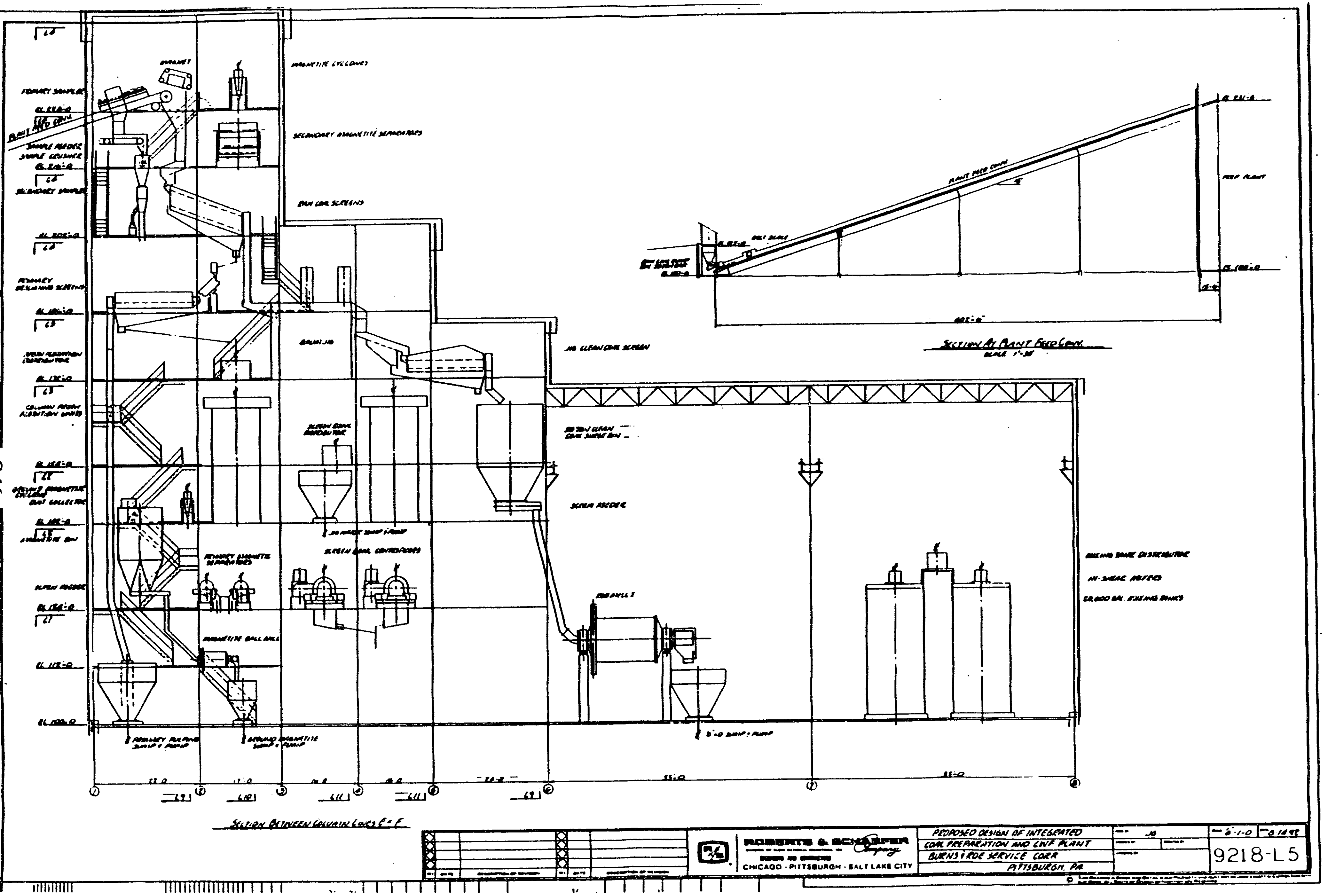
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SECTION BETWEEN COLUMN LINES E-F
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PROPOSED DESIGN OF INTEGRATED
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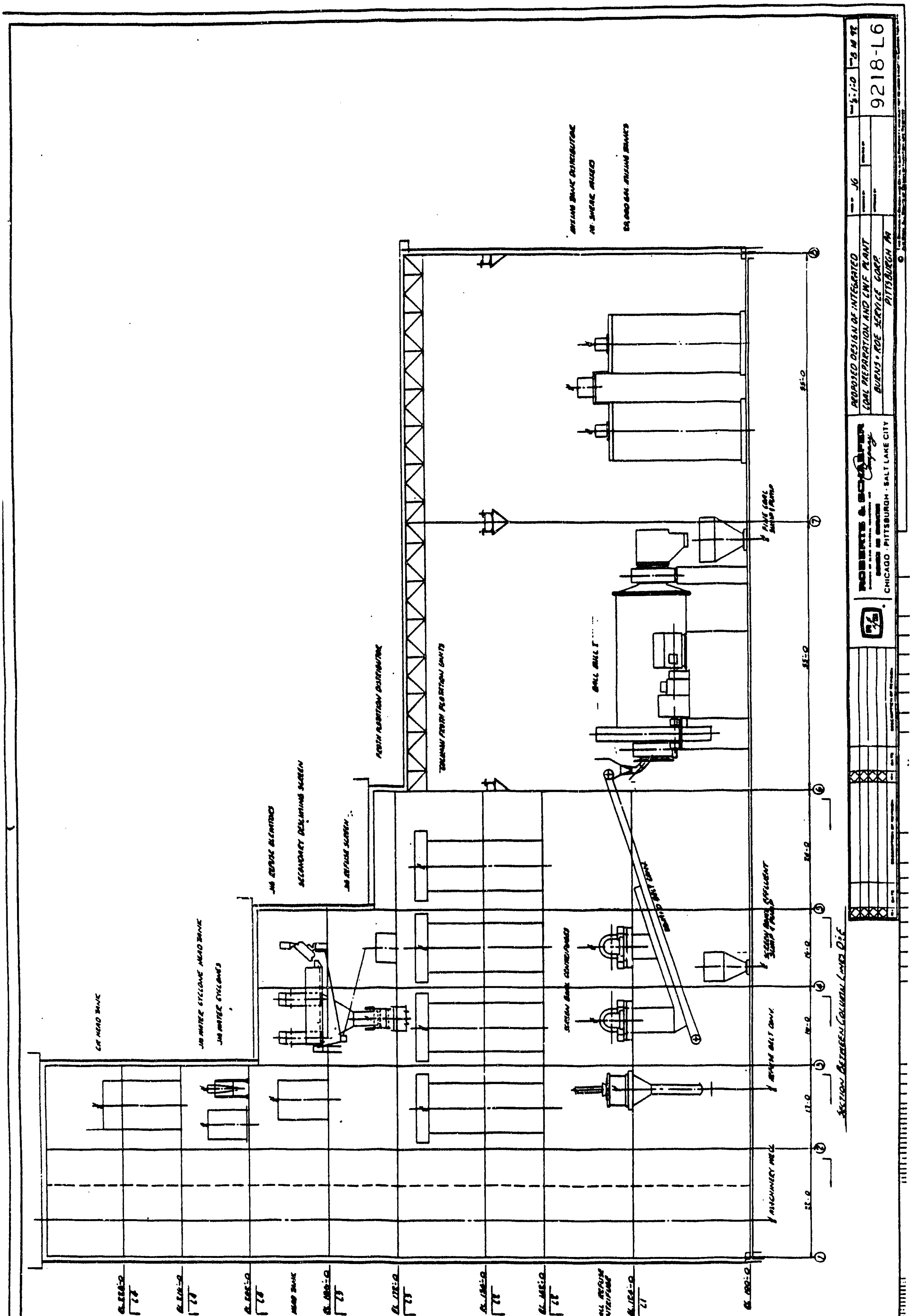
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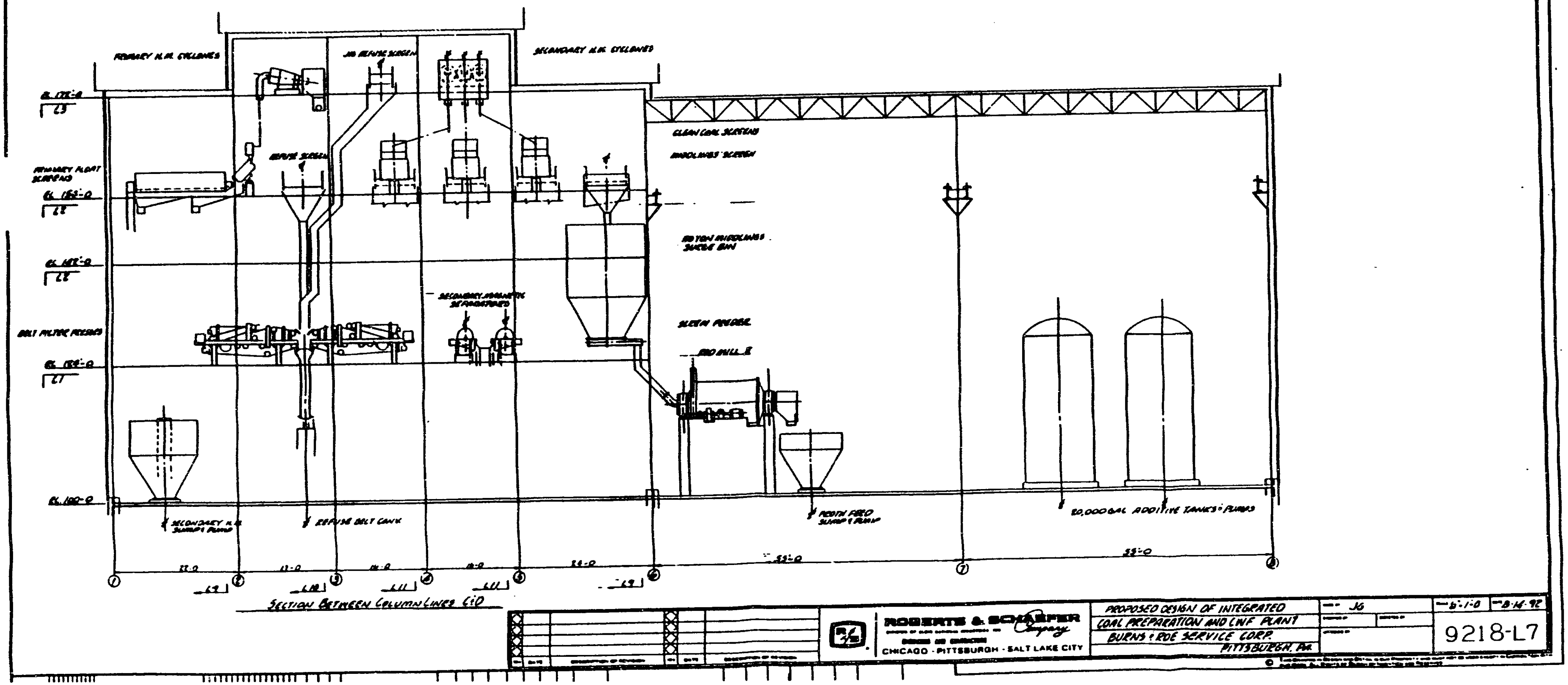
SECTION BETWEEN COLUMN LINES D-E



PRIMARY H.M. CYCLONES
JIG REFUSE SCREEN
SECONDARY H.M. CYCLONES
CLEAN COAL SCREENS
MIDDLINGS SCREEN
REFUSE SCREEN
PRIMARY FLOAT SCREENS
SECONDARY MAGNETIC SEPARATORS
BELT FILTER PRESSES
SCREW FEEDER
ROD MILL
SECONDARY H.M. SUMP & PUMP
REFUSE BELT CONV.
FROTH FEED SUMP & PUMP
20,000 GAL ADDITIVE TANKS & PUMPS
SECTION BETWEEN COLUMN LINES 1 & 8
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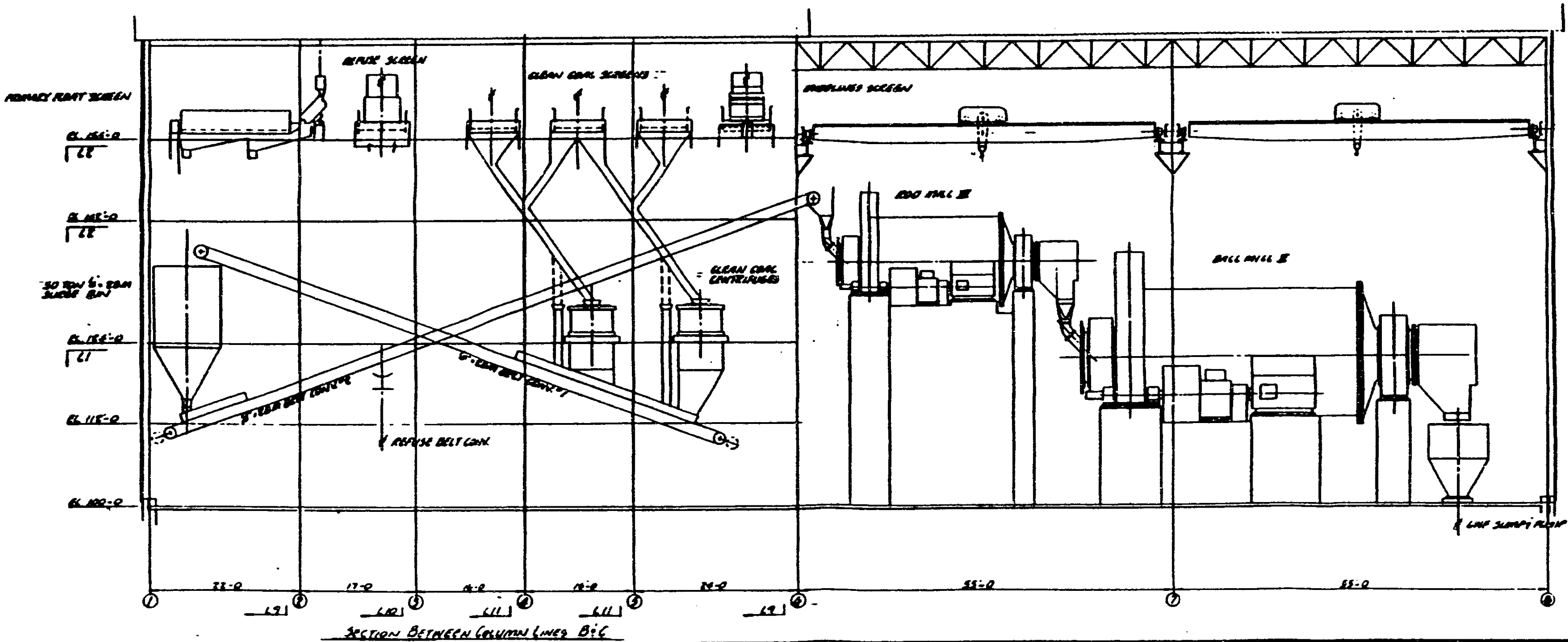

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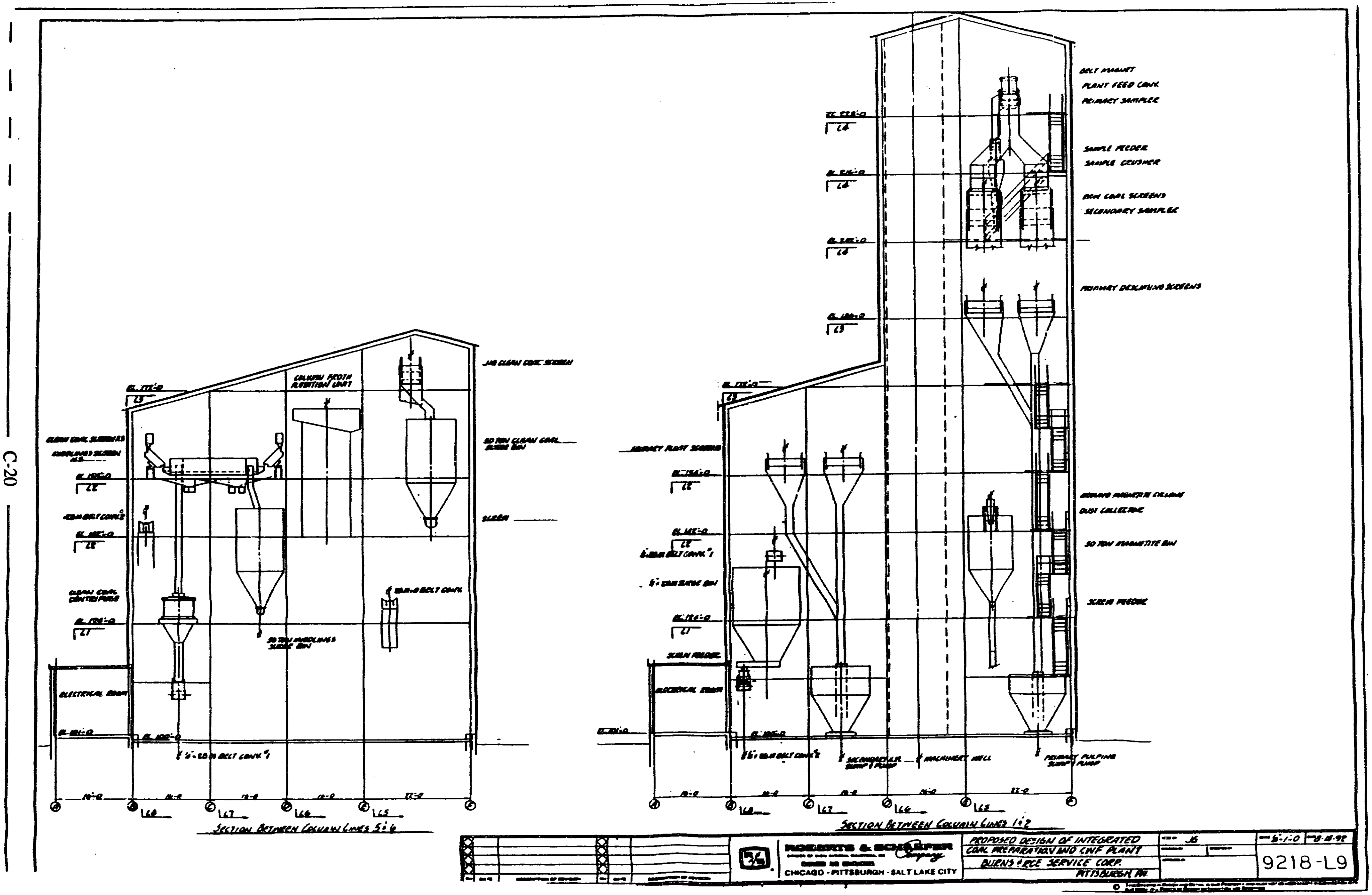
BELT MAGNET
PLANT FEED CONV.
PRIMARY SAMPLER
SAMPLE FEEDER
SAMPLE CRUSHER
RAW COAL SCREENS
SECONDARY SAMPLER
PRIMARY DESLIMING SCREENS
DUST COLLECTOR
50 TON MAGNETITE BIN
SCREW FEEDER
PRIMARY PULPING SUMP & PUMP
MACHINERY WELL
ELECTRICAL ROOM
SCREW FEEDER
CLEAN COAL CENTRIFUGE
COLUMN FROTH FLOTATION UNIT
SCREEN
SECTION BETWEEN COLUMN LINES 5 & 6
SECTION BETWEEN COLUMN LINES 1 & 2
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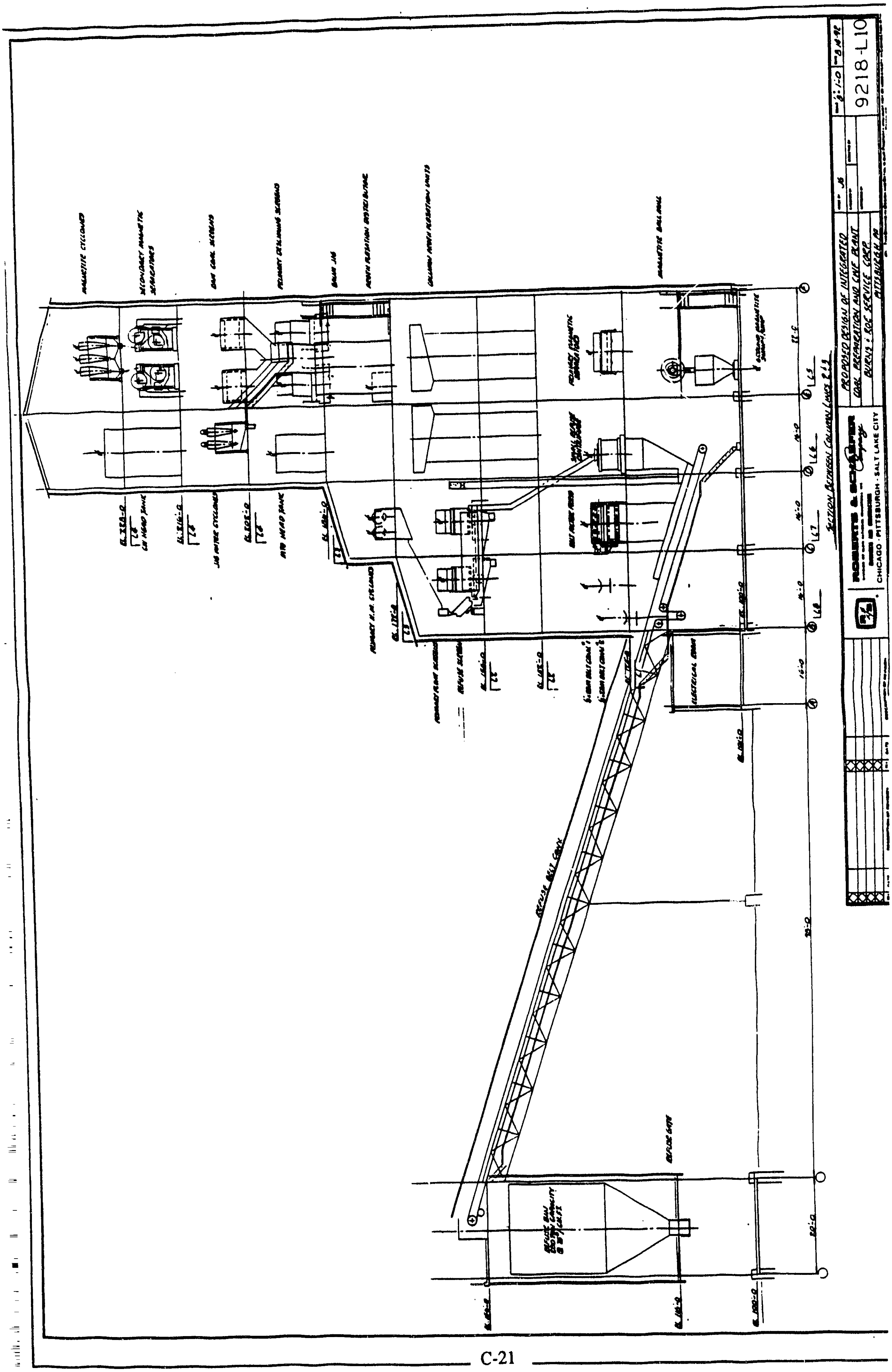

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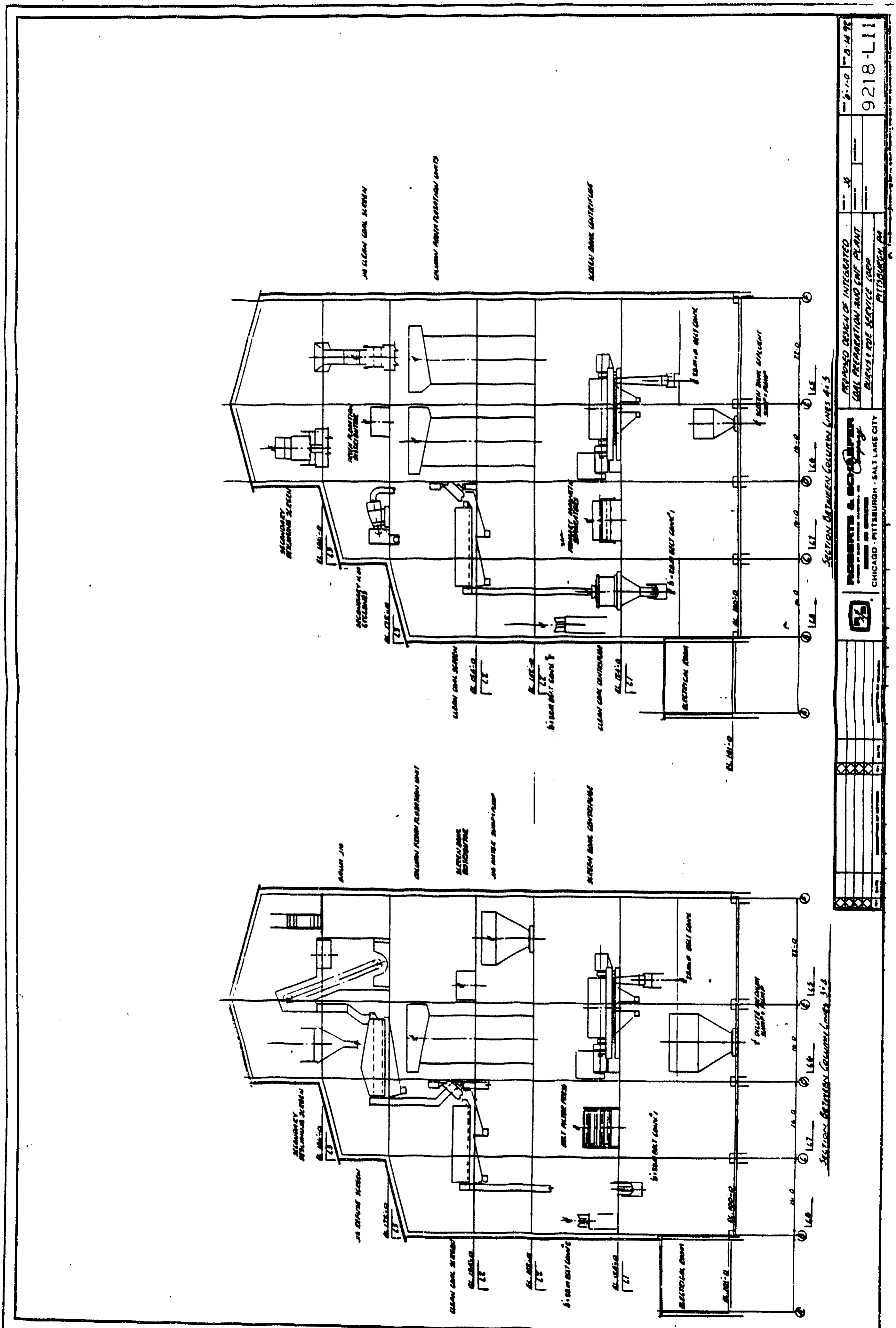
REFUSE BELT CONV.



SECTION BETWEEN COLUMN LINES 4 & 5
SECTION BETWEEN COLUMN LINES 3 & 4
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Appendix D

FLOW STREAM CHARACTERISTICS

The appended tables list the calculated washability characteristics of each product stream shown in Figure 1, with the exception of the column flotation products. Streams are referenced in the tables by their respective stream numbers as well as their origins and destinations. All tabulated stream data shown were calculated by the coal preparation plant simulator used in this study, with the exception of streams # 1 and # 10 whose characteristics are partly based on experimental data supplied to the simulator. The Btu values shown in these tables were calculated from empirical relationships built into the simulator. These sometimes differ from the actual values which are based on proximate analyses and which were used in calculating the heating values of the flowstreams.

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 1 ORIGIN: Plant Feed Conveyor Belt DESTINATION: Primary Raw Coal Screen (1/4")

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt %	Ash %	Total Sulfur %	Btu/lb
2-3/8 by 1	16.6 percent	Float 1.30	17.5	5.1	.65	14,559	17.5	5.1	.65	14,559
		1.30 - 1.40	1.2	8.2	.65	14,052	18.7	5.3	.65	14,526
		1.40 - 1.50	1.7	8.3	.67	14,035	20.4	5.5	.65	14,485
		1.50 - 1.70	1.7	40.7	.67	8,737	22.1	8.3	.65	14,043
		1.70 - 1.80	1.0	89.1	.59	3,718	23.1	11.8	.65	13,596
		1.80 - 1.90	2.0	89.2	.59	3,718	25.1	17.9	.65	12,809
		1.90 - 2.10	5.0	89.1	.59	3,718	30.1	29.8	.64	11,299
		2.10 - 2.30	15.0	89.1	.59	3,718	45.1	49.5	.62	8,777
		Sink 2.30	54.9	89.1	.59	3,718	100.0	71.3	.60	6,000
1 by 1/2	16.5 percent	Float 1.30	40.0	4.7	.74	14,624	40.0	4.7	.74	14,624
		1.30 - 1.40	1.6	5.8	.74	14,444	41.6	4.7	.74	14,617
		1.40 - 1.50	2.2	8.0	1.21	14,084	43.8	4.9	.76	14,590
		1.50 - 1.70	2.3	38.5	1.21	9,096	46.1	6.6	.79	14,316
		1.70 - 1.80	2.5	88.8	.51	3,718	48.6	10.8	.77	13,771
		1.80 - 1.90	2.5	88.8	.51	3,718	51.1	14.6	.76	13,279
		1.90 - 2.10	12.5	88.8	.51	3,718	63.6	29.2	.71	11,400
		2.10 - 2.30	16.0	88.8	.51	3,718	79.6	41.2	.67	9,856
		Sink 2.30	20.4	88.8	.51	3,718	100.0	50.9	.64	8,604
1/2 by 1/4	16.6 percent	Float 1.30	40.5	2.3	.80	15,013	40.5	2.3	.80	15,013
		1.30 - 1.40	16.4	7.7	.98	14,137	56.9	3.9	.85	14,761
		1.40 - 1.50	3.7	17.0	1.55	12,614	60.6	4.7	.89	14,630
		1.50 - 1.70	1.6	29.7	2.57	10,534	62.2	5.3	.94	14,524
		1.70 - 1.80	1.0	87.8	.57	3,718	63.2	6.6	.93	14,353
		1.80 - 1.90	1.0	87.8	.57	3,718	64.2	7.9	.93	14,188
		1.90 - 2.10	3.0	87.8	.57	3,718	67.2	11.5	.91	13,720
		2.10 - 2.30	8.0	87.8	.57	3,718	75.2	19.6	.87	12,656
		Sink 2.30	24.8	87.8	.57	3,718	100.0	36.5	.80	10,439

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 1 (cont.) ORIGIN: Plant Feed Conveyor Belt DESTINATION: Primary Raw Coal Screen (1/4")

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	33.9 percent	Float 1.30	58.3	2.0	[illegible]	15,062	58.3	2.0	.85	15,062
		1.30 - 1.40	9.7	8.8	1.29	13,950	68.0	3.0	.91	14,904
		1.40 - 1.50	2.5	18.4	2.05	12,385	70.5	3.5	.95	14,814
		1.50 - 1.70	1.4	32.3	2.52	10,109	71.9	4.1	.98	14,723
		1.70 - 1.80	1.0	88.9	.64	3,718	72.9	5.3	.98	14,572
		1.80 - 1.90	2.0	88.9	.64	3,718	74.9	7.5	.97	14,282
		1.90 - 2.10	2.5	88.9	.64	3,718	77.4	10.1	.96	13,941
		2.10 - 2.30	8.0	88.9	.64	3,718	85.4	17.5	.93	12,983
		Sink 2.30	14.6	88.9	.64	3,718	100.0	27.9	.89	11,630
28 by 0	16.4 percent	Float 1.30	16.5	2.5	.79	14,987	16.5	2.5	.79	14,987
		1.30 - 1.40	33.8	5.3	.80	14,531	50.3	4.4	.80	14,681
		1.40 - 1.50	11.0	[illegible]	.90	13,662	61.3	5.5	.82	14,498
		1.50 - 1.70	6.7	30.0	.88	10,480	68.0	7.9	.82	14,102
		1.70 - 1.80	2.5	63.8	.85	4,962	70.5	9.9	.82	13,778
		1.80 - 1.90	1.0	63.8	.85	4,962	71.5	10.6	.82	13,655
		1.90 - 2.10	1.5	63.8	.85	4,962	73.0	11.7	.82	13,476
		2.10 - 2.30	5.0	63.8	.85	4,962	78.0	15.1	.83	12,930
		Sink 2.30	22.0	63.8	.85	4,962	100.0	25.8	.83	11,177
Composite	100.0 percent	Float 1.30	38.7	2.8	.80	14,936	38.7	2.8	.80	14,936
		1.30 - 1.40	12.0	6.8	.97	14,273	50.7	3.8	.87	14,779
		1.40 - 1.50	3.9	12.9	1.26	13,287	54.6	4.4	.87	14,672
		1.50 - 1.70	2.5	32.9	1.40	10,009	57.1	5.7	.90	14,468
		1.70 - 1.80	1.5	81.9	.65	[illegible]	58.6	7.6	.89	14,203
		1.80 - 1.90	1.8	86.5	.61	3,834	60.4	9.9	.88	13,902
		1.90 - 2.10	4.5	87.4	.57	3,786	64.9	15.2	.86	13,202
		2.10 - 2.30	10.0	86.7	.60	3,820	74.8	24.8	.83	11,950
		Sink 2.30	25.2	85.2	.62	3,896	100.0	40.0	.77	9,924

Flowstream Summary: Flowrate = 376 tons per hour Ash = 40.0 percent Total Sulfur = 0.77 percent Btu Content = 9,924 Btu/lb SO_2 Content = 1.56 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 2 ORIGIN: Raw Coal Screen (1/4") DESTINATION: Baum Jig

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
2-3/8 by 1	33.8 percent	Float 1.30	17.5	5.1	.65	14,559	17.5	5.1	.65	14,559
		1.30 - 1.40	1.2	8.2	.67	14,052	18.7	5.3	.65	14,526
		1.40 - 1.50	1.7	8.3	.67	14,035	20.4	5.5	.65	14,485
		1.50 - 1.70	1.7	40.7	.59	8,737	22.1	8.3	.65	14,043
		1.70 - 1.80	1.0	89.1	.59	3,718	23.1	11.8	.65	13,596
		1.80 - 1.90	2.0	89.2	.59	3,718	25.1	17.9	.65	12,809
		1.90 - 2.10	5.0	89.1	.59	3,718	30.1	29.8	.64	11,299
		2.10 - 2.30	15.0	89.1	.59	3,718	45.1	49.5	.62	8,777
		Sink 2.30	54.9	89.1	.59	3,718	100.0	71.3	.60	6,000
1 by 1/2	33.6 percent	Float 1.30	40.0	4.7	.74	14,624	40.0	4.7	.74	14,624
		1.30 - 1.40	1.6	5.8	.74	14,444	41.6	4.7	.74	14,617
		1.40 - 1.50	2.2	8.0	1.21	14,084	43.8	4.9	.76	14,590
		1.50 - 1.70	2.3	38.5	1.21	9,096	46.1	6.6	.79	14,316
		1.70 - 1.80	2.5	88.8	.51	3,718	48.6	10.8	.77	13,771
		1.80 - 1.90	2.5	88.8	.51	3,718	51.1	14.6	.76	13,279
		1.90 - 2.10	12.5	88.8	.51	3,718	63.6	29.2	.71	11,400
		2.10 - 2.30	16.0	88.8	.51	3,718	79.6	41.2	.67	9,856
		Sink 2.30	20.4	88.8	.51	3,718	100.0	50.9	.64	8,604
1/2 by 1/4	30.9 percent	Float 1.30	40.5	2.3	.80	15,013	40.5	2.3	.80	15,013
		1.30 - 1.40	16.4	7.7	.98	14,137	56.9	3.9	.85	14,761
		1.40 - 1.50	3.7	17.0	1.55	12,614	60.6	4.7	.89	14,630
		1.50 - 1.70	1.6	29.7	2.57	10,534	62.2	5.3	.94	14,524
		1.70 - 1.80	1.0	87.8	.57	3,718	63.2	6.6	.93	14,353
		1.80 - 1.90	1.0	87.8	.57	3,718	64.2	7.9	.93	14,188
		1.90 - 2.10	3.0	87.8	.57	3,718	67.2	11.5	.91	13,720
		2.10 - 2.30	8.0	87.8	.57	3,718	75.2	19.6	.87	12,656
		Sink 2.30	24.8	87.8	.57	3,718	100.0	36.5	.80	10,439

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 2 (cont.) ORIGIN: Raw Coal Screen (1/4") DESTINATION: Baum Jig

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	1.8 percent	Float 1.30	58.3	2.0	.85	15,062	58.3	2.0	.85	15,062
		1.30 - 1.40	9.7	8.8	1.29	13,950	68.0	3.0	.91	14,904
		1.40 - 1.50	2.5	18.4	2.05	12,385	70.5	3.5	.95	14,814
		1.50 - 1.70	1.4	32.3	2.52	10,109	71.9	4.1	.98	14,723
		1.70 - 1.80	1.0	88.9	.64	3,718	72.9	5.3	.98	14,572
		1.80 - 1.90	2.0	88.9	.64	3,718	74.9	7.5	.97	14,282
		1.90 - 2.10	2.5	88.9	.64	3,718	77.4	10.1	.96	13,941
		2.10 - 2.30	8.0	88.9	.64	3,718	85.4	17.5	.93	12,983
		Sink 2.30	14.6	88.9	.64	3,718	100.0	27.9	.89	11,630
28 by 0	.1 percent	Float 1.30	16.5	2.5	.79	14,987	16.5	2.5	.79	14,987
		1.30 - 1.40	33.8	5.3	.80	14,531	50.3	4.4	.80	14,681
		1.40 - 1.50	11.0	10.6	.90	13,662	61.3	5.5	.82	14,498
		1.50 - 1.70	6.7	30.0	.88	10,480	68.0	7.9	.82	14,102
		1.70 - 1.80	2.5	63.8	.85	4,962	70.5	9.9	.82	13,778
		1.80 - 1.90	1.0	63.8	.85	4,962	71.5	10.6	.82	13,655
		1.90 - 2.10	1.5	63.8	.85	4,962	73.0	11.7	.82	13,476
		2.10 - 2.30	5.0	63.8	.85	4,962	78.0	15.1	.83	12,930
		Sink 2.30	22.0	63.8	.85	4,962	100.0	25.8	.83	11,177
Composite	100.0 percent	Float 1.30	32.9	3.8	.75	14,774	32.9	3.8	.75	14,774
		1.30 - 1.40	6.2	7.6	.95	14,154	39.1	4.4	.78	14,676
		1.40 - 1.50	2.5	12.4	1.26	13,372	41.6	4.9	.81	14,597
		1.50 - 1.70	1.9	36.8	1.42	9,382	43.3	6.2	.84	14,373
		1.70 - 1.80	1.5	88.6	.54	3,719	44.9	9.0	.83	14,016
		1.80 - 1.90	1.9	88.7	.55	3,718	46.8	12.2	.82	13,607
		1.90 - 2.10	6.9	88.7	.54	3,718	53.7	21.9	.78	12,344
		2.10 - 2.30	13.0	88.7	.55	3,718	66.7	35.0	.74	10,657
		Sink 2.30	33.3	88.8	.57	3,718	100.0	52.9	.68	8,346

Flowstream Summary: Flowrate = 185 tons per hour Ash = 52.9 percent Total Sulfur = 0.68 percent Btu Content = 8,346 Btu/lb SO_2 Content = 1.63 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 3			ORIGIN: Raw Coal Screen (1/4") FRACTION				DESTINATION: Primary Raw Coal Screen (28M) CUMULATIVE			
Size Fraction and Weight		Sp. Gr.	Wt. %	Ash %	Total Sulfur %	Btu/lb	Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	2.8 percent	Float 1.30	40.5	2.3	.80	15,013	40.5	2.3	.80	15,013
		1.30 - 1.40	16.4	7.7	.98	14,137	56.9	3.9	.85	14,761
		1.40 - 1.50	3.7	17.0	1.55	12,614	60.6	4.7	.89	14,630
		1.50 - 1.70	1.6	29.7	2.57	10,534	62.2	5.3	.94	14,524
		1.70 - 1.80	1.0	87.8	.57	3,718	63.2	6.6	.93	14,353
		1.80 - 1.90	1.0	87.8	.57	3,718	64.2	7.9	.93	14,188
		1.90 - 2.10	3.0	87.8	.57	3,718	67.2	11.5	.91	13,72[illegible]
		2.10 - 2.30	8.0	87.8	.57	3,718	75.2	16.6	.87	12,656
		Sink 2.30	24.8	87.8	.57	3,718	100.0	36.5	.80	10,439
1/4 by 28	65.0 percent	Float 1.30	58.3	2.0	.85	15,062	58.3	2.0	.85	15,062
		1.30 - 1.40	9.7	8.8	1.29	13,950	68.0	3.0	.91	14,904
		1.40 - 1.50	2.5	18.4	2.05	12,385	70.5	3.5	.95	14,814
		1.50 - 1.70	1.4	32.3	2.52	10,109	71.9	4.1	.98	14,723
		1.70 - 1.80	1.0	88.9	.64	3,718	72.9	5.3	.98	14,572
		1.80 - 1.90	2.0	88.9	.64	3,718	74.9	7.5	.97	14,282
		1.90 - 2.10	2.5	88.9	.64	3,718	77.4	10.1	.96	13,941
		2.10 - 2.30	8.0	88.9	.64	3,718	85.4	17.5	.93	12,983
		Sink 2.30	14.6	88.9	.64	3,718	100.0	27.9	.89	11,630

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 3 (cont.) ORIGIN: Raw Coal Screen (1/4") DESTINATION: Primary Raw Coal Screen (28M)

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
28 by 0	32.2 percent	Float 1.30	16.5	2.5	.79	14,987	16.5	2.5	.79	14,987
		1.30 - 1.40	38.8	5.3	.80	14,531	50.3	4.4	.80	14,681
		1.40 - 1.50	11.0	10.6	.90	13,662	61.3	5.5	.82	14,498
		1.50 - 1.70	6.7	30.0	.88	10,480	68.0	7.9	.82	14,102
		1.70 - 1.80	2.5	63.8	.85	4,962	70.5	9.9	.82	13,778
		1.80 - 1.90	1.0	63.8	.85	4,962	71.5	10.6	.82	13,655
		1.90 - 2.10	1.5	63.8	.85	4,962	73.0	11.7	.82	13,476
		2.10 - 2.30	5.0	63.8	.85	4,962	78.0	13.1	.83	12,930
		Sink 2.30	22.0	63.8	.85	4,962	100.0	25.8	.83	11,177
Composite	100.0 percent	Float 1.30	44.3	2.1	.84	15,052	44.3	2.1	.84	15,052
		1.30 - 1.40	17.7	6.6	.98	14,313	62.0	3.4	.88	14,842
		1.40 - 1.50	5.3	13.1	1.27	13,248	67.3	4.1	.91	14,717
		1.50 - 1.70	3.1	30.7	1.38	10,372	70.4	5.3	.93	14,525
		1.70 - 1.80	1.5	75.2	.75	4,394	71.9	6.8	.93	14,315
		1.80 - 1.90	1.6	84.0	.68	3,961	73.5	8.5	.92	14,083
		1.90 - 2.10	2.2	83.3	.68	3,992	75.7	10.7	.92	13,791
		2.10 - 2.30	7.0	83.1	.69	4,003	82.7	16.8	.50	12,959
		Sink 2.30	17.3	78.5	.72	4,229	100.0	27.5	.87	11,451

Flowstream Summary: Flowrate = 191 tons per hour Ash = 27.5 percent Total Sulfur = 0.87 percent Btu Content = 11,451 Btu/lb SO_2 Content = 1.51 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 4 ORIGIN: Baum Jig DESTINATION: Rod Mill I

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
2-3/8 by 1	15.9 percent	Float 1.30	89.1	5.1	.65	14,559	89.1	5.1	.65	14,559
		1.30 - 1.40	5.2	8.2	.65	14,052	94.3	5.3	.65	14,531
		1.40 - 1.50	4.5	8.3	.67	14,035	98.8	5.4	.65	14,508
		1.50 - 1.70	1.1	40.7	.67	8,737	99.9	5.8	.65	14,442
		1.70 - 1.80	.1	89.1	.59	3,718	100.0	5.9	.65	14,435
		1.80 - 1.90	.0	89.2	.59	3,718	100.0	5.9	.65	14,434
		1.90 - 2.10	.0	89.1	.59	3,718	100.0	5.9	.65	14,434
		2.10 - 2.30	.0	89.1	.59	3,718	100.0	5.9	.65	14,434
		Sink 2.30	.0	89.1	.59	3,718	100.0	5.9	.65	14,434
1 by 1/2	36.7 percent	Float 1.30	89.1	4.7	.74	14,624	89.1	4.7	.74	14,624
		1.30 - 1.40	3.6	5.8	.74	14,444	92.6	4.7	.74	14,617
		1.40 - 1.50	3.7	8.0	1.21	14,084	96.3	4.9	.76	14,597
		1.50 - 1.70	1.9	38.5	1.21	9,096	98.2	5.5	.77	14,493
		1.70 - 1.80	.8	88.8	.51	3,718	98.9	6.2	.76	14,408
		1.80 - 1.90	.4	88.8	.51	3,718	99.3	6.5	.76	14,367
		1.90 - 2.10	.6	88.8	.51	3,718	99.9	6.9	.76	14,308
		2.10 - 2.30	.1	88.8	.51	3,718	100.0	7.0	.76	14,295
		Sink 2.30	.0	88.8	.51	3,718	100.0	7.0	.76	14,295
1/2 by 1/4	44.2 percent	Float 1.30	67.5	2.3	.80	15,013	67.5	2.3	.80	15,013
		1.30 - 1.40	24.9	7.7	.98	14,137	92.5	3.8	.85	14,777
		1.40 - 1.50	4.7	17.0	1.55	12,614	97.2	4.4	.88	14,672
		1.50 - 1.70	1.4	29.7	2.57	10,534	98.5	4.8	.91	14,615
		1.70 - 1.80	.5	87.8	.57	3,718	99.0	5.2	.90	14,562
		1.80 - 1.90	.3	87.8	.57	3,718	99.3	5.4	.90	14,529
		1.90 - 2.10	.4	87.8	.57	3,718	99.7	5.7	.90	14,487
		2.10 - 2.30	.3	87.8	.57	3,718	100.0	6.0	.90	14,458
		Sink 2.30	.0	87.8	.57	3,718	100.0	6.0	.90	14,456

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 4 (cont.)			FRACTION				ORIGIN: Baum Jig	DESTINATION: Rod Mill I CUMULATIVE		
Size Fraction and Weight		Sp. Gr.	Wt. %	Ash %	Total Sulfur %	Btu/lb	Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	3.0 percent	Float 1.30	81.0	2.0	.85	15,062	81.0	2.0	.85	15,062
		1.30 - 1.40	12.6	8.8	1.29	13,950	93.6	2.9	.91	14,913
		1.40 - 1.50	2.9	18.4	2.05	12,385	96.5	3.4	.94	14,838
		1.50 - 1.70	1.2	32.3	2.52	10,109	97.7	3.7	.96	14,780
		1.70 - 1.80	.5	88.9	.64	3,718	98.2	4.2	.96	14,719
		1.80 - 1.90	.7	88.9	.64	3,718	98.9	4.8	.96	14,637
		1.90 - 2.10	.5	88.9	.64	3,718	99.4	5.2	.96	14,586
		2.10 - 2.30	.5	88.9	.64	3,718	99.9	5.7	.95	14,530
		Sink 2.30	.1	88.9	.64	3,718	100.0	5.7	.95	14,521
28 by 0	.1 percent	Float 1.30	25.9	2.5	.79	14,987	25.9	2.5	.79	14,987
		1.30 - 1.40	49.1	5.3	.80	14,531	75.0	4.3	.80	14,688
		1.40 - 1.50	14.2	10.6	.90	13,662	89.2	5.3	.81	14,525
		1.50 - 1.70	6.7	30.0	.88	10,480	95.9	7.0	.82	14,242
		1.70 - 1.80	1.8	63.8	.85	4,962	97.7	8.1	.82	14,072
		1.80 - 1.90	.5	63.8	.85	4,962	98.3	8.4	.82	14,022
		1.90 - 2.10	.5	63.8	.85	4,962	98.8	8.7	.82	13,975
		2.10 - 2.30	.8	63.8	.85	4,962	99.6	9.1	.82	13,904
		Sink 2.30	.4	63.8	.85	4,962	100.0	9.3	.82	13,864
Composite	100.0 percent	Float 1.30	79.3	3.8	.75	14,773	79.3	3.8	.75	14,773
		1.30 - 1.40	13.6	7.6	.94	14,157	92.8	4.3	.78	14,683
		1.40 - 1.50	4.3	12.7	1.30	13,319	97.1	4.7	.80	14,623
		1.50 - 1.70	1.5	35.1	1.72	9,656	98.6	5.2	.82	14,547
		1.70 - 1.80	.5	88.3	.54	3,721	99.1	5.6	.81	14,490
		[illegible]	.3	88.3	.55	3,720	99.4	5.9	.81	14,457
		1.90 - 2.10	.4	88.3	.54	3,719	99.8	6.2	.81	14,415
		2.10 - 2.30	.2	88.1	.56	3,722	100.0	6.3	.81	14,396
		Sink 2.30	.0	87.2	.60	3,764	100.0	6.3	.81	14,395

Flowstream Summary: Flowrate = 76 tons per hour   Ash = 6.3 percent   Total Sulfur = 0.81 percent   Btu Content = 14,395 Btu/lb SO_2 Content = 1.13 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 6 ORIGIN: Raw Coal Screen (28M) DESTINATION: DM Cyclone (1.7) to (primary cyclone circuit)

			FRACTION				CUMULATIVE			
Size Fraction and Weight		Sp. Gr.	Wt. %	Ash %	Total Sulfur %	Btu/lb	Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	4.3 percent	Float 1.30	40.5	2.3	.80	15,013	40.5	2.3	.80	15,013
		1.30 - 1.40	16.4	7.7	.98	14,137	56.9	3.9	.85	14,761
		1.40 - 1.50	3.7	17.0	1.55	12,614	60.6	4.7	.89	14,630
		1.50 - 1.70	1.6	29.7	2.57	10,534	62.2	5.3	.94	14,524
		1.70 - 1.80	1.0	87.8	.57	3,718	63.2	6.6	.93	14,353
		1.80 - 1.90	1.0	87.8	.57	3,718	64.2	7.9	.93	14,188
		1.90 - 2.10	3.0	87.8	.57	3,718	67.2	11.5	.91	13,720
		2.10 - 2.30	8.0	87.8	.57	3,718	75.2	19.6	.87	12,656
		Sink 2.30	24.8	87.8	.57	3,718	100.0	36.5	.80	10,439
1/4 by 28	88.9 percent	Float 1.30	58.3	2.0	.85	15,062	58.3	2.0	.85	15,062
		1.30 - 1.40	9.7	8.8	1.29	13,950	68.0	3.0	.91	14,904
		1.40 - 1.50	2.5	18.4	2.05	12,385	70.5	3.5	.95	14,814
		1.50 - 1.70	1.4	32.3	2.52	10,109	71.9	4.1	.98	14,723
		1.70 - 1.80	1.0	88.9	.64	3,718	72.9	5.3	.98	14,572
		1.80 - 1.90	2.0	88.9	.64	3,718	74.9	7.5	.97	14,282
		1.90 - 2.10	2.5	88.9	.64	3,718	77.4	10.1	.96	13,941
		2.10 - 2.30	8.0	88.9	.64	3,718	85.4	17.5	.93	12,983
		Sink 2.30	14.6	88.9	.64	3,718	100.0	27.9	.89	11,630

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 6 (cont.) ORIGIN: Raw Coal Screen (28M) DESTINATION: DM Cyclone (1.7) to (primary cyclone circuit)

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
28 by 0	6.8 percent	Float 1.30	16.5	2.5	.79	14,987	16.5	2.5	.79	14,987
		1.30 - 1.40	33.8	5.3	.80	14,531	50.3	4.4	.80	14,681
		1.40 - 1.50	11.0	10.6	.90	13,662	61.3	5.5	.82	14,498
		1.50 - 1.70	6.7	30.0	.88	10,480	68.0	7.9	.82	14,102
		1.70 - 1.80	2.5	63.8	.85	4,962	70.5	9.9	.82	13,778
		1.80 - 1.90	1.0	63.8	.85	4,962	71.5	10.6	.82	13,655
		1.90 - 2.10	1.5	63.8	.85	4,962	73.0	11.7	.82	13,476
		2.10 - 2.30	5.0	63.8	.85	4,962	78.0	15.1	.83	12,930
		Sink 2.30	22.0	63.8	.85	4,962	100.0	25.8	.83	11,177
Composite	100.0 percent	Float 1.30	54.7	2.0	.85	15,059	54.7	2.0	.85	15,059
		1.30 - 1.40	11.6	8.0	1.17	14,077	66.3	3.1	.90	14,887
		1.40 - 1.50	3.1	16.4	1.75	12,703	69.5	3.7	.94	14,788
		1.50 - 1.70	1.8	31.6	2.10	10,221	71.2	4.4	.97	14,675
		1.70 - 1.80	1.1	85.0	.67	3,910	72.3	5.6	.97	14,511
		1.80 - 1.90	1.9	88.0	.65	3,763	74.2	7.7	.96	14,237
		1.90 - 2.10	2.5	87.8	.65	3,770	76.7	10.3	.95	13,902
		2.10 - 2.30	7.8	87.8	.65	3,772	84.5	17.4	.92	12,967
		Sink 2.30	15.5	86.4	.66	3,838	100.0	28.1	.88	11,549

Flowstream Summary: Flowrate = 126 tons per hour Ash = 28.1 percent Total Sulfur = 0.88 percent Btu Content = 11,549 Btu/lb SO_2 Content = 1.52 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 7 ORIGIN: Raw Coal Screen (28M) DESTINATION: Column Flotation

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	18.4 percent	Float 1.30	58.3	2.0	.85	15,062	58.3	2.0	.85	15,062
		1.30 - 1.40	9.7	8.8	1.29	13,950	68.0	3.0	.91	14,904
		1.40 - 1.50	2.5	18.4	2.05	12,385	70.5	3.5	.95	14,814
		1.50 - 1.70	1.4	32.3	2.52	10,109	71.9	4.1	.98	14,723
		1.70 - 1.80	1.0	88.9	.64	3,718	72.9	5.3	.98	14,572
		1.80 - 1.90	2.0	88.9	.64	3,718	74.9	7.5	.97	14,282
		1.90 - 2.10	2.5	88.9	.64	3,718	77.4	10.1	.96	13,941
		2.10 - 2.30	8.0	88.9	.64	3,718	85.4	17.5	.93	12,983
		Sink 2.30	14.6	88.9	.64	3,718	100.0	27.9	.89	11,630
28 by 0	81.6 percent	Float 1.30	16.5	2.5	.79	14,987	16.5	2.5	.79	14,987
		1.30 - 1.40	33.8	5.3	.80	14,531	50.3	4.4	.80	14,681
		1.40 - 1.50	11.0	10.6	.90	13,662	61.3	5.5	.82	14,498
		1.50 - 1.70	6.7	30.0	.88	10,480	68.0	7.9	.82	14,102
		1.70 - 1.80	2.5	63.8	.85	4,962	70.5	9.9	.82	13,778
		1.80 - 1.90	1.0	63.8	.85	4,962	71.5	10.6	.82	13,655
		1.90 - 2.10	1.5	63.8	.85	4,962	73.0	11.7	.82	13,476
		2.10 - 2.30	5.0	63.8	.85	4,962	78.0	15.1	.83	12,930
		Sink 2.30	22.0	63.8	.85	4,962	100.0	25.8	.83	11,177
Composite	100.0 percent	Float 1.30	24.2	2.3	.82	15,020	24.2	2.3	.82	15,020
		1.30 - 1.40	29.4	5.5	.83	14,496	53.6	4.0	.82	14,733
		1.40 - 1.50	9.4	11.0	.96	13,600	63.0	5.1	.84	14,563
		1.50 - 1.70	5.7	30.1	.95	10,463	68.7	7.2	.85	14,221
		1.70 - 1.80	2.2	65.9	.83	4,859	70.9	9.0	.85	13,928
		1.80 - 1.90	1.2	71.6	.78	4,576	72.1	10.0	.85	13,774
		1.90 - 2.10	1.7	70.6	.79	4,622	73.8	11.4	.85	13,566
		2.10 - 2.30	5.6	70.4	.79	4,632	79.4	15.5	.85	12,941
		Sink 2.30	20.6	67.0	.82	4,800	100.0	26.2	.84	11,261

Flowstream Summary: Flowrate = 65 tons per hour Ash = 26.2 percent Total Sulfur = 0.84 percent Btu Content = 11,261 Btu/lb SO_2 Content = 1.49 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 8 ORIGIN: DM Cyclone (1.7) (Primary cyclone circuit) DESTINATION: Mix point; stream 8 and stream 12

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	3.7 percent	Float 1.30	65.4	2.3	.80	15,013	65.4	2.3	.80	15,013
		1.30 - 1.40	26.5	7.7	.98	14,137	91.8	3.9	.85	14,761
		1.40 - 1.50	6.0	17.0	1.55	12,614	97.8	4.7	.89	14,630
		1.50 - 1.70	2.1	29.7	2.57	10,534	99.9	5.2	.93	14,545
		1.70 - 1.80	.0	87.8	.57	3,718	99.9	5.2	.93	14,544
		1.80 - 1.90	.0	87.8	.57	3,718	99.9	5.2	.93	14,544
		1.90 - 2.10	.0	87.8	.57	3,718	99.9	5.2	.93	14,543
		2.10 - 2.30	.0	87.8	.57	3,718	99.9	5.2	.93	14,540
		Sink 2.30	.1	87.8	.57	3,718	100.0	5.3	.93	14,533
1/4 by 28	89.7 percent	Float 1.30	80.9	2.0	.85	15,062	80.9	2.0	.85	15,062
		1.30 - 1.40	13.5	8.8	1.29	13,950	94.3	3.0	.91	14,904
		1.40 - 1.50	3.5	18.4	2.05	12,385	97.8	3.5	.95	14,814
		1.50 - 1.70	1.7	32.3	2.52	10,109	99.5	4.0	.98	14,734
		1.70 - 1.80	.1	88.9	.64	3,718	99.6	4.1	.98	14,721
		1.80 - 1.90	.0	88.9	.64	3,718	99.6	4.2	.98	14,716
		1.90 - 2.10	.0	88.9	.64	3,718	99.7	4.2	.98	14,712
		2.10 - 2.30	.1	88.9	.64	3,718	99.8	4.3	.98	14,699
		Sink 2.30	.2	88.9	.64	3,718	100.0	4.5	.98	14,676

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 8 (cont.) ORIGIN: DM Cyclone (1.7) (Primary cyclone circuit) DESTINATION: Mix point; stream 8 and stream 12

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	FRACTION Ash %	FRACTION Total Sulfur %	FRACTION Btu/lb	CUMULATIVE Wt. %	CUMULATIVE Ash %	CUMULATIVE Total Sulfur %	CUMULATIVE Btu/lb
28 by 0	6.7 percent	Float 1.30	23.6	2.5	.79	14,987	23.6	2.5	.79	14,987
		1.30 - 1.40	48.4	5.3	.80	14,531	72.0	4.4	.80	14,681
		1.40 - 1.50	15.8	10.6	.90	13,662	87.8	5.5	.82	14,498
		1.50 - 1.70	9.6	30.0	.88	10,480	97.4	7.9	.82	14,103
		1.70 - 1.80	2.1	63.8	.88	4,962	99.4	9.1	.82	13,911
		1.80 - 1.90	.1	63.8	.85	4,962	99.6	9.1	.82	13,899
		1.90 - 2.10	.0	63.8	.85	4,962	99.6	9.1	.82	13,897
		2.10 - 2.30	.1	63.8	.85	4,962	99.7	9.2	.82	13,890
		Sink 2.30	.3	63.8	.85	4,962	100.0	9.4	.82	13,862
Composite	100.0 percent	Float 1.30	76.5	2.0	.85	15,059	76.5	2.0	.85	15,059
		1.30 - 1.40	16.3	8.0	1.17	14,077	92.7	3.1	.90	14,887
		1.40 - 1.50	4.4	16.4	1.75	12,703	97.1	3.7	.94	14,788
		1.50 - 1.70	2.2	31.6	2.05	10,229	99.3	4.3	.97	14,686
		1.70 - 1.80	.2	74.8	.76	4,419	99.6	4.5	.97	14,661
		1.80 - 1.90	.0	84.2	.68	3,949	99.6	4.5	.97	14,655
		1.90 - 2.10	.0	87.8	.65	3,773	99.7	4.6	.97	14,652
		2.10 - 2.30	.1	87.8	.65	3,773	99.8	4.7	.97	14,640
		Sink 2.30	.2	86.4	.65	3,843	100.0	4.8	.97	14,616

Flowstream Summary: Flowrate = 90 tons per hour Ash = 4.8 percent Total Sulfur = 0.97 percent Btu Content = 14,616 Btu/lb SO_2 Content = 1.32 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 10 ORIGIN: Rod mill I DESTINATION: Secondary screen (28M)

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	70.2 percent	Float 1.30	67.3	2.3	.75	15,013	67.3	2.3	.75	15,013
		1.30 - 1.35	15.9	7.4	.72	14,187	83.2	3.3	.74	14,855
		1.35 - 1.40	7.8	11.4	.73	13,532	91.0	4.0	.74	14,742
		1.40 - 1.45	3.5	17.5	.89	12,524	94.5	4.5	.75	14,660
		1.45 - 1.50	1.7	20.8	1.40	11,985	96.2	4.8	.76	14,613
		1.50 - 1.70	2.0	31.7	1.75	10,202	98.2	5.3	.78	14,523
		Sink 1.70	1.8	69.7	1.26	4,002	100.0	6.5	.79	14,533
28 by 0	29.8 percent	Float 1.30	60.3	1.4	.79	15,157	60.3	1.4	.79	15,157
		1.30 - 1.35	14.9	5.0	.78	14,578	75.2	2.1	.79	15,042
		1.35 - 1.40	11.8	7.3	.72	14,194	87.0	2.8	.78	14,927
		1.40 - 1.45	5.8	11.4	.75	13,530	92.8	3.4	.78	14,840
		1.45 - 1.50	2.4	14.7	.75	12,980	95.2	3.7	.78	14,793
		1.50 - 1.70	2.8	24.1	1.22	11,445	98.0	4.3	.79	14,698
		Sink 1.70	2.0	67.3	2.27	3,718	100.0	5.9	.82	14,478
Composite	100.0 percent	Float 1.30	61.3	1.6	.76	15,053	65.2	2.1	.76	15,053
		1.30 - 1.35	15.0	5.3	.74	14,299	80.8	3.0	.76	14,907
		1.35 - 1.40	11.2	7.7	.73	13,791	89.8	3.7	.75	14,796
		1.40 - 1.45	5.5	12.0	.83	12,940	94.0	4.2	.76	14,713
		1.45 - 1.50	2.3	15.4	1.16	12,358	95.9	4.4	.76	14,666
		1.50 - 1.70	2.7	25.0	1.55	10,665	98.1	5.0	.78	14,575
		Sink 1.70	2.0	85.0	1.58	3,911	100.0	6.3	.80	14,376

Flowstream Summary: Flowrate = 76 tons per hour Ash = 6.3 percent Total Sulfur = 0.80 percent Btu Content = 14,376 Btu/lb SO_2 Content = 1.11 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 11 ORIGIN: Secondary screen (28M) DESTINATION: Flotation Column

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	14.3 percent	Float 1.30	67.3	2.3	.75	15,013	67.3	2.3	.75	15,013
		1.30 - 1.35	15.9	7.4	.72	14,187	83.2	3.3	.74	14,855
		1.35 - 1.40	7.8	11.4	.73	13,532	91.0	4.0	.74	14,742
		1.40 - 1.45	3.5	17.5	.89	12,524	94.5	4.5	.75	14,660
		1.45 - 1.50	1.7	20.8	1.40	11,985	96.2	4.8	.76	14,613
		1.50 - 1.70	2.0	31.7	1.75	10,202	98.2	5.3	.78	14,523
		Sink 1.70	1.8	69.7	1.26	4,002	100.0	6.5	.79	14,333
28 by 0	85.7 percent	Float 1.30	60.3	1.4	.79	15,157	60.3	1.4	.79	15,157
		1.30 - 1.35	14.9	5.0	.78	14,578	75.2	2.1	.79	15,042
		1.35 - 1.40	11.8	7.3	.72	14,194	87.0	2.8	.78	14,927
		1.40 - 1.45	5.8	11.4	.75	13,530	92.8	3.4	.78	14,840
		1.45 - 1.50	2.4	14.7	.75	12,980	95.2	3.7	.78	14,793
		1.50 - 1.70	2.8	24.1	1.22	11,445	98.0	4.3	.79	14,698
		Sink 1.70	2.0	87.3	2.27	3,718	100.0	5.9	.82	14,478
Composite	100.0 percent	Float 1.30	61.3	1.6	.78	15,135	61.3	1.6	.78	15,135
		1.30 - 1.35	15.0	5.3	.77	14,519	76.3	2.3	.78	15,013
		1.35 - 1.40	11.2	7.7	.72	14,128	87.6	3.0	.77	14,900
		1.40 - 1.45	5.5	12.0	.76	13,438	93.0	3.5	.77	14,814
		1.45 - 1.50	2.3	15.4	.82	12,875	95.3	3.8	.77	14,767
		1.50 - 1.70	2.7	25.0	1.28	11,312	98.0	4.4	.79	14,672
		Sink 1.70	2.0	85.0	2.14	3,755	100.0	6.0	.81	14,457

Flowstream Summary: Flowrate = 21 tons per hour Ash = 6.0 percent Total Sulfur = 0.81 percent Btu Content = 14,457 Btu/lb SO_2 Content = 1.13 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 12 ORIGIN: Secondary screen (28M) DESTINATION: Mix point of streams 8 and 12

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/4 by 28	91.3 percent	Float 1.30	67.3	2.3	.75	15,013	67.3	2.3	.75	15,013
		1.30 - 1.35	15.9	7.4	.72	14,187	83.2	3.3	.74	14,855
		1.35 - 1.40	7.8	11.4	.73	13,532	91.0	4.0	.74	14,742
		1.40 - 1.45	3.5	17.5	.89	12,524	94.5	4.5	.75	14,660
		1.45 - 1.50	1.7	20.8	1.40	11,985	96.2	4.8	.76	14,613
		1.50 - 1.70	2.0	31.7	1.75	10,202	98.2	5.3	.78	14,523
		Sink 1.70	1.8	69.7	1.26	4,002	100.0	6.5	.79	14,333
28 by 0	8.7 percent	Float 1.30	60.3	1.4	.79	15,157	60.3	1.4	.79	15,157
		1.30 - 1.35	14.9	5.0	.78	14,578	75.2	2.1	.79	15,042
		1.35 - 1.40	11.8	7.3	.72	14,194	87.0	2.8	.78	14,927
		1.40 - 1.45	5.8	11.4	.75	13,530	92.8	3.4	.78	14,840
		1.45 - 1.50	2.4	14.7	.75	12,980	95.2	3.7	.78	14,793
		1.50 - 1.70	2.8	24.1	1.22	11,445	98.0	4.3	.79	14,698
		Sink 1.70	2.0	87.3	2.27	3,718	100.0	5.9	.82	14,478
Composite	100.0 percent	Float 1.30	66.7	2.3	.75	15,025	66.7	2.3	.75	15,025
		1.30 - 1.35	15.8	7.2	.72	14,220	82.5	3.2	.75	14,870
		1.35 - 1.40	8.1	10.9	.73	13,616	90.7	3.9	.75	14,758
		1.40 - 1.45	3.7	16.7	.87	12,662	94.4	4.4	.75	14,675
		1.45 - 1.50	1.8	20.1	1.32	12,103	96.1	4.7	.76	14,628
		1.50 - 1.70	2.1	30.8	1.69	10,349	98.2	5.2	.78	14,538
		Sink 1.70	1.8	71.4	1.36	3,975	100.0	6.4	.79	14,346

Flowstream Summary: Flowrate = 55 tons per hour Ash = 6.4 percent Total Sulfur = 0.79 percent Btu Content = 14,346 Btu/lb SO_2 Content = 1.10 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 13 ORIGIN: Mix point of streams 8 and 12 DESTINATION: DM cyclone (1.3)

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	2.3 percent	Float 1.30	65.1	2.3	.80	15,217	65.1	2.3	.80	15,217
		1.30 - 1.35	18.0	6.0	.98	14,611	83.1	3.1	.84	15,085
		1.35 - 1.40	8.3	12.0	1.55	13,630	91.4	3.9	.90	14,953
		1.40 - 1.45	4.0	16.0	2.57	12,976	95.4	4.4	.97	14,870
		1.45 - 1.50	2.0	19.0	.57	12,485	97.4	4.7	.97	14,821
		1.50 - 1.70	2.5	29.7	.57	10,736	99.9	5.3	.96	14,719
		Sink 1.70	.1	78.9	.57	3,718	100.0	5.4	.95	14,708
1/4 by 28	89.1 percent	Float 1.30	76.1	2.1	.85	15,249	76.1	2.1	.85	15,249
		1.30 - 1.35	10.8	7.7	1.00	14,333	86.9	2.8	.87	15,136
		1.35 - 1.40	6.1	10.7	.50	13,843	93.0	3.3	.84	15,051
		1.40 - 1.45	2.3	16.8	2.00	12,845	95.3	3.6	.87	14,997
		1.45 - 1.50	1.7	20.3	2.00	12,273	97.1	3.9	.89	14,948
		1.50 - 1.70	1.8	32.1	2.00	10,343	98.9	4.5	.91	14,862
		Sink 1.70	1.1	68.3	1.00	4,423	100.0	5.2	.91	14,750

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 13 (cont.) ORIGIN: Mix point of streams 8 and 12 DESTINATION: DM cyclone (1.3)

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
28 by 0	8.6 percent	Float 1.30	36.7	1.8	.79	15,298	36.7	1.8	.79	15,298
		1.30 - 1.35	23.3	4.2	.85	14,906	59.9	2.7	.79	15,146
		1.35 - 1.40	17.0	7.2	.80	14,415	76.9	3.7	.80	14,985
		1.40 - 1.45	9.8	9.5	.80	14,039	86.7	4.4	.80	14,878
		1.45 - 1.50	3.2	15.6	.80	13,041	89.9	4.8	.80	14,813
		1.50 - 1.70	7.1	29.2	.90	10,817	97.0	6.6	.81	14,520
		Sink 1.70	3.0	58.8	1.00	5,977	100.0	8.1	.82	14,264
Composite	100.0 percent	Float 1.30	72.5	2.1	.85	15,251	72.5	2.1	.85	15,251
		1.30 - 1.35	12.0	7.1	.96	14,438	84.5	2.8	.86	15,135
		1.35 - 1.40	7.1	10.0	.60	13,955	91.6	3.4	.84	15,044
		1.40 - 1.45	3.0	14.7	1.68	13,183	94.6	3.7	.87	14,984
		1.45 - 1.50	1.9	19.6	1.79	12,391	96.5	4.0	.89	14,934
		1.50 - 1.70	2.3	31.3	1.67	10,478	98.8	4.7	.91	14,830
		Sink 1.70	1.2	66.3	1.00	4,752	100.0	5.4	.91	14,708

Flowstream Summary: Flowrate = 145.0 tons per hour Ash = 5.4 percent Total Sulfur = 0.91 percent Btu Content = 14,708 Btu/lb SO_2 Content = 1.23 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 14 ORIGIN: DM Cyclone (1.3) DESTINATION: CWF Processing

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	1.9 percent	Float 1.30	96.9	2.3	.80	15,217	96.9	2.3	.80	15,217
		1.30 - 1.35	3.0	6.0	.98	14,611	99.9	2.4	.81	15,198
		1.35 - 1.40	.0	12.0	1.55	13,630	100.0	2.4	.81	15,198
		1.40 - 1.45	.0	16.0	2.57	12,976	100.0	2.4	.81	15,197
		1.45 - 1.50	.0	19.0	.57	12,485	100.0	2.4	.81	15,197
		1.50 - 1.70	.0	29.7	.57	10,736	100.0	2.4	.81	15,197
		Sink 1.70	.0	78.9	.57	3,718	100.0	2.4	.81	15,197
1/4 by 28	89.8 percent	Float 1.30	94.0	2.1	.85	15,249	94.0	2.1	.85	15,249
		1.30 - 1.35	5.0	7.7	1.00	14,333	99.0	2.4	.86	15,203
		1.35 - 1.40	.9	10.7	.50	13,843	99.8	2.5	.85	15,191
		1.40 - 1.45	.1	16.8	2.00	12,845	99.9	2.5	.86	15,189
		1.45 - 1.50	.0	20.3	2.00	12,273	100.0	2.5	.86	15,188
		1.50 - 1.70	.0	32.1	2.00	10,343	100.0	2.5	.86	15,187
		Sink 1.70	.0	68.3	1.00	4,423	100.0	2.5	.86	15,185

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 14 (cont.) ORIGIN: DM Cyclone (1.3) DESTINATION: CWF Processing

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
28 by 0	8.4 percent	Float 1.30	49.9	1.8	.79	15,298	49.9	1.8	.79	15,298
		1.30 - 1.35	31.0	4.2	.79	14,906	80.9	2.7	.79	15,148
		1.35 - 1.40	15.2	7.2	.85	14,415	96.1	3.4	.80	15,032
		1.40 - 1.45	3.4	9.5	.80	14,039	99.6	3.6	.80	14,998
		1.45 - 1.50	.3	15.5	.80	13,041	99.9	3.7	.80	14,992
		1.50 - 1.70	.1	29.2	.90	10,817	100.0	3.7	.80	14,988
		Sink 1.70	.0	58.8	1.00	5,977	100.0	3.7	.80	14,984
Composite	100.0 percent	Float 1.30	90.3	2.1	.85	15,251	90.3	2.1	.85	15,251
		1.30 - 1.35	7.1	6.4	.92	14,544	97.5	2.4	.85	15,199
		1.35 - 1.40	2.1	8.5	.72	14,199	99.5	2.5	.85	15,179
		1.40 - 1.45	.4	11.2	1.08	13,765	99.9	2.6	.85	15,173
		1.45 - 1.50	.1	18.2	1.45	12,622	100.0	2.6	.85	15,172
		1.50 - 1.70	.0	31.3	1.70	10,472	100.0	2.6	.85	15,170
		Sink 1.70	.0	66.3	1.00	4,749	100.0	2.6	.85	15,169

Flowstream Summary: Flowrate = 109 tons per hour Ash = 2.6 percent Total Sulfur = 0.85 percent Btu Content = 15,169 Btu/lb SO_2 Content = 1.12 lbs SO_2/million Btu

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 15 ORIGIN: DM Cyclone DESTINATION: Flotation Column

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
1/2 by 1/4	3.7 percent	Float 1.30	16.4	2.3	.80	15,217	16.4	2.3	.65	15,217
		1.30 - 1.35	40.9	6.0	.98	14,611	57.4	4.9	.69	14,785
		1.35 - 1.40	20.9	12.0	1.55	13,630	78.3	6.8	.68	14,476
		1.40 - 1.45	10.1	16.0	2.57	12,976	88.4	7.9	.66	14,305
		1.45 - 1.50	5.1	19.0	.57	12,485	93.4	8.5	.66	14,207
		1.50 - 1.70	6.3	29.7	.57	10,736	99.7	9.8	.62	13,987
		Sink 1.70	.3	78.9	.57	3,718	100.0	10.0	.61	13,961
1/4 by 28	87.1 percent	Float 1.30	20.4	2.1	.85	15,249	20.4	2.1	.00	15,249
		1.30 - 1.35	28.8	7.7	1.00	14,333	49.3	5.4	.00	14,713
		1.35 - 1.40	22.5	10.7	.50	13,843	71.8	7.0	.34	14,441
		1.40 - 1.45	9.3	16.8	2.00	12,845	81.0	8.2	.47	14,258
		1.45 - 1.50	7.1	20.3	2.00	12,273	88.1	9.1	.43	14,098
		1.50 - 1.70	7.5	32.1	2.00	10,343	95.7	10.9	.39	13,803
		Sink 1.70	4.3	68.3	1.00	4,423	100.0	13.4	.38	13,395

CALCULATED WASHABILITY ANALYSIS OF FLOWSTREAM NUMBER 15 (cont.) ORIGIN: DM Cyclone DESTINATION: Flotation Column

Size Fraction and Weight		Sp. Gr.	FRACTION Wt. %	Ash %	Total Sulfur %	Btu/lb	CUMULATIVE Wt. %	Ash %	Total Sulfur %	Btu/lb
28 by 0	9.3 percent	Float 1.30	.4	1.8	.79	15,298	.4	1.8	.00	15,298
		1.30 - 1.35	2.2	4.2	.79	14,906	2.6	3.8	.00	14,970
		1.35 - 1.40	21.8	7.2	.85	14,415	24.4	6.8	1.38	14,475
		1.40 - 1.45	27.2	9.5	.80	14,039	51.6	8.2	2.01	14,245
		1.45 - 1.50	11.2	15.6	.80	13,041	62.7	9.6	1.65	14,031
		1.50 - 1.70	26.2	29.2	.90	10,817	88.9	15.3	1.16	13,084
		Sink 1.70	11.1	58.8	1.90	5,977	100.0	20.2	1.04	12,296
Composite	100.0 percent	Float 1.30	18.4	2.1	.85	15,248	18.4	2.1	.02	15,248
		1.30 - 1.35	26.8	7.6	1.00	14,353	45.2	5.3	.03	14,718
		1.35 - 1.40	22.4	10.4	.57	13,887	67.6	7.0	.39	14,443
		1.40 - 1.45	11.0	15.1	1.74	13,123	78.6	8.2	.57	14,259
		1.45 - 1.50	7.4	19.6	1.80	12,386	86.0	9.1	.52	14,098
		1.50 - 1.70	9.2	31.3	1.67	10,478	95.2	11.3	.47	13,748
		Sink 1.70	4.8	66.3	1.00	4,752	100.0	13.9	.45	13,314

Flowstream Summary: Flowrate = 36 tons per hour Ash = 13.9 percent Total Sulfur = 1.08 percent Btu Content = 13,314 Btu/lb SO_2 Content = 1.62 lbs SO_2/million Btu

END

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5/26/93