Technical Progress Report

First Quarter

(September 26, 1989 - December 31, 1989)

DOE/PC/89909--T2

DE91 000011

IN-PLANT TESTING OF MICROBUBBLE COLUMN FLOTATION

Principal Investigators

R. H. Yoon, G. H. Luttrell and G. T. Adel

Virginia Center for Coal and Minerals Processing
Department of Mining and Minerals Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

Contract Number

DE-AC22-89PC89909

Contracting Officer's Representative

Thomas J. Feeley, III

United States Department of Energy
Pittsburgh Energy Technology Center
P. O. Box 10940
Pittsburgh, Pennsylvania 15236-0940

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ABSTRACT

A project to evaluate the performance of the Virginia Tech Microbubble Column Flotation (MCF) process in an operating coal preparation plant was initiated during this past quarter. The project is concerned with the collection of process operating data using a 30-inch diameter column, and using this data to scale-up to a prototype, full-scale plant column. The work is being carried out at the Marrowbone Preparation Plant owned by the Shell Mining Corporation. Work during the past reporting period primarily concentrated on finalizing the project work plan (Task 2.1 - Project Planning), instrumenting the 30-inch diameter column (Task 2.2 - Advanced Instrumentation) and conducting a preliminary parametric study to evaluate the performance of the column (Task 2.3 - Detailed Testing). To date, the column has been consistently capable of producing a 9.5% ash product at a 61% combustible recovery from a -150 mesh classifying cyclone overflow containing 55 - 60% ash at 3 - 5% solids. Tests conducted over an extended period of time indicate that the column consistently maintains grade in spite of fluctuations in the feed characteristics. Preliminary laboratory tests also indicate that there may be substantial benefits to the overall plant operation by utilizing the column to process an entire -28 mesh stream.

PROJECT OBJECTIVES

The objectives of this project are: (1) to conduct in-plant test work on microbubble column flotation of coal to determine the effects of key operating and design parameters on process performance, (2) to develop and validate reliable scale-up criteria for microbubble column flotation of coal, (3) to develop an instrumentation and control system for smooth operation of the microbubble column flotation process, (4) to obtain sufficient engineering

data and cost information to evaluate the technical and economic feasibility of installing full-scale microbubble flotation columns, and (5) to obtain sufficient product from the column flotation unit to perform small-scale combustion tests if DOE so desires.

PROJECT TASKS

Task 2.1 Project Planning

This project was originally divided into three phases. Phase I - Preliminary In-Plant Testing, was a joint effort between the Virginia Center for Coal and Minerals Processing (VCCMP) and Shell Mining Corporation to test the feasibility of using the VCCMP Microbubble Column Flotation (MCF) process to treat fine coal on a commercial scale. This task utilized a 30-inch diameter column and was carried out at the Marrowbone Preparation Plant near Naugatuck, West Virginia. Following the successful completion of the Phase I work, a close-out report was issued to the DOE on November 13, 1989, detailing the results of this test work and providing preliminary information on the technical and economic feasibility of the MCF process. Authorization was then given to proceed on with Phase II - Continued In-Plant Testing and Phase III - Testing of a Prototype Column.

The Phase II work effort is currently underway and involves the continued testing of the 30-inch column to obtain detailed information concerning the operation, optimization scale-up and control of the microbubble flotation column. The Phase III effort has also been initiated and involves the scale-up, engineering, design and testing of a full-scale prototype column. Both of these phases of the test work are being carried out as a joint venture between the VCCMP, the DOE and the Shell Mining Corporation.

During this past quarter, the Phase II and Phase III work efforts were

initiated by issuing a detailed work plan to the DOE on March 29, 1990. This work plan provided (1) a detailed work breakdown structure including all methods employed to achieve the project objectives, (2) a project work schedule for all tasks including a manpower schedule and major milestones, and (3) a general description of the tests to be performed and analytical techniques to be utilized. The work plan was approved by DOE and both phases of this project are now underway.

Task 2.2 Advanced Instrumentation

2.2.a Installation of Instrument Package

A simplified schematic of the proposed instrumentation package for the 30-inch column is shown in Figure 1. As shown, the package consists of flow and density measurements on the feed line, flow measurements on the reject line and flow measurements on the wash water line to aid in determining the material balance around the column. Pressure sensors on the side of the column are being used to control pulp level and determine air hold-up for estimating and controlling bubble size. Sensors around the bubble generation system for monitoring air flow rate, pressure on the static mixer and power draw on the pump motor are used to characterize the performance of the bubble generation system. Controllable reagent pumps are used to maintain constant addition rates for frother and diesel fuel. Finally, conductivity probes placed in the feed, reject and product lines are used to determine the residence time distribution in the column during salt tracer tests.

During the past quarter, nearly all of the proposed instrumentation package was procured and installed. The flow rates of air and wash water, for example, were measured using mechanical rotometers. Prior to the installation of these meters, however, it was found necessary to install pressure regulators on both the air and fresh water feed lines to prevent fluctuations

Figure 1 - Simplified schematic of the proposed instrumentation package for the 30-inch microbubble flotation column.

in flow rate due to changes in the plant pressure supply. In general, the mechanical rotometers were found to perform quite well with the exception of one problem. The presence of condensed water in the air line frequently made the flow rate difficult to measure accurately. Remounting the air flow meter ahead of the pressure regulator on the high pressure side of the supply line helped reduce this problem, but an ideal solution has not yet been found. It may be necessary to install a water trap with an automatic bleed ahead of the rotometer.

Feed slurry flow rate was measured using a Brooks Series 7400 electromagnetic flow meter. The feed flow meter was calibrated to provide $\pm 1.0\%$ flow accuracy over a flow range from 20-200 gpm. In addition, frother and diesel fuel were added using Metronics chemical metering pumps. Both the feed flow meter and the reagent pumps were equipped with 4-20 mA output signal lines for future process control applications.

In order to control column level and monitor air hold-up, twin differential pressure transducers (Honeywell ST 3000) were installed in the upper and lower sections of the 30-inch column. The upper transducer was mounted approximately 4 feet from the top of the column for use in sensing the pulp level, while the lower transducer was installed just above the inlets for the microbubble generators for use in conjunction with the upper transducer to determine air hold-up in the column. The air hold-up and flow rate measurements provide an on-line method for determining the average size of bubbles within the column.

Future work calls for the installation of conductivity probes in the feed, product and reject lines in order to determine residence time distributions from salt tracer tests. Probes capable of performing in an industrial environment are currently being sought. In addition, a port for

injecting a salt tracer will be installed by plant personnel.

2.2.b Installation of Control Loops

Two main control loops are planned for the 30-inch column as shown in Figure 1. The first control loop is designed to maintain a constant level in the column and has been successfully installed and tested. A 4-20 mA signal from the pressure transducer is fed to a Honeywell UDC 2000 Mini-Pro digital controller. Using PID control logic, the controller determines the required adjustment to be made in the control valve mounted on the reject line. The reject control valve consists of a 2-inch diameter pneumatic "pinch" valve manufactured by the Red Valve Corporation. Several problems were experienced with this valve on start-up including mechanical difficulties (cam improperly installed by the manufacturer) and operational instabilities (periodic plugging of the valve due to misplaced +1/4-inch particles in the underflow stream). These problems resulted in the loss of several weeks of time for disassembly of the valve and recalibration in order to obtain satisfactory operation. Furthermore, steps were taken to improve the operation of the classifying cyclone feeding the column to minimize the amount of +1/4-inch material reporting to the cyclone overflow. After resolving these problems, the final system was capable of holding level to within ± 1 inch during normal operation.

The second control loop to be installed on the column is designed to maintain a constant bubble size in the pulp. This system consists of a controller which reads a differential pressure from the two pressure transducers mounted on the column and converts this reading to air hold-up. The air hold-up value is used in conjunction with the air, wash water and reject flow rates to provide an on-line estimate of bubble size. The procedure for estimating bubble size from column operating conditions has been described by M.J. Mankosa, G.T. Adel, G.H. Luttrell and R.H. Yoon in a paper

entitled "Modeling of Column Flotation with a View Toward Scale-Up and Control", Control '90, AIME, New York, 1990. If the bubble size is too large, the air hold-up will fall below a set point value and the addition rate of frother will be increased. If bubble size is too small, the air hold-up will be above the desired set point, and the frother flow rate will be decreased.

This control system was initially tested using a laboratory 2-inch diameter column. Preliminary results for the case of simple, untuned proportional control are shown in Figure 2. In this case, the objective of the control system was to maintain a constant bubble size. As shown, a decrease in the aeration rate resulted in a decrease in the bubble size which caused the controller to decrease the air fraction set point. As a result, the measured air fraction in the column exceeded the set point value and the frother addition rate was decreased to reduce the measured air fraction in the column and increase the bubble size. In the second example, the aeration rate was increased and the bubble size increased. In order to compensate for the increased bubble size, the controller increased the air fraction set point which caused additional frother to be added to the cell and brought the bubble size back down to maintain the desired value. As a result of this initial lab work, it appears that the bubble size control system responds appropriately to changes in the air hold-up set point. This control system has now been installed on the 30-inch column and will be tested as part of Task 2.5.

2.2.c Installation of Data Acquisition System

As a result of detailed discussions with Shell Mining personnel and several vendors of process monitoring and control systems, a system for process control and data acquisition has been specified. This system should go out for bid within the next few weeks.

Figure 2 - Effect of changes in aeration rate on the air fraction setpoint and corresponding response of frother addition control system.

Task 2.3 Detailed Testing

2.3.a Test Plan Development

A detailed test plan describing the parametric study to be carried out on the 30-inch column was submitted to the DOE on January 22, 1990. This test plan consisted of two parts: an exploratory test plan and a parametric test plan. The exploratory test program was designed to establish the appropriate levels at which the various operating parameters would be set for the detailed parametric study. The detailed parametric study was designed to establish mathematical relationships between column operating parameters and column performance. The test plan was approved by DOE and is currently being implemented.

2.3.b Exploratory Testing

Several preliminary tests were performed to determine the overall response of the 30-inch column to changes in key operating variables. The tests were performed by varying one test parameter at a time while holding all others constant. The standard test conditions were:

feed rate	100 gpm
wash water	23 gpm
aeration rate	16.4 cfm
froth depth	40 inches
frother dosage	1.25 lb/ton
collector dosage	1.25 lb/ton.

The metallurgical balance sheets for these tests are provided in Appendix I.

The effect of feed rate on the performance of the column is shown in Figure 3. As shown, combustible recovery decreased slightly from 65.7% to 59.8% when the feed rate was increased from 78 to 120 gpm. A corresponding decrease in product ash content was observed over the same range of feed rates. The slight dip in the ash curve at 100 gpm was primarily due to a momentary decrease in the feed ash to the column which resulted in a slightly improved clean coal quality. The fact that feed rate had only a limited

Figure 3 - Effect of feed rate on combustible recovery and product ash content.

Figure 4 - Effect of feed rate on the solids content of the product, reject and feed streams.

impact on column performance tends to indicate that the column is operating under conditions of maximum carrying capacity. Under these conditions, changes in retention time have little impact on the overall column performance.

The solids content of the feed, product and reject streams for the various feed flow rates is shown in Figure 4. In general, the solids content of the feed and reject streams remained relatively constant. The product stream, on the other hand, appeared to decrease as the feed rate increased. The decrease in the product solids content may be due to an increase in the frother concentration in the cell. Since the lb/ton dosage of frother was held constant, a higher feed rate produced a larger flow of feed relative to the wash water and, thus, a higher concentration of frother was present in the column. This, in turn, reduced the bubble size in the froth producing a wetter froth and a lower solids content in the product.

The response of the column to changes in aeration rate is shown in Figure 5. As shown, the combustible recovery was relatively insensitive to changes in aeration rate over a range from 12.3 to 19.9 scfm. In contrast, the product ash content increased significantly from 8.0% to over 10.5% by increasing the air flow rate. The increased product ash was probably due to an increase in nonselective entrainment of fine particles of mineral matter as air rate was increased. In general, higher air rates produce an increase in the water recovery rate which, in turn, decreases the effectiveness of the wash water. This conclusion is supported by examining the solids content plot shown in Figure 6. As the air rate increased, the solids content of the product dropped from 14.1% to 10.9% despite the fact that the solids content of the feed stream was increasing during this period. This result indicates that there exists a very strong relationship between product grade and factors

Figure 5 - Effect of air flow rate on combustible recovery and product ash content.

Figure 6 - Effect of air flow rate on the solids content of the product, reject and feed streams.

which impact the effectiveness of the wash water. Such parameters include frother addition, aeration rate, wash water rate and wash water injection point. This may be an area which will require further study.

The effect of froth depth on combustible recovery is shown in Figure 7. As shown, a froth depth of 31 inches produced a combustible recovery of 52.2%, while an increase in froth depth by 16 inches increased the combustible recovery to 66.5%. The product ash content, on the other hand, remained relative unchanged over the same range of froth depths. The exact cause of the improved recovery with a deep froth bed is not yet fully understood. However, preliminary indications suggest that this response may be due to a shift in the split of wash water which enters the column. As shown in Figure 8, the froth appears to become wetter as the froth depth is increased. This implies that a larger percentage of the wash water is reporting to the product stream and that less is diluting the pulp. This behavior may have many implications on column performance. First, since less wash water reports to the pulp when using a deep froth, less dilution of the frother occurs. This produces a higher residual concentration of frother in the cell which allows smaller bubbles to be produced. The smaller bubbles may account for the higher recovery rates. It may also be possible that the increased water content of a deep froth may reduce bubble coalescence. This would result in a larger bubble surface area available for carrying particles, thus, increasing the carrying capacity of the froth. Nevertheless, the results shown in Figures 7 and 8 do demonstrate the importance of maintaining a deep and stable froth in order to achieve good recoveries while keeping a low product ash content.

In addition to the exploratory tests conducted for the purpose of establishing parameter levels for the detailed parametric study, a long term test was conducted to determine whether the column performance would remain

Figure 7 - Effect of froth depth rate on combustible recovery and product ash content.

Figure 8 - Effect of froth depth on the solids content of the product, reject and feed streams.

stable during the normal feed fluctuations occurring over the period of several plant shifts. This long term test was carried out over a period of 48 hours and samples were taken approximately every three hours. The feed rate was fixed at 100 gpm during the entire run. The aeration rate and wash water rates were held constant at 16.4 scfm and 23 gpm, respectively. Both the collector and frother addition rates were set at 1.25 lb/ton.

Figure 9 shows the combustible recovery and product ash values obtained during the extended test run. The metallurgical balance sheets for these tests are shown in Appendix 2. For reference, the feed ash content is also provided to show the large variations in the feed stream quality during testing. As can be seen, the product ash content remained relatively constant and well within the target value of 10% during the entire duration of the test. The average values of the combustible recovery and product ash for the entire test run were 61.2% and 9.46%, respectively. The major impact of fluctuations in the ash content of the feed stream appeared to be reflected only in the combustible recovery. From a plant operation point-of-view, this is a very significant finding since it indicates that product quality is always maintained.

The results shown in Figure 9 also demonstrate the importance of adding a proper amount of diesel collector. At one point in the test run, the supply tank for the diesel fuel ran empty. Recovery immediately fell in response to the loss of collector. However, product grade still remained stable. These results are very encouraging and suggest that the column should be able to maintain product grade within a close tolerance specification despite the presence of system disturbances.

Another objective of the preliminary test work was to determine whether coarse particles could be effectively treated by microbubble column flotation

Marrowbone Preparation Plant

Figure 9 - Schematic showing the variations in combustible recovery and product ash content as a function of time.

without sacrificing either recovery or grade. This may have several advantages at the existing operation including improved dewatering, improved classification performance and simplification of the plant flowsheet. Initial test work was conducted using a 2-inch laboratory column and a sample collected at the plant site from the classifying cyclone feed stream. The sample, as received, was split into four representative lots and then screened to produce four different size distributions. The sizes selected for the preliminary work included -28 mesh, -48 mesh, -65 mesh and -150 mesh.

Figure 10 shows the results of this test work, while the metallurgical balance sheets for these tests are provided in Appendix 3. As shown, the coarser material generally appeared to produce a higher overall grade-recovery curve. Contrary to preliminary estimates, these results imply that a substantial portion of very good coal is available in the coarse size fractions that could be effectively recovered by flotation.

The potential benefits to the plant operation resulting from processing coarser material by flotation made it worthwhile to conduct additional follow-up test work with the 30-inch column at the plant site. In order to get a coarser size distribution at the plant site, a portion of the cyclone feed stream was used as feed to the column. Several different sets of operating conditions were examined in an attempt to duplicate the laboratory data. The results of this work are shown in Figure 11, and the metallurgical balance sheets are provided in Appendix 3. As shown, a combustible recovery greater than 45% was never achieved in any of the test work. Several possible explanations may be given for the discrepancy between the laboratory and in-plant test results. First and probably of most significance, a great deal of difficulty was experienced in obtaining a proper feed size distribution in the plant. Because of upstream problems with classification, a substantial portion of +1/8-inch material was generally present in the feed stream to the

Marrowbone Preparation Plant

Figure 10 - Combustible recovery and product ash values obtained with various size fractions using a laboratory microbubble flotation column.

Figure 11 - Combustible recovery and product ash values obtained during the processing of classifying cyclone feed.

cyclones. At times, this accounted for nearly 60-70% of the feed stream by weight. It may be necessary to repeat these tests when the plant circuits are operating more efficiently in order to resolve this discrepancy. Another possible explanation for the poorer recoveries in the plant tests may be due to differences in conditioning. The laboratory samples were generally conditioned for at least 15 minutes prior to flotation. The coal provided to the in-plant column was never conditioned for longer than a few minutes. Additional laboratory tests may need to be conducted as a function of conditioning time in order to determine whether this had any impact on the results.

As a result of the data collected in the exploratory test program, new levels were determined to be appropriate for the parametric test work to be carried out in Task 2.3.c. The recommended settings for each parameter are summarized in Table 1. It should be noted that the measured parameter settings are very close to those initially suggested in the original work outline. The only major change is in the frother and collector addition rates which has been changed from a weight ratio (i.e., lb/ton) to a flow rate (ml/min). This change is required due to difficulties in maintaining a fixed solids content in the feed stream. Since the feed solids content is variable, a lb/ton dosage cannot be determined until after the samples are obtained. However, the levels recommended in Table 1 for the flow rates of frother and collector should provide lb/ton dosages very close to those which were originally proposed.

With the exception of some parameters which may be investigated in more detail at the request of Shell Mining personnel, the exploratory testing has now been completed per the contract requirements and this task appears to be well ahead of schedule.

Table 1 - Recommended Levels for the Detailed Parametric Testing

<u>Parameter</u>	<u>Unit</u>	<u>Low</u>	<u>Normal</u>	<u>High</u>
pulp height	inches	20	40	60
frother rate	ml/min	6	11	16
collector rate	ml/min	6	11	16
feed rate	gpm	60	100	140
wash water rate	gpm	20	25	30
aeration rate	cfm	10	16	22

Task 2.4 Design Evaluation/Modification

2.4.a Evaluation of Column Design Features

During the past quarter, three different wash water distributors were constructed and tested in the 30-inch column. These three designs are shown in Figure 12. As a result of this test work, it was found that the original design (Figure 12a) did not provide sufficient distribution of wash water across the top of the froth. A second distributor with more wash water "legs" (Figure 12b) was constructed and installed to provide better wash water distribution; however, this distributor presented a new problem. In a normal laboratory test, the wash water injection point is usually 1-3 inches below the froth surface. This allows the portion of froth above the wash water injection point to dewater slightly before it leaves the column, and it tends to allow more water to pass down through the froth for improved cleaning action. However, on larger diameter columns, the center of the froth tends to drain too much and collapse when the wash water distributor is positioned below the top of the froth. When the wash water distributor is raised high enough to prevent the collapse of the center of the froth, the wash water becomes less effective in removing entrained mineral matter. In the flotation column marketed by the Deister Concentrator Company, this problem has been resolved by introducing a patented froth crowder into the center of the column. This is simply an inverted cone which directs material to the cell overflow lip. Unfortunately, the presence of this froth crowder tends to cut down on the available cross section of the column and adversely affect the carrying capacity which is directly proportional to the available cross-sectional area. As a result, a twin ring design (Figure 12c) was developed to maximize the washing action while improving the stability of the center of the froth. In this design, the center ring was positioned just above the froth to

Figure 12 - Schematic showing the different wash water designs evaluated during the testing of the 30-inch micro-bubble flotation column.

maintain a very wet and stable froth in this region, while the outer ring was positioned just below the cell lip. This arrangement allowed the froth to drain slightly just before it spilled over the cell lip. Also, by adjusting the depth of the outer ring, the wash water split could be easily adjusted. For example, if the outer ring was positioned too deep, less wash water reported to the product, the product solids content increased and better washing action was achieved. However, the resultant bubble coalescence in the froth reduced the amount of available bubble surface area for particle attachment and decreased the overall product yield. If the outer ring was positioned too high, more wash water reported to the product and improved froth stability was observed. However, this decreased the effectiveness of the wash water in removing entrained particles. Thus, by properly adjusting the depth of the outer ring, an optimum balance between yield and grade could be achieved. Because of the excellent results and flexibility provided by this system, a similar type of wash water distribution system will be designed and installed on the full-scale column when it is tested.

The other distribution systems in the column were found to operate quite well. The feed slurry seemed to distribute within just a few feet of depth within the column. The turbulence caused by the bubble generators near the bottom of the column also provided an excellent method for properly distributing the air across the column cross-section. Since no problems were encountered with these systems, no special plans are being made for further design modifications in these areas.

Another concern regarding the original column design was whether the froth product would flow unrestricted from the launder through the product collection line. High-pressure, low-flow water sprays were mounted just above the launder to break the froth should problems arise. In addition, a very

smooth ceramic coating was used in the launder construction to help in product removal. After conducting a wide range of tests, it was found that the ceramic coating was sufficiently slick to prevent hold-up of the froth and that little or no additional water was required in the launder to break the froth.

It now appears that this task is approximately 50% complete. Test work remaining includes evaluation of the feed, wash water and frother injection points, characterization of the bubble generation circuit, and testing of baffles in the column.

2.4.b Measurement of Wear on Key Components

The major components in which wear is a concern include bubble generators, the centrifugal bubble generation pump, tailing discharge valve and associated piping. The wear rates of the centrifugal pump, discharge control valve and associated piping are expected to be in line with that of other similar systems within the plant. As a result, the life expectancy of these components has been well documented by plant personnel and are now believed to be of no great concern. However, because of the tortuous path and relatively high slurry velocity through the bubble generators, it was believed that wear might be of particular concern in these devices. In fact, the original column design called for quick-release couplings so that the generators could be removed, inspected, and replaced if necessary on a routine basis. However, after an extended period of testing over the past quarter, no visual wear of these components was noted and little or no loss of weight was detected for the generators. It is planned to continue monitoring the wear of the bubble generators throughout the duration of the test program.

SUMMARY STATUS AND PLANNED WORK

The overall project to date appears to be ahead of schedule. Task 2.1 (Project Planning) is now complete and Task 2.2 (Advanced Instrumentation) is approximately 80% complete with the procurement and installation of the data acquisition system all that remains to complete this task. It is hoped that the procurement of this system will be completed during the next quarter. Task 2.3 (Detailed Testing) is now approximately 50% complete as a result of completing the exploratory test work during this past period. This task has been purposely moved ahead since the data are needed for the design and operation of the prototype column. It is expected that a substantial portion of the detailed parametric study will be completed during the upcoming quarter. Finally, Task 2.4 (Design Evaluation/Modification) is progressing well and is about 50% complete. Since this task is carried out over the duration of the project, it appears that it will keep pace with the project time table.

In-Plant Testing of Microbubble Column Flotation

Phase I – Preliminary In-Plant Testing

- 1.1 Site Evaluation
- 1.2 Laboratory Testing
- 1.3 Column Design and Installation
- 1.4 Shakedown Testing
- 1.5 Data Analysis
- 1.6 Scale-Up Projections
- 1.7 Feasibility Analysis

Phase II – Continued In-Plant Testing

- 2.1 Project Planning
- 2.2 Advanced Instrumentation
- 2.3 Detailed Testing
- 2.4 Design Evaluation/Modification
- 2.5 Control Systems

Phase III – Prototype Testing

- 3.1 Project Planning
- 3.2 Column Installation
- 3.3 Column Testing
- 3.4 Cost Analysis
- 3.5 Final Recommendations

Reporting

Appendix I

Summary of Test Results Obtained During Exploratory Testing

Marrowbone Prep. Plant
Operating Parameters
(Feed Rate)
In-Plant

Column Geometry:

Column Height	26.5 Feet
Column Diameter	29.25 inches
Distance to Feed Pt.	4.5 Feet
Distance to CCW (Upper)	3.0 inches (Above Froth)
Distance to CCW (Lower)	7.0 inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (gpm)	78	100	120
CCW Rate (gpm)	21	21	21
Collector (Diesel #/ton)	0.77	1.13	0.77
Frother (DF1012 #/ton)	1.09	1.59	1.09
Aeration Rate (scfm)	16.4	16.4	16.1
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:	-150 mesh	-150 mesh	-150 mesh
Particle Size	-----	-----	-----
% Solids			
Ph	as is	as is	as is

Results: Feed Rate Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.72	65.74	28.58
Reject	81.18	34.26	71.42
Feed	60.76	100.0	100.0

Results: Feed Rate Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.06	62.27	32.85
Reject	72.74	37.73	61.15
Feed	51.49	100.0	100.0

Results: Feed Rate Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.96	59.08	27.53
Reject	76.05	40.92	72.47
Feed	57.58	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
(Aeration Rate)
In-Plant

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	21	21	21
Collector (Diesel #/ton)	1.11	1.13	0.85
Frother (DF1012 #/ton)	1.58	1.59	1.20
Aeration Rate (scfm)	12.3	16.4	19.9
Froth Zone Depth (in.)	30	40	40

Feed Characteristics:

Particle Size	-150 mesh	-150 mesh	-150 mesh
% Solids	-----	-----	-----
Ph	as is	as is	as is

Results: Aeration Rate Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.02	61.19	29.74
Reject	75.39	38.81	70.26
Feed	55.29	100.0	100.0

Results: Aeration Rate Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.06	62.27	32.85
Reject	72.74	37.73	61.15
Feed	51.49	100.0	100.0

Results: Aeration Rate Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.52	61.18	27.05
Reject	78.94	38.82	72.95
Feed	60.43	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
(Froth Height)
In-Plant

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	21	21	21
Collector (Diesel #/ton)	0.99	1.13	1.22
Frother (DF1012 #/ton)	1.40	1.59	1.72
Aeration Rate (scfm)	16.4	16.4	16.4
Froth Zone Depth (in.)	31	40	46

Feed Characteristics:

Particle Size	-150 mesh	-150 mesh	-150 mesh
% Solids	-----	-----	-----
Ph	as is	as is	as is

Results: Froth Height Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	7.41	52.15	26.32
Reject	69.65	47.85	73.68
Feed	53.27	100.0	100.0

Results: Froth Height Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.06	62.27	32.85
Reject	72.74	37.73	61.15
Feed	51.49	100.0	100.0

Results: Froth Height Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.19	66.53	32.34
Reject	77.92	33.47	67.66
Feed	55.37	100.0	100.0

Appendix II

Summary of Test Results Obtained
During a 40-Hour Duration

Marrowbone Prep. Plant
Long Term Test
Tests 1 to 4
In-Plant

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	Feet
Distance to Feed Pt.	1.5	Inches (Above Froth)
Distance to CCW	6.0	Inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3	Test 4
Feed Rate (gpm)	98	98	98	98
CCW Rate (gpm)	20	21	21	21
Aeration Rate (scfm)	17.2	16.8	16.4	16.8
Frother (DF1012 #/ton)	2.50	1.52	1.09	1.24
Collector (Diesel #/ton)	1.26	1.08	0.93	1.02

Feed Characteristics:	Test 1	Test 2	Test 3	Test 4
Particle Size	Fine	Fine	Fine	Fine
% Solids (feed)	3.56	4.13	4.80	4.62
Ph	as is	as is	as is	as is

Results: Test 1 10/31/89 3:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.85	64.24	29.99
Reject	78.50	35.76	70.01
Feed	57.91	100.0	100.0

Results: Test 2 10/31/89 6:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.44	63.71	29.69
Reject	78.21	36.29	70.31
Feed	57.79	100.0	100.0

Results: Test 3 10/31/89 9:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.24	58.05	26.31
Reject	76.58	41.95	73.69
Feed	58.86	100.0	100.0

Results: Test 4 11/01/89 1:00 am

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.69	56.73	25.37
Reject	76.32	43.27	74.63
Feed	59.16	100.0	100.0

Marrowbone Prep. Plant
Long Term Test
Tests 5 to 8
In-Plant

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	Feet
Distance to Feed Pt.	1.5	Inches (Above Froth)
Distance to CCW	6.0	Inches (Below Overflow Lip)

Operating Parameters:	Test 5	Test 6	Test 7	Test 8
Feed Rate (gpm)	100	104	104	100
CCW Rate (gpm)	21	20	17	21
Aeration Rate (scfm)	17.2	16.0	16.4	16.8
Frother (DF1012 #/ton)	1.32	1.14	1.22	1.26
Collector (Diesel #/ton)	1.02	0.48	0.94	0.98

Feed Characteristics:

Particle Size	Fine	Coarse	Coarse	Coarse
% Solids (feed)	3.89	4.73	4.44	4.47
Ph	as is	as is	as is	as is

Results: Test 5 11/01/89 6:30 am

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.29	58.88	27.64
Reject	76.07	41.12	72.36
Feed	57.89	100.0	100.0

Results: Test 6 11/01/89 1:00 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.29	25.72	11.62
Reject	65.18	74.28	88.38
Feed	58.57	100.0	100.0

Results: Test 7 11/01/89 9:00 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.13	65.95	35.15
Reject	74.57	34.05	64.85
Feed	51.57	100.0	100.0

Results: Test 8 11/01/89 7:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.67	63.00	33.44
Reject	73.06	37.00	66.56
Feed	51.53	100.0	100.0

Marrowbone Prep. Plant
Long Term Test
Tests 9 to 12
In-Plant

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	Feet
Distance to Feed Pt.	1.5	Inches (Above Froth)
Distance to CCW	6.0	Inches (Below Overflow Lip)

Operating Parameters:	Test 9	Test 10	Test 11	Test 12
Feed Rate (gpm)	102	100	100	100
CCW Rate (gpm)	18	21	20	20
Aeration Rate (scfm)	16.4	16.0	16.8	16.4
Frother (DF1012 #/ton)	1.35	1.43	1.51	1.31
Collector (Diesel #/ton)	1.15	1.01	1.07	1.01

Feed Characteristics:

Particle Size	Fine	Fine	Fine	Fine
% Solids (feed)	4.07	3.93	3.73	4.31
Ph	as is	as is	as is	as is

Results: Test 9 11/01/89 11:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.20	60.29	25.14
Reject	80.14	39.71	74.86
Feed	62.56	100.0	100.0

Results: Test 10 11/02/89 2:30 am

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.72	59.64	23.55
Reject	81.39	40.36	76.45
Feed	64.75	100.0	100.0

Results: Test 11 11/02/89 5:30 am

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.33	62.31	33.38
Reject	72.83	37.69	66.62
Feed	51.97	100.0	100.0

Results: Test 12 11/02/89 12:30 am

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.86	52.40	25.17
Reject	72.15	47.60	74.83
Feed	56.22	100.0	100.0

Marrowbone Prep. Plant
Long Term Test
Tests 13 & 14
In-Plant

Column Geometry:

Column Height	26.5 Feet
Column Diameter	29.25 Feet
Distance to Feed Pt.	1.5 Inches (Above Froth)
Distance to CCW	6.0 Inches (Below Overflow Lip)

Operating Parameters:

Test 13

Test 14

Feed Rate (gpm)	104	104
CCW Rate (gpm)	21	21
Aeration Rate (scfm)	16.4	16.0
Frother (DF1012 #/ton)	1.51	1.68
Collector (Diesel #/ton)	1.17	1.54

Feed Characteristics:

Particle Size	Fine	Fine
% Solids (feed)	3.59	3.24
Ph	as is	as is

Results: Test 13 11/02/89 2:30 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.92	63.72	32.38
Reject	75.16	36.28	67.62
Feed	53.71	100.0	100.0

Results: Test 14 11/02/89 5:00 pm

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.64	66.80	33.41
Reject	77.22	33.20	66.59
Feed	54.31	100.0	100.0

Appendix III

Summary of Test Results Obtained
With Various Size Distributions

Marrowbone Prep. Plant
Feed Size Distribution
(-28 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	6.0	inches

Operating Parameters:	Test 1	Test 2	Test 3	Test 4
Feed Rate (ml/min)	1000	1500	2000	2000
CCW Rate (ml/min)	400	400	400	400
Collector (Diesel #/ton)	1.25	1.25	1.25	1.25
Frother (DF1012 #/ton)	1.39	1.68	2.12	1.25
Aeration Rate (cc/min)	1000	1300	1200	1000

Feed Characteristics:

Particle Size	-28 mesh	-28 mesh	-28 mesh	-28 mesh
% Solids	5.2	5.2	5.2	5.9
Ph	as is	as is	as is	as is

Results: -28 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	16.09	86.51	54.74
Reject	84.17	13.49	42.26
Feed	46.94	100.0	100.0

Results: -28 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.98	82.07	49.63
Reject	81.05	17.93	50.37
Feed	46.77	100.0	100.0

Results: -28 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.81	66.31	37.83
Reject	72.12	33.69	62.17
Feed	48.55	100.0	100.0

Results: -28 Mesh Test 4

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	7.47	65.93	35.39
Reject	73.81	34.07	64.61
Feed	50.33	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-48 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (ml/min)	1000	1500	2000
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.25	1.25	1.25
Frother (PSM #/ton)	1.25	1.25	1.25
Aeration Rate (cc/min)	2140	2140	2140

Feed Characteristics:

Particle Size	-48 mesh	-48 mesh	-48 mesh
% Solids	4.3	4.3	4.3
Ph	as is	as is	as is

Results: -48 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.48	70.78	32.96
Reject	82.06	29.22	67.04
Feed	58.82	100.0	100.0

Results: -48 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.21	76.86	36.05
Reject	85.10	23.14	63.95
Feed	58.82	100.0	100.0

Results: -48 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.81	67.83	32.04
Reject	80.51	32.17	67.96
Feed	58.82	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
(-65 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3	Test 4
Feed Rate (ml/min)	500	1000	1500	2000
CCW Rate (ml/min)	400	400	400	400
Collector (Diesel #/ton)	1	1	1	1
Frother (DF1012 #/ton)	0.63	0.90	1.02	0.87
Aeration Rate (cc/min)	1500	1500	1500	1500

Feed Characteristics:

Particle Size	-65 mesh	-65 mesh	-65 mesh	-65 mesh
% Solids	5.5	5.5	5.5	5.5
Ph	as is	as is	as is	as is

Results: -65 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.45	69.83	33.58
Reject	80.44	30.17	66.42
Feed	56.94	100.0	100.0

Results: -65 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.05	64.93	30.90
Reject	78.27	35.07	69.10
Feed	57.19	100.0	100.0

Results: -65 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.68	58.58	28.03
Reject	75.40	41.42	71.97
Feed	57.26	100.0	100.0

Results: -65 Mesh Test 4

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.80	48.11	22.52
Reject	71.40	51.89	77.48
Feed	56.94	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-150 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:

	Test 1	Test 2	Test 3
Feed Rate (ml/min)	500	1000	1500
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.0	1.0	1.0
Frother (PSM #/ton)	0.85	1.12	1.31
Aeration Rate (cc/min)	1500	1500	1500

Feed Characteristics:

	-150 mesh	-150 mesh	-150 mesh
Particle Size	4.9	4.9	4.9
% Solids			
Ph	as is	as is	as is

Results: -150 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.85	64.56	31.13
Reject	78.13	35.44	68.87
Feed	57.50	100.0	100.0

Results: -150 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.61	62.38	30.62
Reject	76.47	37.62	69.38
Feed	56.61	100.0	100.0

Results: -65 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.68	58.58	28.03
Reject	75.40	41.42	71.97
Feed	57.26	100.0	100.0

Results: -65 Mesh Test 4

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.80	48.11	22.52
Reject	71.40	51.89	77.48
Feed	56.94	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-150 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (ml/min)	500	1000	1500
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.0	1.0	1.0
Frother (PSM #/ton)	0.85	1.12	1.31
Aeration Rate (cc/min)	1500	1500	1500

Feed Characteristics:

Particle Size	-150 mesh	-150 mesh	-150 mesh
% Solids	4.9	4.9	4.9
Ph	as is	as is	as is

Results: -150 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.85	64.56	31.13
Reject	78.13	35.44	68.87
Feed	57.50	100.0	100.0

Results: -150 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.61	62.38	30.62
Reject	76.47	37.62	69.38
Feed	56.61	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distributions)
28 * 150 Mesh
Lab Tests

Column Geometry:

Column Height	60.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	2.5	inches

Operating Parameters:

Test 1

Feed Rate (ml/min)	1500
CCW Rate (ml/min)	560
Collector (Diesel #/ton)	1.25
Frother (DF1012 #/ton)	0.12
Aeration Rate (cc/min)	760
Froth Height (inches)	15

Feed Characteristics:

Particle Size	28*150
% Solids	3.54
Ph	as is

Results: (28*150 Mesh) Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	21.39	96.21	83.99
Reject	83.77	3.79	16.01
Feed	31.38	100.0	100.0

Appendix IV

Summary of Test Results Obtained Using Classifying Cyclone Feed

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 12/14/89

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 1

Feed Rate (gpm)	96-128
CCW Rate (gpm)	23
Collector (Diesel ml/min)	11
Frother (DF1012 ml/min)	11
Aeration Rate (scfm)	16.4
Froth Height (inches)	40

Feed Characteristics:

Particle Size	Coarse
% Solids	Feed 5.65% Product 14.25% Reject 4.46%
Ph	Nat.

Results: (Cyclone Feed) Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.81	43.50	27.50
Reject	55.55	56.50	72.50
Feed	42.97	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	21	21	21
Frother (DF1012 ml/min)	10	15	25
Aeration Rate (scfm)	16.4	16.4	16.4
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:

Particle Size	+28 mesh	+28 mesh	+28 mesh
% Solids	6.52	7.41	8.00
Ph	as is	as is	as is

Results: Frother Addition Test 1 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.68	41.53	23.93
Reject	61.33	58.47	76.07
Feed	49.69	100.0	100.0

Results: Frother Addition Test 2 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.21	28.73	16.20
Reject	56.94	71.27	83.80
Feed	49.37	100.0	100.0

Results: Frother Addition Test 3 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.92	28.14	15.58
Reject	57.54	71.86	84.42
Feed	50.12	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 4	Test 5	Test 6
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	21	21	21
Frother (DF1012 ml/min)	25	15	10
Aeration Rate (scfm)	18.45	18.45	18.45
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:

Particle Size	+28 mesh	+28 mesh	+28 mesh
% Solids	7.79	8.53	9.87
Ph	as is	as is	as is

Results: Frother Addition Test 4 (cum)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.35	30.46	18.26
Reject	54.27	69.54	81.74
Feed	46.25	100.0	100.0

Results: Frother Addition Test 5 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.66	32.74	17.50
Reject	61.07	67.26	82.50
Feed	52.25	100.0	100.0

Results: Frother Addition Test 6 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.63	25.21	13.63
Reject	57.69	74.79	86.37
Feed	51.14	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 7	Test 8	Test 9
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	16	16	16
Frother (DF1012 ml/min)	10	15	25
Aeration Rate (scfm)	18.45	18.45	18.45
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:

Particle Size	+28 mesh	+28 mesh	+28 mesh
% Solids	9.20	----	----
Ph	as is	as is	as is

Results: Frother Addition Test 7 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.33	23.75	12.81
Reject	57.72	76.25	87.19
Feed	51.65	100.0	100.0

Results: Frother Addition Test 8 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.69	15.12	8.20
Reject	55.69	84.88	91.80
Feed	52.08	100.0	100.0

Results: Frother Addition Test 9 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.60	21.30	11.68
Reject	56.81	78.70	88.32
Feed	51.53	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 1

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	11
Frother (DF1012 ml/min)	13
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	6.17
Ph	Nat.

Results: (Cyclone Feed) Test 1 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.88	52.63	34.02
Reject	58.64	47.37	65.98
Feed	42.39	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 2

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	15
Frother (DF1012 ml/min)	16
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	8.68
Ph	Nat.

Results: (Cyclone Feed) Test 2 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.44	41.34	24.78
Reject	58.14	58.66	75.22
Feed	46.14	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet	
Column Diameter	29.25	inches	
Distance to Feed Pt.	4.5	Feet	
Distance to CCW (Upper)	3.0	inches	(Above Froth)
Distance to CCW (Lower)	7.0	inches	(Below Overflow Lip)

Operating Parameters:

Test 3

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	15
Frother (DF1012 ml/min)	11
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	8.16
Ph	Nat.

Results: (Cyclone Feed) Test 3 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.97	43.14	26.52
Reject	57.18	56.86	73.48
Feed	44.66	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-48 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (ml/min)	1000	1500	2000
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.25	1.25	1.25
Frother (PSM #/ton)	1.25	1.25	1.25
Aeration Rate (cc/min)	2140	2140	2140

Feed Characteristics:	-48 mesh	-48 mesh	-48 mesh
Particle Size	4.3	4.3	4.3
% Solids	as is	as is	as is
Ph			

Results: -48 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.48	70.78	32.96
Reject	82.06	29.22	67.04
Feed	58.82	100.0	100.0

Results: -48 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.21	76.86	36.05
Reject	85.10	23.14	63.95
Feed	58.82	100.0	100.0

Results: -48 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.81	67.83	32.04
Reject	80.51	32.17	67.96
Feed	58.82	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
(-65 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3	Test 4
Feed Rate (ml/min)	500	1000	1500	2000
CCW Rate (ml/min)	400	400	400	400
Collector (Diesel #/ton)	1	1	1	1
Frother (DF1012 #/ton)	0.63	0.90	1.02	0.87
Aeration Rate (cc/min)	1500	1500	1500	1500

Feed Characteristics:

Particle Size	-65 mesh	-65 mesh	-65 mesh	-65 mesh
% Solids	5.5	5.5	5.5	5.5
Ph	as is	as is	as is	as is

Results: -65 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.45	69.83	33.58
Reject	80.44	30.17	66.42
Feed	56.94	100.0	100.0

Results: -65 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.05	64.93	30.90
Reject	78.27	35.07	69.10
Feed	57.19	100.0	100.0

Results: -65 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.68	58.58	28.03
Reject	75.40	41.42	71.97
Feed	57.26	100.0	100.0

Results: -65 Mesh Test 4

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.80	48.11	22.52
Reject	71.40	51.89	77.48
Feed	56.94	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-150 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (ml/min)	500	1000	1500
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.0	1.0	1.0
Frother (PSM #/ton)	0.85	1.12	1.31
Aeration Rate (cc/min)	1500	1500	1500

Feed Characteristics:

Particle Size	-150 mesh	-150 mesh	-150 mesh
% Solids	4.9	4.9	4.9
Ph	as is	as is	as is

Results: -150 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.85	64.56	31.13
Reject	78.13	35.44	68.87
Feed	57.50	100.0	100.0

Results: -150 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.61	62.38	30.62
Reject	76.47	37.62	69.38
Feed	56.61	100.0	100.0

Results: -65 Mesh Test 3

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.68	58.58	28.03
Reject	75.40	41.42	71.97
Feed	57.26	100.0	100.0

Results: -65 Mesh Test 4

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	8.80	48.11	22.52
Reject	71.40	51.89	77.48
Feed	56.94	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distribution)
(-150 Mesh)
Lab Tests

Column Geometry:

Column Height	72.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	3.5	inches

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (ml/min)	500	1000	1500
CCW Rate (ml/min)	400	400	400
Collector (Diesel #/ton)	1.0	1.0	1.0
Frother (PSM #/ton)	0.85	1.12	1.31
Aeration Rate (cc/min)	1500	1500	1500

Feed Characteristics:

Particle Size	-150 mesh	-150 mesh	-150 mesh
% Solids	4.9	4.9	4.9
Ph	as is	as is	as is

Results: -150 Mesh Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.85	64.56	31.13
Reject	78.13	35.44	68.87
Feed	57.50	100.0	100.0

Results: -150 Mesh Test 2

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.61	62.38	30.62
Reject	76.47	37.62	69.38
Feed	56.61	100.0	100.0

Marrowbone Prep. Plant
(Feed Size Distributions)
28 * 150 Mesh
Lab Tests

Column Geometry:

Column Height	60.0	inches
Column Diameter	2.0	inches
Distance to Feed Pt.	18.5	inches
Distance to CCW	2.5	inches

Operating Parameters:

Test 1

Feed Rate (ml/min)	1500
CCW Rate (ml/min)	560
Collector (Diesel #/ton)	1.25
Frother (DF1012 #/ton)	0.12
Aeration Rate (cc/min)	760
Froth Height (inches)	15

Feed Characteristics:

Particle Size	28*150
% Solids	3.54
Ph	as is

Results: (28*150 Mesh) Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	21.39	96.21	83.99
Reject	83.77	3.79	16.01
Feed	31.38	100.0	100.0

Appendix IV

Summary of Test Results Obtained Using Classifying Cyclone Feed

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 12/14/89

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 1

Feed Rate (gpm)	96-128
CCW Rate (gpm)	23
Collector (Diesel ml/min)	11
Frother (DF1012 ml/min)	11
Aeration Rate (scfm)	16.4
Froth Height (inches)	40

Feed Characteristics:

Particle Size	Coarse
% Solids	Feed 5.65% Product 14.25% Reject 4.46%
Ph	Nat.

Results: (Cyclone Feed) Test 1

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.81	43.50	27.50
Reject	55.55	56.50	72.50
Feed	42.97	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:	Test 1	Test 2	Test 3
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	21	21	21
Frother (DF1012 ml/min)	10	15	25
Aeration Rate (scfm)	16.4	16.4	16.4
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:	+28 mesh	+28 mesh	+28 mesh
Particle Size	6.52	7.41	8.00
% Solids	as is	as is	as is
Ph			

Results: Frother Addition Test 1 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	12.68	41.53	23.93
Reject	61.33	58.47	76.07
Feed	49.69	100.0	100.0

Results: Frother Addition Test 2 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.21	28.73	16.20
Reject	56.94	71.27	83.80
Feed	49.37	100.0	100.0

Results: Frother Addition Test 3 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.92	28.14	15.58
Reject	57.54	71.86	84.42
Feed	50.12	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

	Test 4	Test 5	Test 6
Feed Rate (gpm)	100	100	120
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	21	21	21
Frother (DF1012 ml/min)	25	15	10
Aeration Rate (scfm)	18.45	18.45	18.45
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:

Particle Size	+28 mesh	+28 mesh	+28 mesh
% Solids	7.79	8.53	9.87
Ph	as is	as is	as is

Results: Frother Addition Test 4 (cum)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.35	30.46	18.26
Reject	54.27	69.54	81.74
Feed	46.25	100.0	100.0

Results: Frother Addition Test 5 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.66	32.74	17.50
Reject	61.07	67.26	82.50
Feed	52.25	100.0	100.0

Results: Frother Addition Test 6 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.63	25.21	13.63
Reject	57.69	74.79	86.37
Feed	51.14	100.0	100.0

Marrowbone Prep. Plant
Operating Parameters
Cyclone Feed
(Frother Addition)
In-Plant

Date: 02/08/90

Column Geometry:

Column Height	26.5 Feet
Column Diameter	29.25 inches
Distance to Feed Pt.	4.5 Feet
Distance to CCW (Upper)	3.0 inches (Above Froth)
to CCW (Lower)	7.0 inches (Below Overflow Lip)

Operating Parameters:	Test 7	Test 8	Test 9
Feed Rate (gpm)	100	100	100
CCW Rate (gpm)	23	23	23
Collector (Diesel ml/min)	16	16	16
Frother (DF1012 ml/min)	10	15	25
Aeration Rate (scfm)	18.45	18.45	18.45
Froth Zone Depth (in.)	40	40	40

Feed Characteristics:

Particle Size	+28 mesh	+28 mesh	+28 mesh
% Solids	9.20	----	----
Ph	as is	as is	as is

Results: Frother Addition Test 7 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.33	23.75	12.81
Reject	57.72	76.25	87.19
Feed	51.65	100.0	100.0

Results: Frother Addition Test 8 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.69	15.12	8.20
Reject	55.69	84.88	91.80
Feed	52.08	100.0	100.0

Results: Frother Addition Test 9 (-28 mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	11.60	21.30	11.68
Reject	56.81	78.70	88.32
Feed	51.53	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 1

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	11
Frother (DF1012 ml/min)	13
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	6.17
Ph	Nat.

Results: (Cyclone Feed) Test 1 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.88	52.63	34.02
Reject	58.64	47.37	65.98
Feed	42.39	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet
Column Diameter	29.25	inches
Distance to Feed Pt.	4.5	Feet
Distance to CCW (Upper)	3.0	inches (Above Froth)
Distance to CCW (Lower)	7.0	inches (Below Overflow Lip)

Operating Parameters:

Test 2

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	15
Frother (DF1012 ml/min)	16
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	8.68
Ph	Nat.

Results: (Cyclone Feed) Test 2 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	10.44	41.34	24.78
Reject	58.14	58.66	75.22
Feed	46.14	100.0	100.0

Marrowbone Prep. Plant
Feed Size Distribution
In-Plant
Cyclone Feed

Date: 1/25/90

Column Geometry:

Column Height	26.5	Feet	
Column Diameter	29.25	inches	
Distance to Feed Pt.	4.5	Feet	
Distance to CCW (Upper)	3.0	inches	(Above Froth)
Distance to CCW (Lower)	7.0	inches	(Below Overflow Lip)

Operating Parameters:

Test 3

Feed Rate (gpm)	95 (plus/minus 10 gal.)
CCW Rate (gpm)	23
Collector (Diesel ml/min)	15
Frother (DF1012 ml/min)	11
Aeration Rate (scfm)	18.45
Froth Height (inches)	42

Feed Characteristics:

Particle Size	Coarse
Feed % Solids	8.16
Ph	Nat.

Results: (Cyclone Feed) Test 3 (-28 Mesh)

Component	Ash (%)	Combustible Recovery (%)	Yield (%)
Product	9.97	43.14	26.52
Reject	57.18	56.86	73.48
Feed	44.66	100.0	100.0

END

DATE FILMED

10 / 26 / 90