DOE/PC/93157--T5

~~FINAL~~

IMPROVEMENT OF STORAGE, HANDLING, AND TRANSPORTABILITY OF FINE COAL

Contract No. DE-AC22-93PC93157

QUARTERLY TECHNICAL PROGRESS REPORT NO. 3

Covering the Period July 1, 1994 to September 30, 1994

Prepared for:
U.S. Department of Energy
Pittsburgh Energy Technology Center
P. O. Box 10940
Pittsburgh, PA 15236-0940

Submitted by:
Energy International Corporation
135 William Pitt Way
Pittsburgh, PA 15238

March 6, 1996
Revised: August 16, 1996

DISCLAIMER

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 PROJECT SUMMARY

1.1 Background and Objectives

Fine coal production is on the rise in the U.S., and it will continue to increase as underground mining companies invest in more productive equipment. Fine coal cleaning technologies have been developed to efficiently and economically separate coal from clay and other mineral matter in the fine size fractions, but have not gained universal acceptance in the coal industry because their product is considered too wet by major coal users.

Historically coal producers take one of two approaches in dealing with fine coal production. On the one hand, they may wash it and recover it as a wet cake, which must be thermally dried prior to shipment. On the other hand, many operators make no attempt to recover fine coal, and dispose of it as a wet cake or slurry in refuse piles, slurry impoundments, and abandoned deep mines. There are environmental problems related to both of these practices.

The Mulled Coal process was developed as a means of overcoming the adverse handling characteristics of wet fine coal without thermal drying. The process involves the addition of a low cost, harmless reagent to wet fine coal using off-the-shelf mixing equipment. Based on laboratory- and bench-scale testing, Mulled Coal can be stored, shipped, and burned without causing any of the plugging, pasting, carryback, and freezing problems normally associated with wet coal. On the other hand, Mulled Coal does not cause the fugitive and airborne dust problems normally associated with thermally dried coal.

The objectives of this project are to demonstrate that:

- The Mulled Coal process, which has been proven to work on a wide range of wet fine coals at bench scale, will work equally well on a continuous basis, producing consistent quality at a convincing rate of production in a commercial coal preparation plant.

- The wet product from a fine coal cleaning circuit can be converted to a solid fuel form for ease of handling and cost savings in storage and rail car transportation.

- A wet fine coal product thus converted to a solid fuel form, can be stored, shipped, and burned with conventional fuel handling, transportation, and combustion systems.

1.2 Project Overview

It is useful to describe the project in groups of activities in order to fully understand the interactions between activities and to better understand the information flow and decisions of the project. The project is organized around two major demonstrations: (1) the production of Mulled Coal in a commercial operating setting, and (2) the delivery of the Mulled Coal product through existing commercial storage, transport, and handling systems.

The initial project activities are performed largely at the EI facilities and will produce the formulations, test procedures, and design packages required to procure and install the Mulled Coal circuit at the Drummond Company, Inc., Chetopa Preparation Plant in Graysville, Alabama. The installed circuit will be used for the demonstration of Mulled Coal production. The second set of demonstrations will be the shipment and handling of Mulled Coal in existing coal transportation systems. Data collected from all phases of production and delivery will then be analyzed, evaluated, and reported.

The Mulled Coal circuit will be installed in the operating preparation plant located at the Chetopa Mine site. The Chetopa Plant processes 360 to 400 tonnes/hr (400 to 500 tons/hr) of raw coal to produce 250 to 320 tonnes/hr (275 to 350 tons/hr) of clean coal for shipment to the steam coal market. Approximately 45 to 55 tonnes/hr (50 to 60 tons/hr) of fine coal is cleaned in froth cells to produce 40 to 45 tonnes/hr (45 to 50 tons/hr) of a fine clean coal that is 10-14 percent ash. Froth concentrate reports to a vacuum filter where a 24-27 percent moisture filter cake is discharged to a collecting belt. In current operations, the wet filter cake is combined with the coarser size fractions of clean coal for storage and delivery to market. The wet filter cake comprises about 15 to 18 percent of the total clean coal product from the plant.

The proof-of-concept (or POC) circuit will process a 2.7 tonnes/hr (3 tons/hr) slipstream of froth concentrate from the existing froth cells in the Chetopa Plant as feed to the Mulled Coal circuit. The froth concentrate will be dewatered in a centrifuge to prepare a wet fine coal feed material for conversion into a free-flowing granular material. The Mulled Coal product will be directed to a 450 tonne (500 ton) open storage pile. The POC unit will be of a design that can be scaled up to 135 tonnes/hr (150 tons/hr). Figure 1 shows the key components of the Chetopa Plant cleaning circuit and the Mulled Coal circuit that will be installed.

The Mulled Coal circuit will be installed in an empty bay at the Chetopa Plant. This area is convenient to the discharge location from the froth cells and at a lower elevation. The use of gravity feeds will minimize field fabrication. Equipment will be installed to divert a 2.7 tonnes/hr (3 tons/hr) slipstream of the froth concentrate to a dewatering centrifuge. The concentrated wet coal fines from the centrifuge will be dropped through a chute directly into a surge hopper and feed system for the Mulled Coal circuit. The Mulled Coal product will be gravity discharged from the circuit to a truck or product discharge area from which it will be hauled to a stockpile which will be located at the edge of the active clean coal stockpile area.

During the 3-month operating period, the facility should produce 910 tonnes (1000 tons) of the Mulled Coal for evaluation in various storage, handling, and transportation equipment and operations.

2.0 PROJECT TECHNICAL WORK PLANS

2.1 Technical Approach and Work Plan Overview

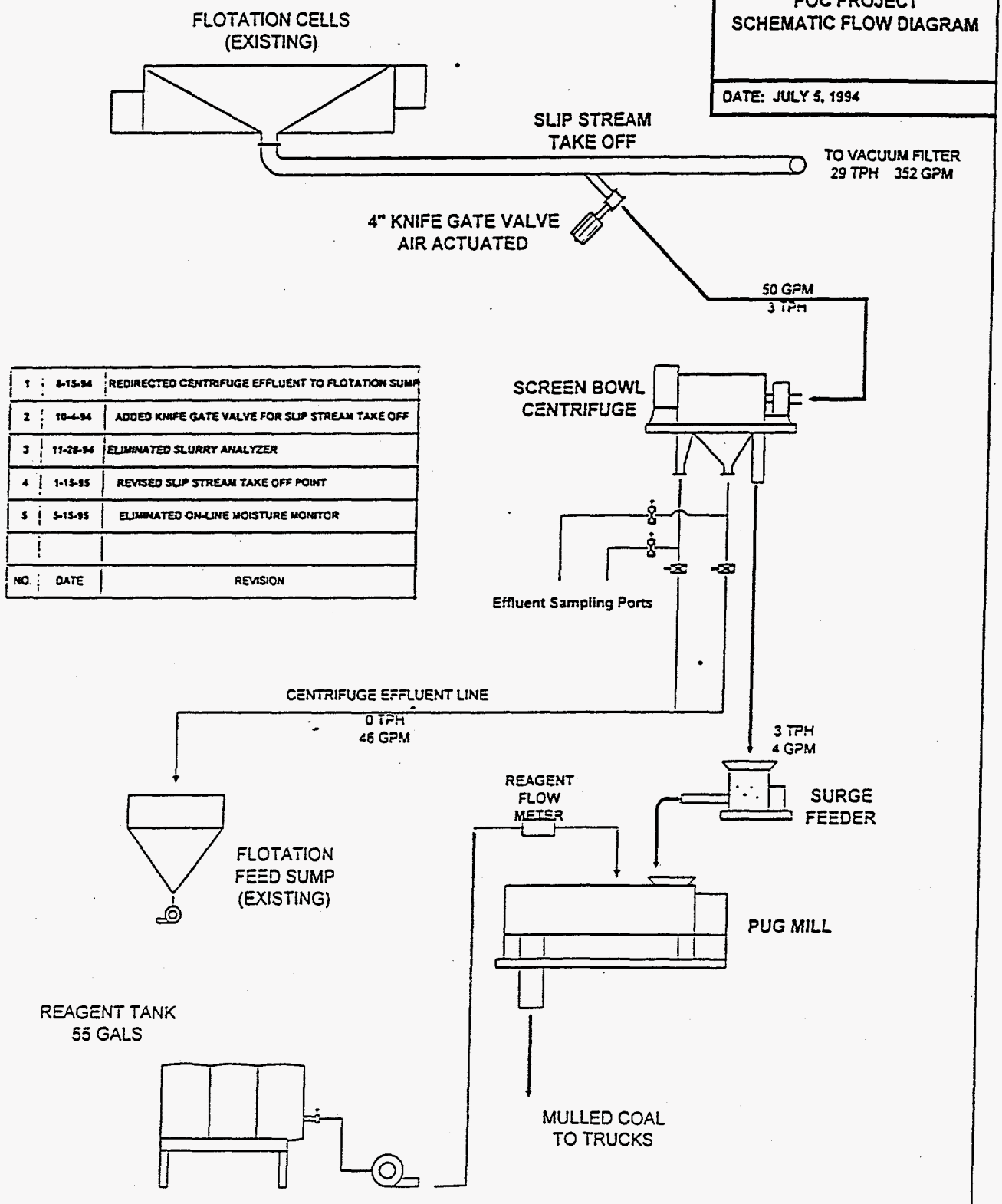
This project focuses on achieving two demonstrations of the Mulled Coal technology: (1) Production in commercial operating environment, and (2) Delivery of product in existing storage

Figure 1

ENERGY INTERNATIONAL

POC PROJECT
SCHEMATIC FLOW DIAGRAM

DATE: JULY 5, 1994



NO.	DATE	REVISION
1	8-15-94	REDIRECTED CENTRIFUGE EFFLUENT TO FLOTATION SUMP
2	10-4-94	ADDED KNIFE GATE VALVE FOR SLIP STREAM TAKE OFF
3	11-28-94	ELIMINATED SLURRY ANALYZER
4	1-15-95	REVISED SLIP STREAM TAKE OFF POINT
5	5-15-95	ELIMINATED ON-LINE MOISTURE MONITOR

transportation, and handling systems. To successfully complete these demonstrations, the project has been organized into a series of task activities which lead to the demonstrations, support the engineering and management needs of the project, and assess and report the activities and results. The development of the design basis and assessment of Mulled Coal technology application are direct parallels to activities that would be needed in any specific individual commercial application.

The technical approach is comprised of the following:

1. Prepare work plans at the beginning of the project with mechanisms for adding detail and updating the plans as new information is generated.

2. Collect and evaluate information specific to the coal and plant operations at the host site that is needed to complete the circuit design, equipment selections, installation plans, and production scheduling and plans.

3. Use the evaluation results to complete the design, equipment selection, and production planning.

4. Procure, install, and start-up the Mulled Coal circuit at the host site.

5. Conduct the demonstration of production operations.

6. Select delivery destinations and develop specific plans for monitoring dumping, fuel handling, etc. at each unique destination. Final decisions and detailed plans will be made when coal deliveries are ready to be scheduled, which in commercial practice is several months from the expected availability of product for shipment.

7. Conduct the demonstration of Mulled Coal technology in existing storage, transportation, and handling operations.

8. Prepare technical and economic assessment of the technology based on the data generated in the demonstration operations.

The key features to this approach include defined work plans, generation of information that enables specific decisions and contingencies to be addressed, and the utilization of experience to adjust the operations and data collection processes.

The evaluations and tests conducted in the early bench-scale engineering activities provided information needed to make key decisions. If we find that results fall outside the expected range, then the plans and the capabilities of the facilities and personnel are sufficiently versatile to revise the work plans.

2.2 Work Plan Assumptions

Developing the work plans has required making key assumptions, which are:

1. The fine wet clean coal produced at the Chetopa Plant can be mulled using the experience base of reagent formulations and dosage rates.

2. The dilute froth concentrate will be a suitable alternative feedstock should the vacuum filter cake not be suitable.

3. The slipstream from the froth cell discharge can be taken without disruption of the existing plant operations.

4. The storage, transportation, handling, and stability characteristics of Mulled Coal will be similar to those properties as evaluated in the bench-scale engineering evaluations and testing.

3.0 TECHNICAL PROGRESS

3.1 Overview

During this reporting period, technical progress was made in three general activity areas. Those activity areas are: characterizing and evaluating project feed sources, bench-scale and pugmill test evaluations, and preliminary process design and equipment selection. Work in the other activity areas will be described in following sections.

The approach used during this period of technical activities was to collect sufficient information in bench-scale mulling tests and pugmill tests to enable the selection of the project feedstock coal and to permit the development of the preliminary Mulled Coal circuit schematic flow diagram. Samples of wet filter cake and froth concentrate were collected from the Drummond preparation plant. These coals were characterized and tested to determine the mulling characteristics.

Based on these evaluations, it was determined that the filter cake, which contains flocculent, would not be a suitable feedstock material for the project circuit demonstration. The froth concentrate is diverted from the plant circuit after the discharge from the froth cells and prior to the addition of the flocculent and vacuum filtration. This froth concentrate is well suited as a project feedstock. The technical decision was then made to design the circuit with the froth concentrate as the project feedstock.

A project schematic flow diagram for the Mulled Coal circuit as it is to be installed at Drummond was developed and is shown in Figure 1. The initial concept as shown in this figure allows for the diversion of a slipstream of the froth concentrate from the discharge stream from the flotation cells. It will most likely be taken from the feed end of the flotation cell launder, which will

enable a high and consistent quality of the project feed and will have a minimal disruption to the plant process flow stream. The detailed design and location of the slipstream take-off will be reviewed with Drummond for approval.

With the selection of froth concentrate as the project feedstock, it will be necessary to include a screen bowl centrifuge to concentrate the solids content and produce a wet cake of acceptable moisture content for the mulling circuit. This centrifuge will be supplied to the project by Decanter Machine at no cost to the project for the demonstration activities. The discharge from the centrifuge will then be fed through a surge feeder with a moisture probe to the pugmill for mulling.

The development of the preliminary project schematic flow diagram and conceptual design basis then provided sufficient information to begin specific selection and design of major equipment. Long lead time procurement actions are to be initiated as quickly as specifications and bid packages can be prepared. Along with that, additional testing in the bench-scale and pugmill tests will provide the more detailed database needed for the project operations.

3.2 Characterize Project Feedstock

Project feed coal was to be provided by a 2.7 tonnes/hr (3 TPH) slipstream of the normal Chetopa 28M x 0 clean coal product. 28M x 0 ROM coal in the Chetopa plant is separated from the coarser size fractions with 4 cross flow screens and 4 lowhead desliming screens. The fine coal is washed in a parallel circuit of two banks of froth flotation cells (Denver - 4 cell, 300 cu ft each; Wemco - 3 cell, 300 cu ft each). Froth concentrate is dewatered by a 12' 6" diameter by 14 disc Peterson vacuum filter (Figure 2).

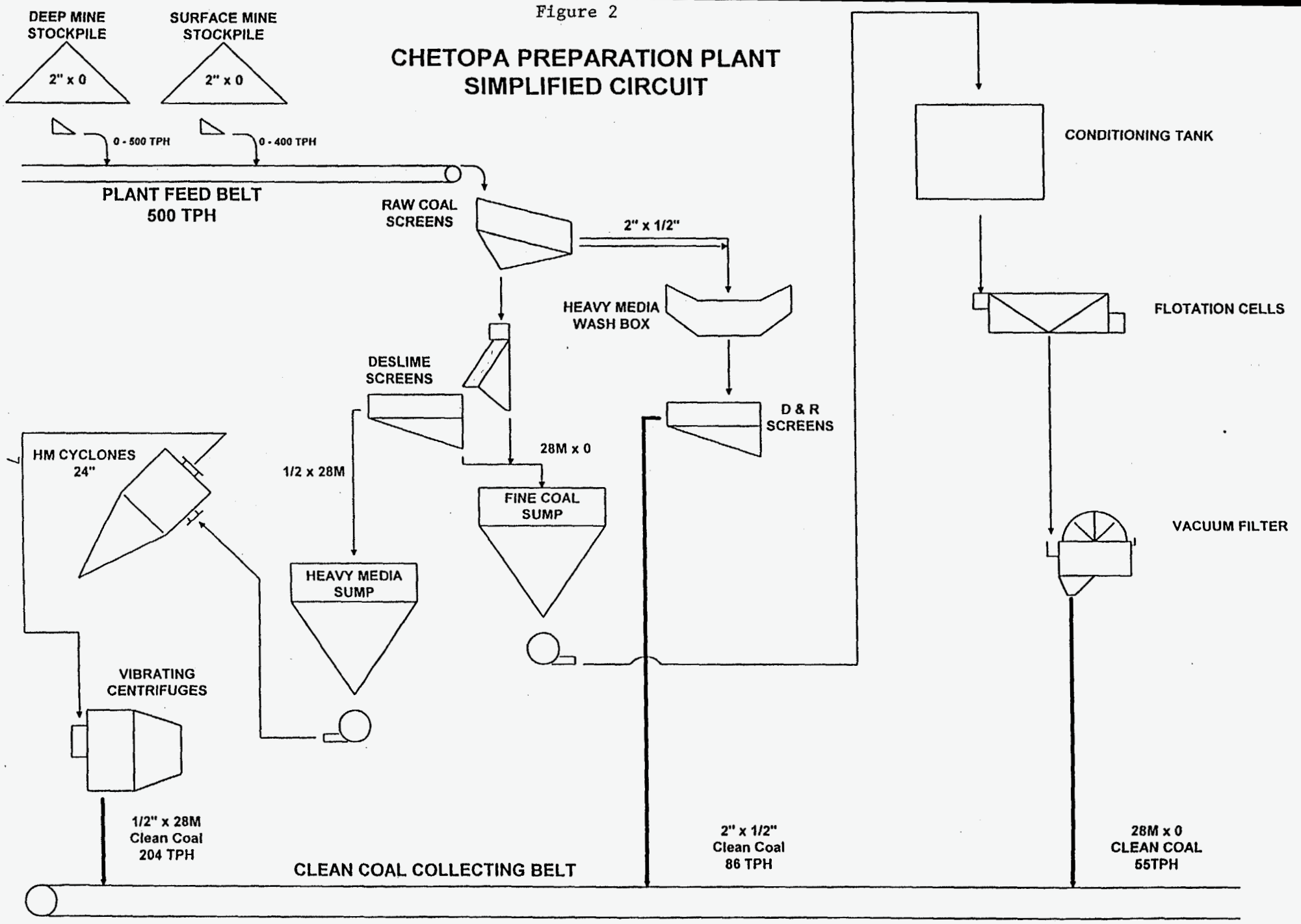
Preliminary screening tests indicated that the Chetopa 28M x 0 clean coal product had a fairly narrow ash range (11% to 13% dry ash) and about a 4% moisture range (23% to 27%).

In order to design a Mulled Coal circuit which could be expected to perform well over the full range of variations in feed quality and size distribution, we decided to verify the results of preliminary screening tests and Drummond historical records through a series of two bulk samples which spanned up to three consecutive shifts of plant operation.

From time to time, the Chetopa plant adds flocculent to froth concentrate in an attempt to improve vacuum filter dewatering performance. The use of flocculent is not an every day occurrence, and when it is used, dosages vary depending on operating conditions. There was some indication from preliminary screening tests at Chetopa, that the presence of flocculent on filter cake, especially in the case of an overdose, could have an adverse effect on the mulling process.

Because of potential problems with flocculent and some mechanical considerations which will be explained later, we were not certain of just where we would pull off the slipstream, so it was decided that one of the bulk samples for feedstock characterization would represent only filter cake which had been treated with flocculent, and the other would represent only froth concentrate which had not been treated with flocculent.

Figure 2


CHETOPA PREPARATION PLANT
SIMPLIFIED CIRCUIT
DEEP MINE STOCKPILE
2" x 0
SURFACE MINE STOCKPILE
2" x 0
0 - 500 TPH
0 - 400 TPH
PLANT FEED BELT
500 TPH
RAW COAL SCREENS
2" x 1/2"
HEAVY MEDIA WASH BOX
DESLIME SCREENS
D & R SCREENS
28M x 0
1/2 x 28M
HM CYCLONES 24"
FINE COAL SUMP
HEAVY MEDIA SUMP
VIBRATING CENTRIFUGES
CONDITIONING TANK
FLOTATION CELLS
VACUUM FILTER
1/2" x 28M Clean Coal 204 TPH
CLEAN COAL COLLECTING BELT
2" x 1/2" Clean Coal 86 TPH
28M x 0 CLEAN COAL 55TPH

It was relatively simple to collect incremental full stream cuts of filter cake from the belt head of the filter cake collecting belt. Collecting representative full stream cuts of froth concentrate was more of a problem. By the time the concentrate from individual flotation cells was collected into one pipe, there was no place to sample the stream between that point and the point where flocculent is added.

For purposes of the feedstock characterization and subsequent tests, we had to be certain that our composite froth concentrate sample would be representative of the full stream of 28M x 0 clean coal. We tested individual flotation cells and made calculations of the percentage of the total amount of concentrate coming off each cell. Then we could sample the concentrate stream coming off individual cells and combine the samples in the proper proportion to produce a representative composite. We verified the procedure by comparing the quality and size distribution of the concentrate sample to filter cake sample results where we were certain that we had a representative cross section of the full stream of 28M x 0 coal (Figure 3).

3.2.1 Filter Cake

The first bulk sample was a filter cake treated with flocculent. The sample amounted to five full drums of filter cake (approximately 2000 lbs) gathered in 10 lb increments from the belt head of the filter cake collecting belt. It was gathered by EI personnel on March 8 and 9, 1994. Characterization tests (ash, moisture and size distribution) were performed at the EI mineral preparation laboratories during the period of March 15, 1994 to April 6, 1994.

This first sample was to be used as a marker for the main source of plant feed, so the plant ran on straight Mary Lee deep mine coal for the duration of the test.

The objectives of the characterization tests were to establish the full quality range of the project feedstock as to ash, moisture, and size distribution, and to determine whether or not there was a predictable relationship between any of those characteristics.

Each drum of the first sample was cored, and the cores were combined to form a composite sample covering the entire sampling period. A cut of the composite sample was sent to a commercial laboratory for proximate analysis (Table I). Then the drums were cored again, and the drum cores plus the composite samples were individually tested to determine the following (see Table II):

ash
moisture
wet screen analysis (6 size fractions)
differential volume analysis (microtrac) on the 28M x 0 fraction

Test results indicated that, for the duration of the tests, there was a very narrow range in the key feedstock characteristics which might affect the performance of a Mulled Coal circuit.

Figure 3

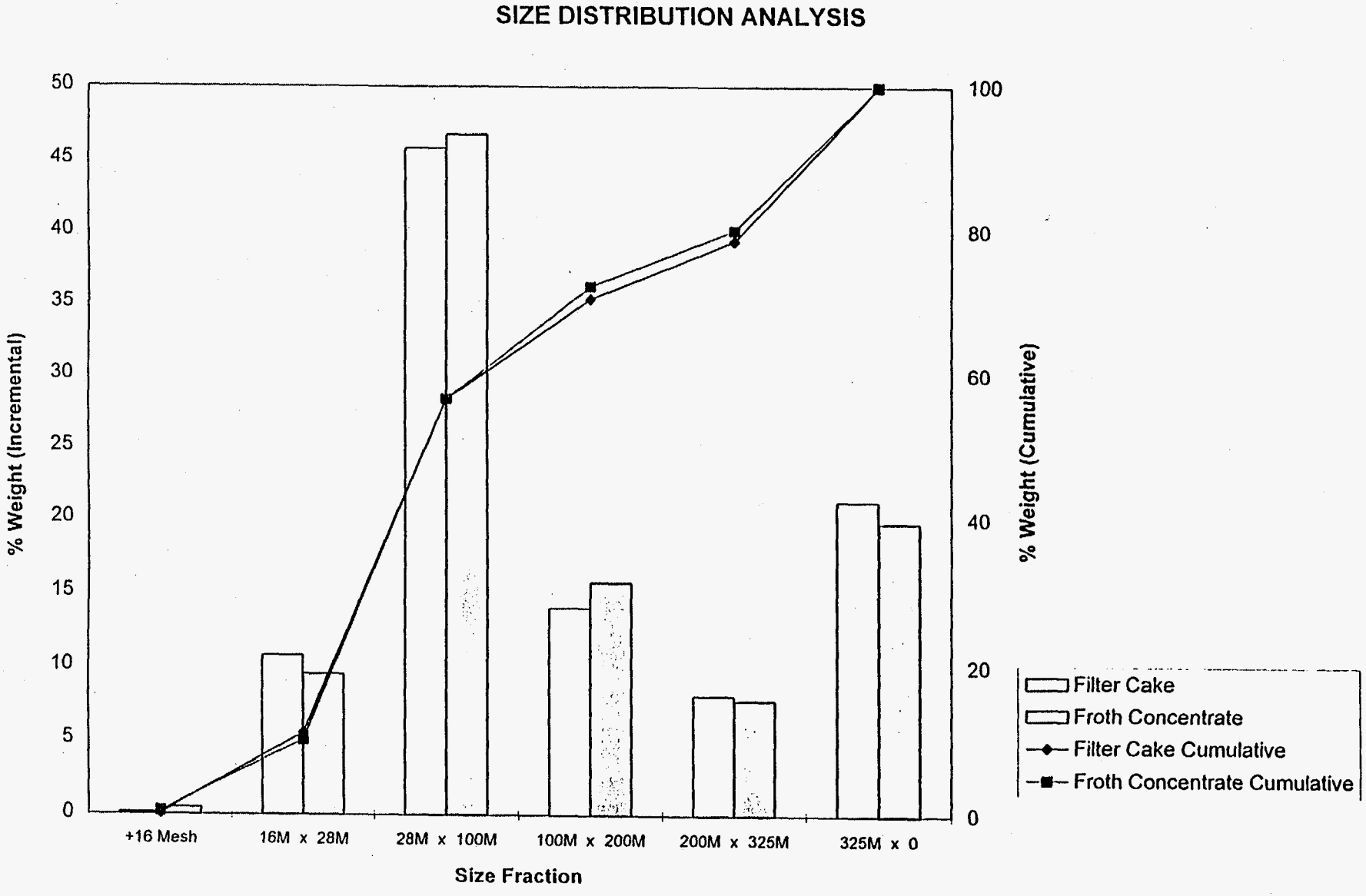

SIZE DISTRIBUTION ANALYSIS
% Weight (Incremental)
% Weight (Cumulative)
50
45
40
35
30
25
20
15
10
5
0
100
80
60
40
20
0
+16 Mesh
16M x 28M
28M x 100M
100M x 200M
200M x 325M
325M x 0
Size Fraction
Filter Cake
Froth Concentrate
Filter Cake Cumulative
Froth Concentrate Cumulative

Table I

COMMERCIAL TESTING & ENGINEERING CO.
GENERAL OFFICES: 1919 SOUTH HIGHLAND AVE., SUITE 210-B, LOMBARD, ILLINOIS 60148 • TEL: 708-953-9300 FAX: 708-953-9306
Member of the SGS Group (Société Générale de Surveillance)

PLEASE ADDRESS ALL CORRESPONDENCE TO:
P.O. BOX 32, CHARLEROI, PA 15022
TEL: (412) 483-3548
FAX: (412) 483-0892

March 22, 1994

Energy International Inc.
135 William Pitt Way
Pittsburgh PA 15238

Sample identification by
Energy International Inc.

FC 016 038
3/18/94

Kind of sample reported to us: COAL SAMPLE

Sample taken at: --

Sample taken by: SUBMITTED

Date sampled: ------

Date received: March 18, 1994

Analysis Report No. 43-146778

PROXIMATE ANALYSIS

	As Received	Dry Basis		
% Moisture	22.11	xxxxx		
% Ash	9.25	11.88		
% Volatile	23.48	30.14		
% Fixed Carbon	45.16	57.98		
	100.00	100.00		
Btu/lb	10494	13473	MAF	15289
% Sulfur	1.06	1.36		

FREE SWELLING INDEX = 7.5

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, Charleroi Laboratory

Table II

CHARACTERIZATION TESTS - FILTER CAKE CONDITIONED WITH FLOCCULENT

Pre Production Feed Source Testing Filter Cake

Lab No.	Date	Sample Location	Sample ID	Moisture	Size Distribution											
					+16 Mesh		16M x 28M		28M x 100M		100M x 200M		200M x 325M		325M x 0		Composite	
					% WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH
016-39A	3/24/94	2	Drum 1	22.00	0.11	*	10.59	7.60	46.76	11.00	13.97	12.50	8.06	12.30	20.51	14.80	100.00	11.73
016-39B	3/24/94	2	Drum 2	23.00	0.20	*	11.61	7.70	46.55	11.40	13.68	12.40	7.76	10.90	20.20	15.30	100.00	11.86
016-40A	3/24/94	2	Drum 3	24.00	0.15	*	10.38	7.40	46.79	11.00	13.97	12.70	8.25	12.00	20.46	15.10	100.00	11.79
016-40B	4/5/94	2	Drum 4	25.00	0.19	*	9.98	7.60	44.99	11.10	13.97	13.20	7.93	11.50	22.94	15.60	100.00	12.11
016-41	4/6/94	2	Drum 5	26.00	0.13	*	9.12	7.20	46.25	10.30	14.20	11.60	8.22	10.50	22.08	15.30	100.00	11.32
			Average	24.00	0.16	*	10.34	7.50	46.27	10.96	13.96	12.48	8.04	11.44	21.24	15.22	100.00	11.76
016-38	3/17/94	2	Composite	23.00	0.20	*	11.06	7.90	46.52	11.40	13.75	12.90	7.95	13.20	20.52	15.40	100.00	12.18

Sample Location
2. Filter Cake Belt Head
3. Froth Cells Launder

Sample ID
1. Filter Cake
2. Froth Concentrate

Characteristic	Range		
	Low	Average	High
Ash (% dry)	11.32	11.76	12.11
Moisture (%)	22.00	24.00	26.00
325M x 0 (% of total)	20.20	21.24	22.94
Mean Particle Diameter (microns)	198.45	204.93	216.95
Calculated Surface Area (m^2/cc)	0.165	0.172	0.183

The ranges for the tested characteristics of the filter cake were so narrow that it can be assumed that the quality of the 28M x 0 clean coal product remained virtually unchanged throughout the two shift time period covered by the sample.

3.2.2 Froth Concentrate

The second bulk sample was limited to froth concentrate which had not been conditioned with flocculent. The sample was gathered by EI personnel on May 23 and 24, 1994. The sampling period covered 24 continuous hours of plant operation, over which 4 drums of decanted froth concentrate were collected and shipped to the EI minerals preparation laboratory in Pittsburgh. Characterization tests were conducted during the period of June 10-24, 1994.

The size distribution and quantity of coal in the concentrate discharging from individual cells in a bank of froth cells varies significantly from cell to cell (Figure 4), and is influenced by such factors as feed characteristics, amount and type of chemicals used, and cell design and method of operation. From previous screening tests at Chetopa, we expected about 60% of the concentrate to be coming off the feed end cell, 20% off the next cell, 15% off the next cell and 5% off the tailings end cell.

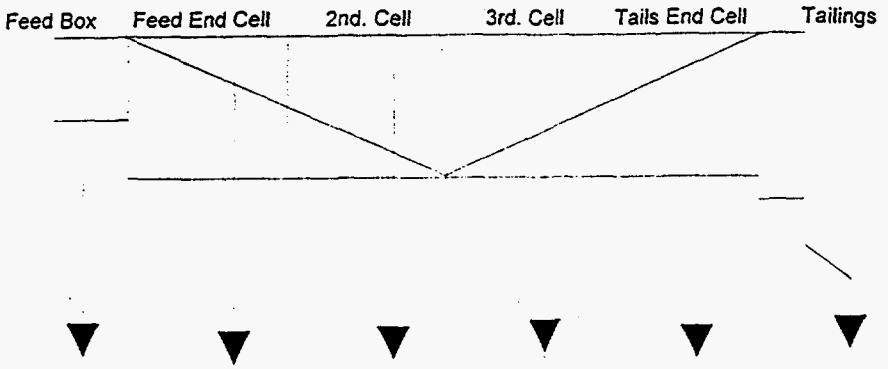
In gathering the froth concentrate bulk sample, individual cell discharges were sampled in accordance with the proportions determined in the screening tests. The individual cell samples were combined in each drum in accordance with the predetermined proportions and the composite ash and size distribution of each drum compared very favorably with the results of filter cake samples (Table III) indicating that the bulk sample was representative of the full stream of 28M x 0 clean coal.

In order to conserve space and obtain as much coal as possible for subsequent parametric mulling tests, we decanted each sample grab from the froth cells. For each grab, 3 to 4 gallons of concentrate was collected in a 5 gallon bucket. The bucket of dilute concentrate was then set aside and allowed to settle for 20 to 30 minutes. Excess water was poured off, and the decanted sample was transferred to the 55 gallon drums used to collect the bulk sample. By this method we were able to increase percent solids from the 30%-35% range which was normal for dilute concentrate up to 54%-58% for the bulk sample.

For purposes of the characterization tests, each of the four concentrate drums was sampled while being stirred, and the individual samples were tested for ash, wet screen analysis at 6 size

Figure 4

DENVER FLOTATION CELL PERFORMANCE



% Solids		38.00	34.00	27.00	24.00	
% Ash (Dry)	39.10	8.10	12.90	15.60	16.60	70.18
Size Distribution						
+ 28 Mesh	6.04	8.20	10.30	3.10	3.00	6.56
28M x 100M	29.82	36.70	56.40	41.60	19.40	15.54
100M x 200M	11.51	33.00	12.60	13.60	12.60	7.20
200M x 325M	7.20	8.30	7.20	10.70	13.60	5.66
325M x 0	45.43	13.80	13.50	31.00	51.40	65.04
KA Mulling Test						
% Moisture		25.00	22.00	28.00	28.00	
Reagent Dose (%)		2.00	2.00	2.00	2.00	
Uniformity Results						
+ 6 Mesh		-	-	13.47	25.75	
6M x 14M		4.72	14.03	47.63	61.01	
14M x 28M		38.39	38.74	31.88	12.69	
28M x 0		56.89	47.23	7.02	0.56	
Handleability Index		95.28	85.97	38.90	13.25	

Table III

CHARACTERIZATION TESTS - FROTH CONCENTRATE

Pre Production Feed Source Testing Froth Concentrate																			
					Size Distribution														
Lab No.	Date	Sample Location	Sample ID	Ash %	+16 Mesh		16M x 28M		28M x 100M		100M x 200M		200M x 325M		325M x 0		Composite	
					% WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH	%WT	%ASH
016-77A	6/15/94	3	Drum 4	10.96	0.65	*	10.16	7.67	48.42	9.95	14.45	11.48	7.51	10.68	18.81	17.11	100.00	11.35
016-77B	6/16/94	3	Drum 3	10.82	0.34	*	8.20	7.37	45.24	9.69	17.09	9.88	8.06	11.27	21.07	17.12	100.00	11.23
016-78A	6/17/94	3	Drum 2	11.51	0.41	*	8.37	7.40	45.26	9.97	16.56	13.09	8.38	11.88	21.04	18.85	100.00	12.31
016-78B	6/21/94	3	Drum 1	13.12	0.51	*	11.30	7.98	48.03	11.71	14.83	12.75	7.12	13.75	18.21	20.56	100.00	13.21
		Average		11.60	0.48	*	9.51	7.61	46.74	10.33	15.73	11.80	7.76	11.90	19.78	18.41	100.00	12.02

Sample Location
2. Filter Cake Belt Head
3. Froth Cells Launder

Sample ID
1. Filter Cake
2. Froth Concentrate

fractions, and differential volume analysis (Microtrac). Test results indicated that the bulk sample accurately represented the full stream of 28M x 0 coal, and, for the duration of the test, there was a very narrow range of key feedstock characteristics which might affect the performance of a Mulled Coal circuit (Table IV).

It should be noted that plant feed for the filter cake sample was straight Mary Lee deep mine coal, but the plant feed during the concentrate sampling period was 75% Mary Lee deep mine with 25% coming from a combination of high ash surface mine coals. The ash and size distribution of the clean coal throughout both sampling periods was very similar with a narrow range; indicating that variations in plant feed may not have a significant impact on the operation of a Mulled Coal circuit.

3.3 Evaluate Alternative Feed Sources

The feedstock for the project was set at a nominal 2.7 tonnes/hr (3 TPH) of 28M x 0 clean coal. This required cutting out a slipstream from the normal flow of 45-55 TPH in the Chetopa 28M x 0 clean coal circuit. The slipstream had to be cut out in such a way as to cause a minimum of interference with normal plant operations and to provide a controllable and representative cross section of the Chetopa plant fine coal product.

There were two alternative sources for the slipstream (Figure 5).

1. Dewatered filter cake at some point between the cake discharge chute on the vacuum filter and the point where 28M x 0 coal was combined with coarser clean coal products, or

2. Dilute froth concentrate somewhere between the bottom of the concentrate launder on the flotation cells and the point where the concentrate was discharged to the vacuum filter.

There were advantages and disadvantages associated with both alternatives. The objectives of this evaluation were to select the alternative which would provide a reliable and controllable feedstock which was compatible with other project objectives, and to select the exact take-out point and take-out mechanism which was most cost effective, while at the same time causing the least amount of interruption to normal Chetopa plant operations.

3.3.1 Filter Cake

From time to time the Chetopa plant adds flocculent to froth concentrate in an attempt to improve vacuum filter performance. The use of flocculent as a filter feed conditioner is not an every day occurrence, and when it is used, dosages vary depending on operating conditions and particular operators (dosages are set with manual controls). The presence of flocculent on filter cake, especially in the case of an overdose, could have an adverse effect on the mulling process.

We looked at three potential points where we could take off a filter cake slipstream:

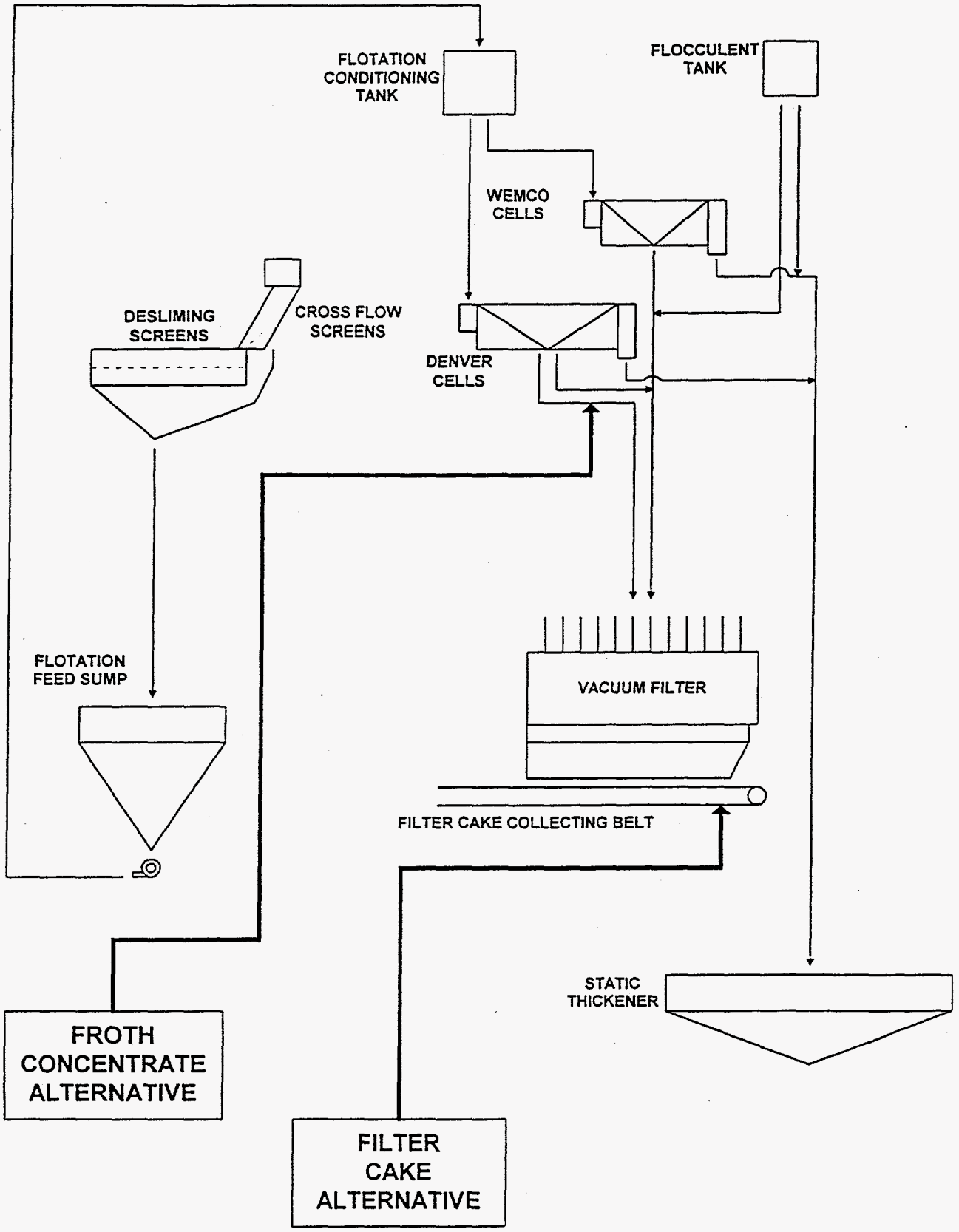
Table IV

FEEDSTOCK CHARACTERISTICS

Characteristic	Range		
	Low	Average	High
Ash (% Dry)	11.23	12.03	13.21
325M x 0	18.21	19.78	21.07
Mean Particle Diameter (microns)	202.37	219.06	239.47
Calculated Surface Area (m^2/cc)	0.133	0.114	0.093

Figure 5

ALTERNATIVE FEED SOURCES



1. The belt head of the filter cake collecting belt which was about 50' from the project bay.

2. From the top of the collecting belt somewhere near the project bay (the collecting belt ran parallel to and just above the project bay).

3. Under the vacuum filter cake discharge chute near the collecting belt tail piece. This point was within 25' of the project bay.

We encountered major obstacles at each potential location.

As is the case with many vacuum filter installations, the cake discharge chutes on the Chetopa filter would periodically hang up for a few blow cycles and then suddenly release the backed up material. This would result in the collecting belt carrying two to three times its normal load for a few seconds. It happened often enough that we knew that, if we selected filter cake for the project feedstock, we would often be presented with 30 second surges which were way beyond our set point. It was felt that the surges would probably be too great to be absorbed by the surge feeder which was selected for the project.

Even if we were able to handle surges, we ruled out taking the slipstream from the head of the collecting belt. There was not enough room for a splitter at the belt head, and there was no way to convey the material back to the project bay in a straight line.

Because the filter cake was so wet and sticky, we could not simply plow a slipstream off the top of the collecting belt as it passed by the project bay. The use of a rotating arm automatic sampler taking rapid grabs would have enabled us to take filter cake off the top of the collecting belt, and it would have solved the surge problem, but it would have been prohibitively expensive, and there was a possibility that the filter cake would hang up in the sampler.

We eventually decided that the best place to get a filter cake slipstream was from beneath the cake discharge chute in the vicinity of the last two filter discs. However, we recognized that the closer we got to the cake discharge chutes (which routinely hung up), the more risk we had of shutting down the entire plant as a result of our take-off equipment causing the cake discharge chutes to back up.

At the same time we were evaluating the mechanical considerations related to the filter cake alternative, we were proceeding with laboratory mulling tests to compare filter cake to froth concentrate, and to evaluate the effect of flocculent on mullability. We were also looking at the possibility of adding a centrifuge to the circuit if we selected froth concentrate as the feedstock. However, the closer we looked at taking off a slipstream of filter cake, the more concerned we became about the risk of interfering with normal Chetopa plant operations. Before completing the full feed source evaluation, we decided that, if the major project objectives could be achieved through the use of froth concentrate as the feedstock, we were definitely going to select that alternative -- even though it would mean adding a centrifuge to our circuit.

3.3.2 Laboratory Testing

To conduct relative mullability tests at the laboratory scale, we mixed wet cakes and reagents under controlled conditions with specific equipment and procedures. This test, developed by EI in previous Mulled Coal research work, is known internally as the K.A. mulling test.

"K.A." in the name refers to Kitchen Aid. We use a heavy duty, stainless steel, laboratory grade Kitchen Aid mixer to simulate the mixing action of a Pug Mill. In the K. A. mulling test, one kg of wet cake, with known ash, moisture and size distribution, is placed in the stainless steel bowl and mixed for one minute to eliminate any agglomeration and packing which results from the way the sample had been stored. Reagent, in measured quantities, is added in one shot, and the material is mixed for 5 minutes at a set mixing speed.

At the completion of mixing, the Mulled Coal is immediately removed from the mixer and tested for uniformity, handleability, and stability as may have been prescribed. The uniformity test is the most reliable indicator of the relative quality of Mulled Coals. The test is a recognized procedure for the evaluation of the handling characteristics of bulk materials, however, we interpret test results a bit differently than one would for a non coal or drier material.

In the laboratory uniformity test, 50 grams of Mulled Coal is placed on the top deck of a stack of three screens with deck openings of 6 mesh, 14 mesh, and 28 mesh. The material is dry screened with a rotap for 5 minutes and results are reported as the percentages of:

+6 mesh
6M x 14M
14M x 28M
28M x 0

The test is an indicator of whether or not agglomerated coal particles are completely covered with a thin membrane of reagent. If the mulling process is incomplete, agglomerated particles remain "sticky", as with most wet fine coals, and they tend to form marble sized balls, as do most wet fine coals, when they pass over vibrating screens. When the mulling process is complete, balls do not form, and a greater percentage of the sample freely flows through the screens to the bottom decks.

When a uniformity test is run on bone dry coal, virtually 100% of the material reports to the 14M x 0 size fraction. When the uniformity test is run on a mulled wet cake, the percentage of material reporting to the 14M x 0 size fraction is considered to be the Handleability Index for that sample - where 100 equals the Handleability Index of dry coal.

For the relative mullability tests, the following test conditions were maintained.

	Filter Cake	Froth Concentrate
Ash (Dry)	11.64	12.30
Reagent Dose (% by dry wt)	2.00	2.00
Mix Time (minutes)	5.00	5.00
Moisture Range (%)	23.00-27.00	23.00-27.00

There was a very significant difference between the mullability of filter cake and froth concentrate (Figure 6). Under the test conditions, the 23% moisture froth concentrate sample was converted into an excellent Mulled Coal with handling characteristics very similar to those of dry coal. The 23% moisture filter cake mull graded only fair. At higher moistures, the differences were even more significant. Throughout the entire moisture range the froth concentrate mulls remained in the excellent category, but the 25% to 27% moisture filter cake samples showed almost no improvement in handling characteristics as a result of the mulling process.

3.3.3 Flocculent

Since it was demonstrated in the feed characterization tests that filter cake and froth concentrate were essentially interchangeable, it was assumed that the presence of flocculent on the filter cake accounted for the differences in mullability between the two alternatives.

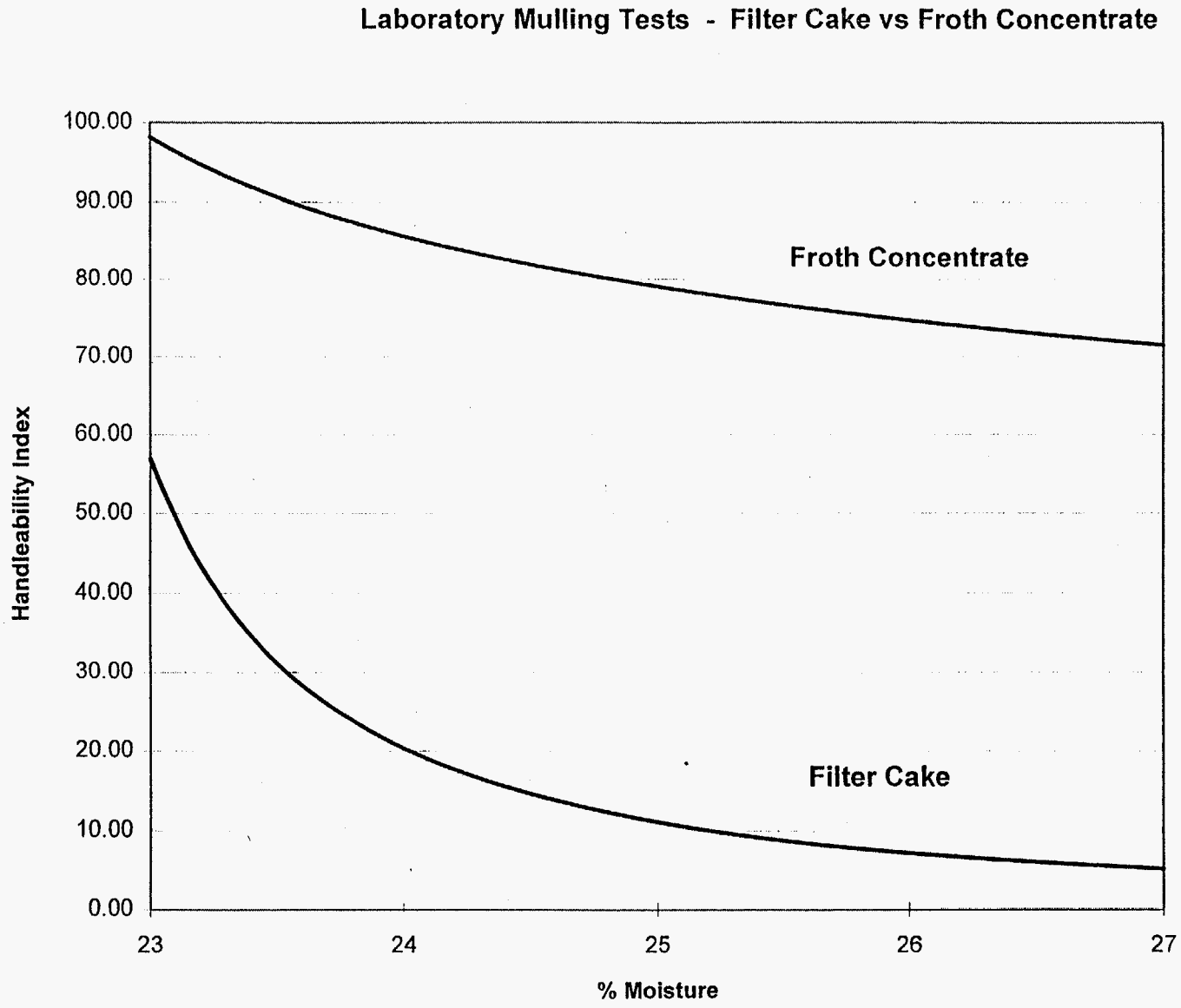
In order to verify that flocculent was the problem with filter cake mullability, we ran a special K. A. mulling test on froth concentrate with and without flocculent.

The flocculent used in the test was the actual dilute anionic flocculent used in the Chetopa plant to condition vacuum filter feed. Froth concentrate used for the test was the low ash concentrate coming off the feed end cell of the Denver cells. This particular concentrate was selected because a sample was available, and because it would be expected to form an excellent mull under normal circumstances.

The froth concentrate for this test had been decanted and filtered for other test purposes, and it was at a 28% moisture level at the beginning of the test. A 1000 gram split was set aside to air dry and be used in the concentrate without flocculent portion of the test.

Three thousand grams of the 28% moisture material was mixed with water (which had previously been filtered from froth concentrate - as opposed to tap water) to form a 29% solids dilute froth concentrate. Then dilute anionic flocculent was mixed in by hand and the flocculent conditioned sample was allowed to stand for one hour. Then the sample was refiltered and 1000 grams was split off for the K. A. mulling test.

Figure 6


Laboratory Mulling Tests - Filter Cake vs Froth Concentrate
Handleability Index
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
23
24
25
26
27
% Moisture
Froth Concentrate
Filter Cake

Specific K. A. mulling test conditions:

	Froth Concentrate	Froth Concentrate with Flocculent
Sample Size (grams)	1000	1000
Ash (% dry)	8.10	8.10
Moisture (as tested)	25.00	23.00
Flocculent Dose (lb/ton)	-0-	3.00
Reagent Dose (% by dry wt of coal)	2.00	2.00
Mix Time (minutes)	5.00	5.00

UNIFORMITY TEST RESULTS

	+6M	6M x 14M	14M x 28M	28M x 0	Handleability Index
Froth Concentrate (with Flocculent)	36.74	62.12	0.95	0.19	1.14
Froth Concentrate (no Flocculent)	-0-	4.72	38.39	56.89	95.28

For purposes of this test, we used an obvious flocculent overdose, but it was felt that such a condition could occur at the Chetopa plant from time to time.

From available test data, we knew that the presence of flocculent had an adverse effect on the mullability of filter cake. We also knew from subsequent parametric testing that we could overcome those adverse effects with increased reagent doses and reagent additives. However, when poor mullability was coupled with the mechanical disadvantages of taking off a slipstream of filter cake, it was clear that we should select the froth concentrate alternatives if:

1. We could devise a way to fit a centrifuge into the Mulled Coal circuit within the scope of resources which were available to the project, and

2. The use of a centrifuge would permit us to control the feed in such a way as to test the Mulled Coal circuit over a wide range of operating conditions.

3.3.4 Centrifuge

By April of 1994, it was clear that froth concentrate which had not been conditioned with flocculent was the preferred feed source for the project. Since concentrate came off the Chetopa

flotation cells at about 70% moisture, it would be necessary to dewater it to test the Mulled Coal Process over the moisture ranges which are common in commercial 28M x 0 coal preparation circuits.

We considered vacuum filters, filter presses and centrifuges; all of which should be capable of drying at least 2.7 tonnes/hr (3 TPH) of 28M x 0 clean coal to a 20% to 27% moisture range - all without the use of flocculent. We quickly abandoned vacuum filters and filter presses due to cost and space limitations.

In May of 1994, Decanter Machine Inc. of Johnson City, TN agreed to furnish an 18" x 42" screen bowl centrifuge at no cost to the project. Decanter Machine is one of the major suppliers of screen bowl centrifuges to the coal industry. Their 18" x 42" machine was normally used for trial demonstrations, and it was not previously booked for use during the months scheduled for the operation of the Mulled Coal circuit.

The 18" x 42" machine capacity was an ideal match for the project. It was rated at 50 GPM, and it was fully capable of dewatering 2.5 - 5.5 TPH of froth concentrate with the solids content encountered at the Chetopa plant.

We made a quick survey of space, power, pumping, piping and chute requirements for the centrifuge. It was determined that the machine would fit easily and economically into our circuit, and its use would create an absolute minimum of interference with normal Chetopa operations. The actual setup for the centrifuge, and the slipstream take-out mechanism will be discussed in the narrative sections of this report which deal with design engineering.

3.4 Evaluate The Application of The Mulled Coal Process

In this important pre-operations test procedure, we were attempting to make certain that the design of the Mulled Coal circuit would permit us to successfully and continuously produce a handleable fine coal product over the full range of feed conditions which could be reasonably expected at the Chetopa plant and other similar 28M x 0 coal preparation circuits. The test procedure involved running an extensive series of laboratory scale parametric mullability tests, and measuring various handleability and stability characteristics of the Mulled Coal produced in each test. We were searching for predictable relationships between such parameters as Mulled Coal quality, feed ash, feed moisture, feed size distribution, reagent formulation, equipment configuration, and feed rates.

The primary sample used for parametric testing was a one ton bulk sample of decanted froth concentrate which was gathered over three consecutive production shifts on May 23-24, 1994. During the same sampling period, the following 5 gallon and 10 gallon side samples were collected:

Raw coal feed to the Denver flotation cells
Concentrate discharge from the feed end Denver cell
Concentrate discharge from the 2nd Denver cell
Concentrate discharge from the 3rd Denver cell
Concentrate discharge from the tailings and Denver cell

Concentrate discharge from the feed end Wemco cell
Dilute anionic flocculent as used in the Chetopa plant

Characterization tests (ash, moisture and size distribution as previously reported) on the bulk froth concentrate sample were completed in late May and early June.

In June and July we concentrated on the analysis of the side samples from the flotation cells. Our primary objective in evaluating flotation cell performance was to be certain that the take-off point selected for the slipstream would yield a representative cross section of the 28M x 0 clean coal product.

In late July and early August we began filtering the decanted froth concentrate sample to reduce moisture from the 50% level to the 20% to 27% range which was required for parametric sampling. Filtering the bulk sample was a slow process, but, as soon as some filtered material was available, testing began. However, the actual parametric K. A. mulling tests did not begin until early August, and they were not completed until December.

The time line for parametric sampling is presented here because a significant problem developed which affected the entire series of tests. By the time we actually ran the K. A. mulling tests, the sample was between 90 and 180 days old. As the sample aged, mullability deteriorated, and tests run under exactly the same conditions but at different times would yield entirely different results.

Even though we realized right away that we had a serious problem, we continued with and completed the parametric test series. We were more interested in relative results than absolute values, and while absolute results were sometimes very confusing, relative results for most tests conducted within two days of each other yielded meaningful information.

Our original parametric test objective was to establish a predictable relationship between Mulled Coal quality and reagent dose at various levels of feed ash, moisture and size distribution. We were able to establish with a high degree of certainty that the Mulled Coal process would work successfully over the full range of feed ash, feed moisture, and feed size distribution which we expected to encounter. We were unable to predict the exact reagent dose to apply at various levels of feed quality, but we were able to verify that particular levels of feed quality required a higher or lower reagent dose.

On September 16, 1994 we ran a repeat K. A. mulling test on a sample of froth concentrate which had been collected from the feed end cell of the Denver flotation cells. This sample was chosen for repeat testing because it was originally a small sample (5 gallon bucket) taken over a short period of time (5 minutes), and we were fairly certain that we would be retesting the exact same product. In addition, the sample, as originally tested, converted into an excellent grade of Mulled Coal. While not all of the samples deteriorated to the same extent or at the same rate as this sample, the results of the retest are indicative of the extensive deterioration which was taking place over time.

Test Conditions	Original Test	Repeat Test
Date sampled	May 24,1994	May 24, 1994
Date tested	May 27, 1994	Sept. 16, 1994
Age at testing (days)	3	115
% Moisture	23	23
% Ash	8.10	8.10
Uniformity Test Results		
+6 mesh	0.00	19.22
6M x 14M	4.72	75.42
14M x 28M	38.39	5.36
28M x 0	56.89	0.00
Handleability Index	95.28	5.36

During the period between May 27, 1994 and September 16, 1994 (the period between the original test and the retest) the pH of the water in the 38% solids froth concentrate dropped from 7.9 to 2.5. Apparently some sort of oxidation was taking place, and the oxidation process was in some way shielding hydrophobic sites on the coal particles. In order for the Mulled Coal process to work properly, there must be hydrophobic sites available for the reagent to attach itself to coal particles and agglomerates.

Not all of the samples deteriorated as rapidly or as completely as the concentrate sample from the feed end of the Denver cells. All of the froth concentrate samples were highly mullable when containers were first opened and tested, and we were certain that the aging problem with samples would not affect our field operations or the stability of the Mulled Coal we were to produce.

The probable source of the aging problem was oxidation of pyrite. This would result in the dropping of the pH of the aqueous phase and render the surface hydrophylic rather than hydrophobic. As it turned out, there was never a problem with mullability during the three month production demonstration. We were unable to predict reagent doses as a result of parametric testing of oxidized samples, but even if none of the samples had oxidized, we would not have been able to predict reliable reagent doses. The full scale Mulled Coal circuit, as demonstrated, was far more efficient than our laboratory K. A. mulling procedure, and we ended up using far less reagent than the amounts predicted from laboratory test results on fresh samples.

3.4.1 Flotation Performance Tests

The objectives of the flotation performance tests were to:

1. Insure that the slipstream take-off point would yield a representative cross section of the 28M x 0 clean coal product.

2. All of the bulk samples of filter cake and froth concentrate fell within a very narrow range of ash and size distribution. Since it was expected that there would be cell to cell differences in concentrate quality, we would be able to run K. A. mulling tests at several different ash and size distribution levels without having to make up artificial levels.

3. We wanted to look at flotation cell efficiency to see if we could develop an idea of the range of feed quality we might expect as a result of major changes in plant feed rate, raw coal quality or changes in flotation chemical dosages.

Froth concentrate is discharged from one side of the Wemco cells and both sides of the Denver cells. Flocculent is inserted directly into the concentrate launder on the feed end of the Wemco cells (Figure 7). Taking a slipstream from the Wemco cells would have required moving the flocculent insertion point somewhere downstream from the slipstream take-off point. It had been reported that the clean coal product from the Denver and Wemco cells was about the same. The easiest and most cost effective point to take off our slipstream was somewhere between the Denver cells launders and the point where they joined the flocculent treated material from the Wemco cells. In order to verify that the products from the Denver and Wemco cells were about the same, we sampled and compared several characteristics of the concentrate coming off the feed end cells on both machines (Table V).

There were differences in some characteristics, but it must be taken into account that the Wemco machine has only three 300 cu ft cells, while the Denver machine has four 300 cu ft cells. It would be expected that the concentrate from the feed end of the Wemco cells would be higher in ash, lower in percent solids, and higher in 325M x 0. Since it is higher in ash it would also be expected that it would have a lower handleability index from a K. A. mulling test. Since there were no surprises in the comparison between the Wemco and Denver cells, it was safe to assume that we would have a representative slipstream if we took it from the Denver cells.

During the early planning stages for a froth concentrate slipstream, we considered inserting a false launder inside the main launder on one side of the Denver cells. Under this scheme we would install a false launder to cut out about 25% of the concentrate flowing off one side of the cells to obtain a flow rate of 2.7 tonnes/hr (3 TPH). In order to find out if there was one area along the length of the launder where we could take out a representative slipstream, we decided to test and compare the characteristics of the concentrate coming off each cell along the length of the launder (Figure 8).

Due to significant differences in quality and flow rates along the length of the launder, we abandoned the alternative of using a false launder.

On May 24, 1994 we took samples of feed, concentrate and tailings from the Denver flotation cells. The various products were tested for ash and size distribution, and then recoveries were calculated for each size fraction (Table VI). Flotation feed ash was 39.10, concentrate ash was 12.00 and tailings ash was 70.18. This is considered to be a very efficient operation for a plant producing steam coal where the operating emphasis is on product recovery.

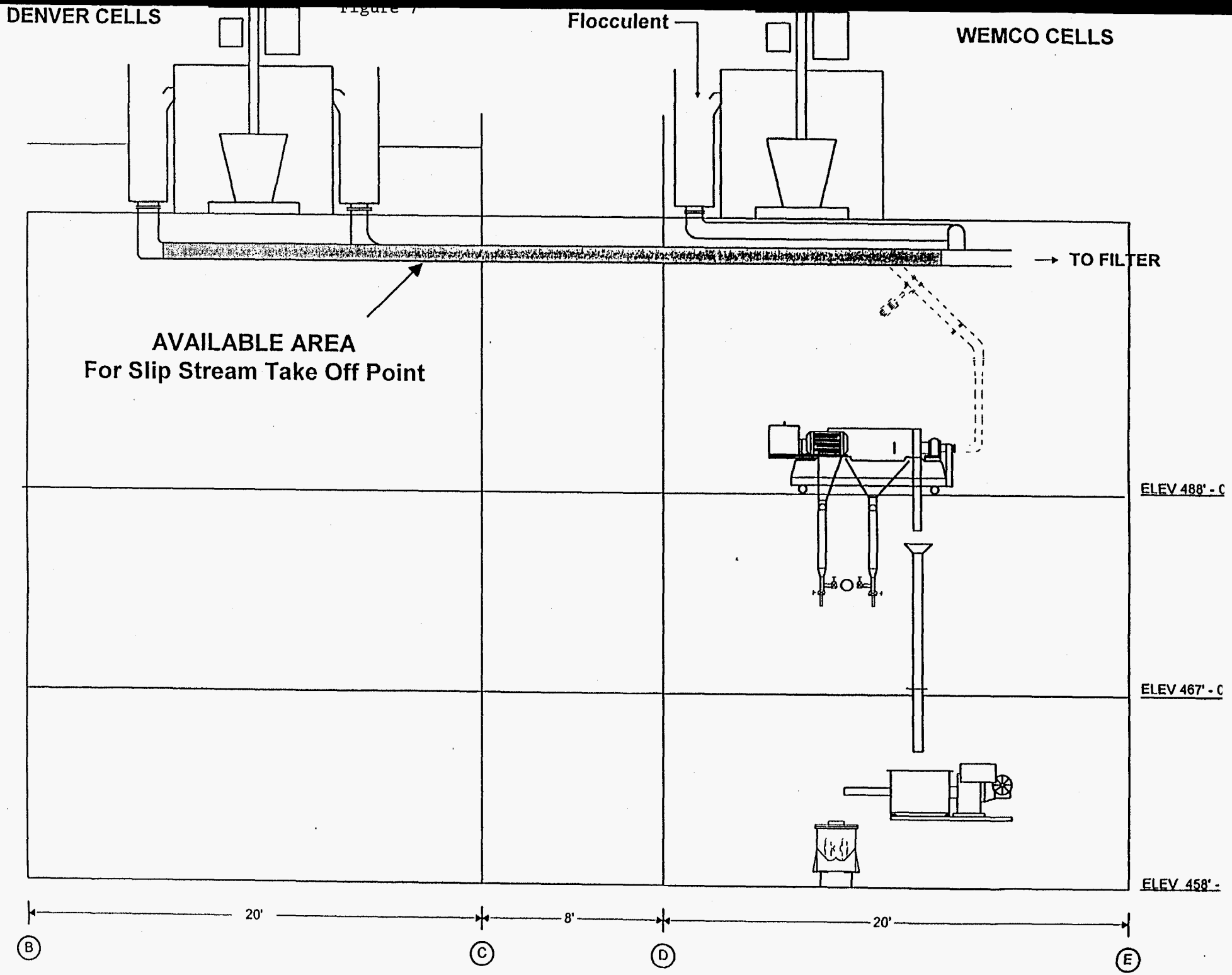

DENVER CELLS
Flocculent
WEMCO CELLS
TO FILTER
AVAILABLE AREA
For Slip Stream Take Off Point
ELEV 488' - 0
ELEV 467' - 0
ELEV 458' -
20'
8'
20'
B
C
D
E

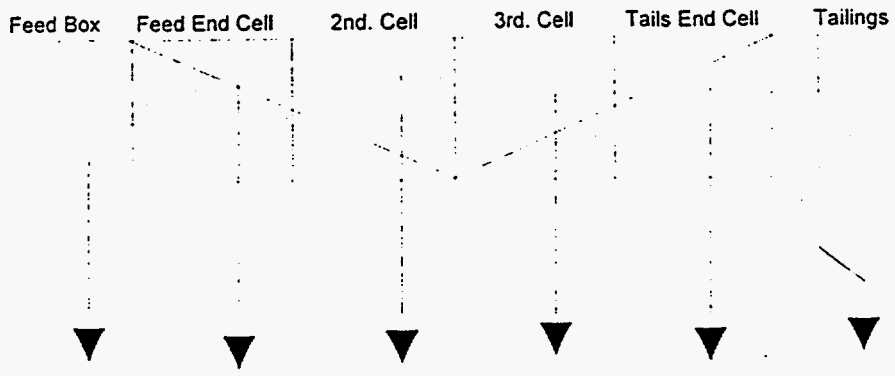
Table V

DENVER CELLS vs. WEMCO CELLS

	Denver	Wemco
Cell Location	Feed End	Feed End
% Solids	38.00	30.00
% Ash	8.10	10.60
Size Distribution		
+ 28M	8.20	7.42
28M x 100M	36.70	46.14
100M x 200M	33.00	15.41
200M x 325M	8.30	9.18
325M x 0	13.80	21.85
K.A. Mulling Test		
% Moisture	25.00	24.00
% Reagent Dose	2.00	2.00
Uniformity Test Results		
+ 6 Mesh	-	4.69
6M x 14M	4.72	18.01
14M x 28M	38.59	45.03
28M x 0	56.89	32.27
Hand. Index	95.28	77.30

Figure 8

DENVER FLOTATION CELL PERFORMANCE



% Solids		38.00	34.00	27.00	24.00	
% Ash (Dry)	39.10	8.10	12.90	15.60	16.60	70.18
Size Distribution						
+ 28 Mesh	6.04	8.20	10.30	3.10	3.00	6.56
28M x 100M	29.82	36.70	56.40	41.60	19.40	15.54
100M x 200M	11.51	33.00	12.60	13.60	12.60	7.20
200M x 325M	7.20	8.30	7.20	10.70	13.60	5.66
325M x 0	45.43	13.80	13.50	31.00	51.40	65.04
KA Mulling Test						
% Moisture		25.00	22.00	28.00	28.00	
Reagent Dose (%)		2.00	2.00	2.00	2.00	
Uniformity Results						
+ 6 Mesh		-	-	13.47	25.75	
6M x 14M		4.72	14.03	47.63	61.01	
14M x 28M		38.39	38.74	31.88	12.69	
28M x 0		56.89	47.23	7.02	0.56	
Handleability Index		95.28	85.97	38.90	13.25	

Table VI

DENVER FLOTATION CELLS

PERFORMANCE ANALYSIS

SAMPLE DESCRIPTION	FROTH FEED GRAB SAMPLE		CONCENTRATE COMPOSITE		FROTH TAILS GRAB SAMPLE	
	% WT	% ASH	% WT	% ASH	% WT	% ASH
+ 28 MESH	6.04	12.38	10.00	7.61	6.56	30.00
28 M x 100M	29.82	15.43	46.73	10.33	15.54	39.2
100M x 200M	11.51	25.16	15.73	11.80	7.20	60.4
200M x 325M	7.20	27.45	7.76	11.89	5.66	71.4
325M x 0	45.43	63.96	19.78	18.41	65.04	82.6
TOTALS	100.00	39.10	100.00	12.00	100.00	70.18

ASH ONLY

SIZE FRACTION	FEED	CONCENTRATE	TAILS	RECOVERY
+ 28 MESH	12.38	7.61	30.0	78.7
28M x 100M	15.43	10.33	39.2	82.3
100M x 200M	25.16	11.80	60.4	72.5
200M x 325M	27.45	11.89	71.4	73.9
325M x 0	63.96	18.41	82.6	29.0
TOTALS	39.10	12.00	70.18	56.1

In order to confirm flotation circuit efficiency, a complete flotation release analysis was run on a split of the feed sample collected in May (Figure 9). The flotation circuit operating point (actual concentrate ash and recovery rate) fell very close to the theoretical release curve - confirming that the circuit was operating very efficiently.

Our conclusions from the series of tests of flotation circuit performance were that the circuit had more than adequate capacity to handle swings in plant feed rate, and that it did a very efficient job of separation. We could expect a very narrow ash range in the feed to the Mulled Coal circuit, and therefore it would not be necessary to constantly adjust reagent dosage to compensate for wide swings in feed ash.

3.4.2 Repeatability Tests

Parametric testing began with a short series of repeatability tests to see if the results of a K.A. mulling test of the same wet cake sample, run at the same time, and under the same conditions would repeat within an acceptable margin.

The standard laboratory procedure for the parametric test series was to use 1000 g of untreated wet cake for a K. A. mulling test. After adding reagent and mixing in the Kitchen Aid mixer for 10 minutes, 50 g of the Mulled Coal produced was tested for uniformity. The percentage of Mulled Coal which reported to the 14M x 0 size fraction (the Handleability Index) was the principal characteristic used to describe the quality of Mulled Coal produced in that particular K. A. mulling test.

Repeatability was not simply one 1000 g K. A. mulling test with two 50 g splits of the same Mulled Coal used for uniformity testing. For each repeatability test the entire procedure was completed beginning with the 1000 g. K. A. mulling test.

Results of the repeatability tests are shown in Table VII. The variation in the Handleability Index from test to test was considered acceptable, but we would have preferred a narrower margin. Since our database up to that point consisted of all 50 g uniformity tests, we decided to complete the parametric test sequence with the same procedures. During the production phase of the project we increased the amount of Mulled Coal for uniformity tests to 250 g, and we achieved much more uniform results from test to test.

The differences in Mulled Coal quality between the 10.96 ash test and the 13.12 ash test (the samples came from different drums which were collected at different times during the 36 hour field sampling period) was one of the first indicators that there was a problem with the bulk samples. Although we did not realize at the time that the problem was oxidation, we knew from past experience that the difference of a few percentage points in ash could never account for such a wide difference in Mulled Coal quality.

Coal from these particular drums was selected for the parametric testing series because it represented the lowest and highest ash levels encountered in the 36 hour sampling cycle.

Figure 9

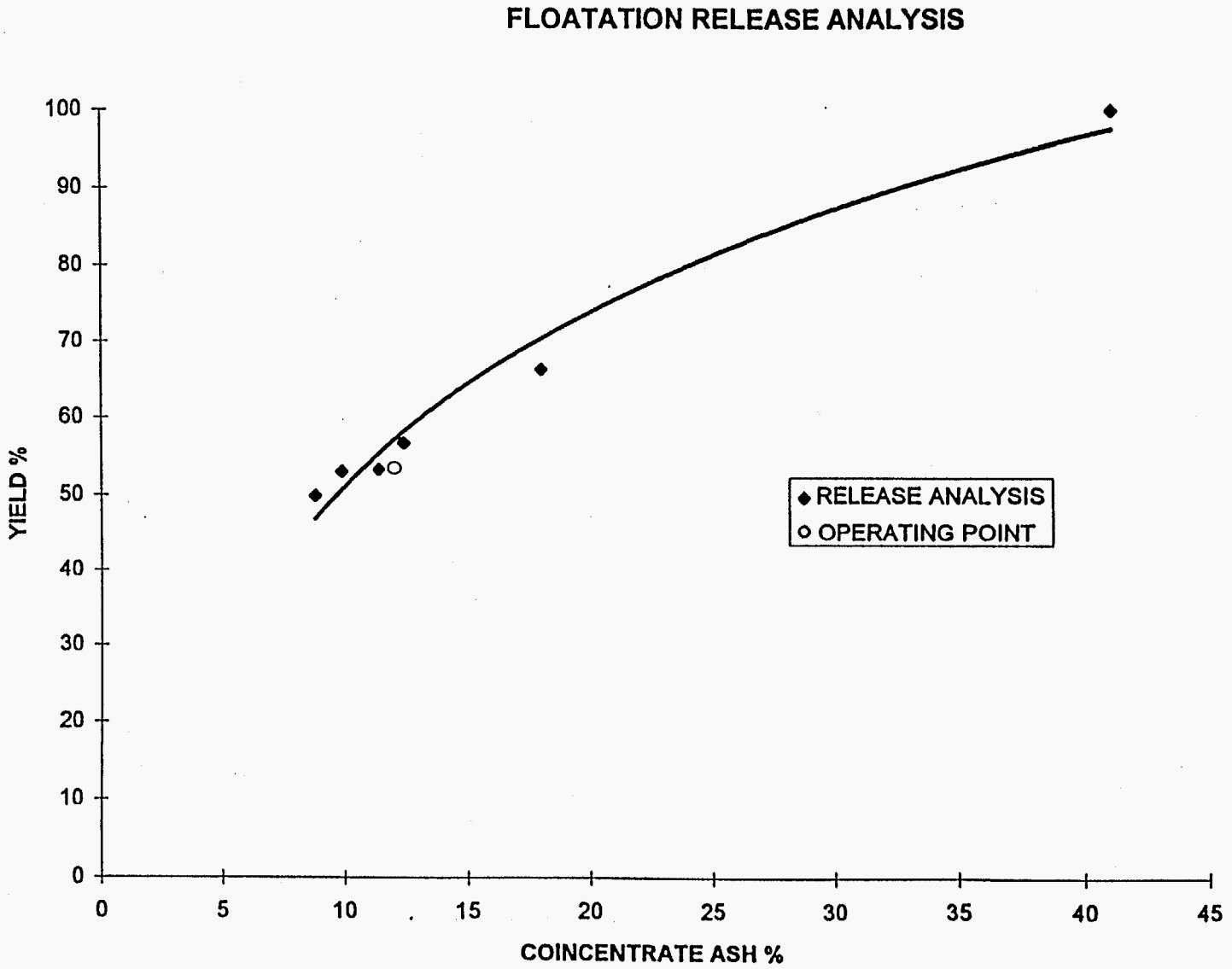

FLOATATION RELEASE ANALYSIS
YIELD %
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
COINCENTRATE ASH %
RELEASE ANALYSIS
OPERATING POINT

Table VII

Repeatability Of Uniformity Tests

Lab No	Ash	Moisture	Reagent Dose	Size	Uniformity Test Results				
					+6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-81A	10.96	23	2.00	28M x 0	3.07	25.34	49.33	22.26	71.59
016-81B	10.96	23	2.00	28M x 0	5.34	16.98	42.37	35.31	77.68

Lab No	Ash	Moisture	Reagent Dose	Size	Uniformity Test Results				
					+6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-82B	13.12	22	2.00	28M x 0	18.13	67.48	14.39	0.00	14.39
016-82C	13.12	22	2.00	28M x 0	11.22	72.25	15.94	0.59	16.53

The two drums had either been opened at different times, handled differently after opening, or there was something very different about the coal in the higher ash drum. What we later recognized as an oxidation problem had for some reason progressed at different rates. The coal in the higher ash drum probably did not account for the difference because eventually all of the bulk sample deteriorated to the point where it could not be converted to an acceptable grade mull in either a laboratory or pilot plant test.

In any event, while absolute test results from drum to drum or from time to time were meaningless, we felt that relative results from sample to sample taken from the same drum at the same time would give us information we could use to design the reagent delivery system for the project.

3.4.3 Parametric Testing

In this series of tests we attempted to evaluate the effects on mullability which result from variations in size distribution, reagent dose, moisture, ash, and temperature.

3.4.3.1 Size Distribution

From previous testing we know that generally:

Mullability improves as the mean particle size of a wet cake decreases.
Mullability declines as the ash content of a wet cake increases.
The ash content of froth concentrate increases as the mean particle size decreases.

In the first series of size distribution tests, K. A. mulling tests were run on various size fractions from wet screen analyses. Generally, mullability improved as the particle size decreased, but the effect was offset somewhat because the ash of the various size fractions ranged from 9.55% for the coarsest (28M x 100M) to 16.85% for the finest (325M x 0) (Table VIII). There were anomalies in the test results for the various size fractions which in hindsight were attributed to the aging process on the various samples selected for the tests.

In order to hold ash at the same level for tests in two different size ranges, a froth concentrate sample was wet screened to produce about 2000 g in the 28M x 100M size range. Half of the sample was tested at 28M x 100M. The other half was ground and retested at 100M x 0. The Handleability Index went from 19 on the 28M x 100M fraction to 91 on the 100M x 0 fraction (Table VIII). We expected a substantial improvement, but nothing on the order of 19 to 91. We attribute a significant portion of the improvement to the aging process of the various samples, and the fact that we exposed fresh hydrophobic surfaces in the grinding process.

3.4.3.2 Moisture

Increases in moisture had the most profound effect on mullability of any of the parameters tested. However, with the Mulled Coal process, the effect of increased moisture can be offset by increasing the reagent dose.

Table VIII

EFFECT OF SIZE DISTRIBUTION ON MULLABILITY									
Lab No	Ash	Moisture	Particle Size	Reagent Dose	Uniformity Test Results				
					+6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-89	16.85	24	325M x 0	2.00	3.74	33.65	24.67	37.94	62.61
016-87B	15.26	23	200M x 0	2.00	6.04	30.77	29.12	34.07	63.19
016-86B	13.36	23	100M x 0	2.00	18.39	32.57	31.99	17.05	49.04
016-81C	10.96	23	28M x 0	2.00	5.21	35.57	49.72	9.50	59.22

EFFECT OF SIZE DISTRIBUTION ON MULLABILITY									
Lab No	Ash	Moisture	Particle Size	Reagent Dose	Uniformity Test Results				
					+6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-86A	13.96	23	100M x 0	1.50	6.55	37.96	43.74	11.75	55.49
016-86B	13.96	23	100M x 0	2.00	18.39	32.57	31.99	17.05	49.04
016-87A	13.96	23	100M x 0	3.00	5.08	31.83	45.20	17.89	63.09
016-13	9.30	23	100M x 0	2.00	0.78	8.24	20.00	70.98	90.98

EFFECT OF SIZE DISTRIBUTION ON MULLABILITY									
Lab No	Ash	Moisture	Particle Size	Reagent Dose	Uniformity Test Results				
					+6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
019-9B	9.55	23	28M x 100M	2.00	13.04	67.49	17.58	1.89	19.47
019-10A	9.93	23	28M x 200M	2.00	2.63	30.57	42.51	24.29	66.80
019-10B	9.93	23	28M x 200M	1.50	3.35	55.51	30.71	10.43	41.14
019-11A	9.93	23	28M x 200M	3.00	5.99	53.97	32.88	7.16	40.04
019-11B	10.00	23	28M x 325M	2.00	13.04	51.16	31.13	4.67	35.80
019-12A	10.00	23	28M x 325M	1.50	7.65	39.02	45.49	7.84	53.33
019-12B	10.00	23	28M x 325M	3.00	12.21	48.29	34.54	4.96	39.50

The results for parametric testing for the effect of moisture are shown in Table IX. Again, it is apparent that the aging of the samples had a significant effect on absolute values for this series of tests. Separate tests were run on the lowest and highest ash portions of the May 23-24 bulk sample.

While absolute values for the moisture series are of little value, relative differences show the profound effect of moisture on mullability. We were not able to use these test results to predict the actual dosages of reagent which would be required at different moisture levels, but the results reinforced our initial guess that moisture was the parameter we would use to automatically control reagent dose.

3.4.3.3 Reagent Dose

By the time we started parametric testing for reagent dose (8/10/94), the bulk samples had oxidized to the point where test results were meaningless. We were aware at the time that there was a problem with the bulk samples, but we did not know what it was, and we did not know how significant it was. We went ahead with the reagent dose series hoping that relative results would yield information we could use to design the reagent delivery system for the production phase of the contract.

The results of reagent dose testing are shown in Table X. There are two tables which summarize reagent dose test results. The difference in absolute values from one table to the other illustrated the trouble we were having with oxidation.

Both tables show test results on samples taken from the same drum of the bulk sample. Our standard procedure was to take two 5 gallon buckets of decanted froth concentrate from the bulk sample drum. Next the sample would be filtered in the lab to produce about one 5 gallon bucket of 23% wet cake. Filtrate would be saved and used (instead of tap water or distilled water) to adjust moisture if it was necessary.

A series of tests would be run until all of the filtered wet cake in the bucket had been consumed. Then another sample would be pulled from the bulk sample drum, and the filtering and testing process would begin again.

Lab test No. 016-92B was run on 8/11/94 on the last remaining 23% moisture wet cake in a 5 gallon bucket. The following day, a new sample was pulled from the same bulk sample drum and again filtered to 23% moisture. Late that same day (8/12/94), the newly filtered wet cake was tested under exactly the same conditions as 016-92B. The Handleability Index for the new test (016-94A) was 70.53, but the Handleability Index for 016-92B was only 5.33.

Obviously the oxidation process was accelerated once a sample was pulled from the bulk sample drum, and especially after it was exposed to air in the filtering process.

While results of the reagent dose series were disappointing and of little use in designing the circuit, there was no concern that the poor mullability we were experiencing with aged samples would

Table IX

EFFECT OF MOISTURE ON MULLABILITY								
Lab No	Ash	Moisture	Reagent Dose	Uniformity Test Results				
				+ 6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-85B	13.12	19	2.00	4.22	56.62	38.20	0.96	39.16
016-85A	13.12	20	2.00	11.75	55.30	31.60	1.35	32.95
016-82C	13.12	22	2.00	11.22	72.75	15.94	0.59	16.53
016-84A	13.12	26	2.00	49.03	49.81	1.16	0.00	1.16
016-84B	13.12	29	2.00	72.68	27.32	0.00	0.00	0.00

EFFECT OF MOISTURE ON MULLABILITY								
Lab No	Ash	Moisture	Reagent Dose	Uniformity Test Results				
				+ 6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-88	10.96	20	2.00	8.37	63.94	26.10	1.59	27.69
016-81C	10.96	23	2.00	5.21	35.57	49.72	9.50	59.22
016-83A	10.96	26	2.00	9.62	52.64	31.51	6.23	37.74
016-83B	10.96	29	2.00	17.88	78.27	3.85	0.00	3.85

Table X

REAGENT DOSE - EFFECT ON MULLABILITY

Lab No	Ash	Moisture	Reagent Dose	Uniformity Test Results				
				+ 6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-90A	10.96	23	0.50	41.29	55.41	3.30	0.00	3.30
016-90B	10.96	23	0.75	33.67	61.95	4.38	0.00	4.38
016-91A	10.96	23	1.00	38.59	57.80	3.61	0.00	3.61
016-91B	10.96	23	1.25	19.22	75.42	5.36	0.00	5.36
016-92A	10.96	23	1.50	17.90	75.43	6.67	0.00	6.67
016-92B	10.96	23	1.75	34.74	59.93	5.33	0.00	5.33

Lab No	Ash	Moisture	Reagent Dose	Uniformity Test Results				
				+ 6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
016-94A	10.96	23	1.75	2.36	27.11	55.79	14.74	70.53
016-94B	10.96	23	2.25	4.60	35.44	50.19	9.77	59.96
016-95A	10.96	23	2.50	2.70	14.50	56.65	26.20	82.85
016-95B	10.96	23	2.75	6.41	30.10	44.46	19.03	63.49
016-96A	10.96	23	3.00	3.28	12.36	52.12	32.24	84.36
016-96B	10.96	23	3.50	4.32	25.36	58.09	12.23	70.32
019-6A	10.96	23	4.00	3.29	17.92	57.22	21.57	78.79
019-6B	10.96	23	5.00	5.88	30.00	52.94	11.18	64.12

cause any problems in the production phase of the project. Every time a fresh sample of froth concentrate was tested, an excellent mull was produced, and the quality and stability of the Mulled Coal was not deteriorating to any significant extent as a result of the aging process.

In the final analysis, we had to rely on testing from previous projects to estimate reagent dosages at various moisture levels. As it turned out, no amount of laboratory work (even with samples which were not oxidizing), would ever have prepared us for the reagent doses which were actually required in the production phase of the project. In actual operation, we used only a fraction of the reagent dosage predicted from all previous testing. There were economics of scale in mixing and in delivering reagent at higher flow rates and higher pressure which never could have been predicted with laboratory testing.

3.4.3.4 Temperature

Our production demonstration was scheduled for the coldest months of the year, and it is not unusual to have sub-freezing weather in Birmingham during those months. To insure that there would be no weather related problems with the production phase of the project, and to get some idea of how colder climates might affect the process, we did a short series of tests to evaluate the effect of temperature on both the mulling reagent and the wet cake.

We discovered that the cloud point for the reagent we intended to use for the project was about 40°F. At temperatures between freezing and 40°F, the reagent would form a thick gel. Because of the low reagent flow rates for the 2.7 tonnes/hr (3 TPH) demonstration circuit, we used reagent spray nozzles with very small openings in order to get the system pressure that we needed to atomize the reagent. We did not want waxing or any other temperature related problem to result in a plugged up reagent delivery system. Since we were using 55 gallon drums as the reagent reservoir, we provided drum heaters to maintain reagent temperatures above 40°F.

With the minimum reagent temperature established, we decided to determine if hot weather would affect the process, so we set up a short parametric test series to compare test results at ambient temperatures with results at temperature extremes of 40°F and 100°F. Test results are shown in Table XI. Although test results are mixed due to the aging problem, there is a strong indication that the temperature range expected for the project and for other commercial installations will not have any significant effect on the process.

4.0 SUMMARY

During this third quarter of the contract period, activities were underway under Tasks 2 and 3. Sufficient characterization of the feedstock coal options at the Chetopa Plant was conducted and mulling characteristics determined to enable a decision to be made regarding the feedstock selection. It was decided that the froth concentrate will be the feedstock wet fine coal used for the project. On that basis, activities in the areas of design and procurement were initiated.

Table XI

EFFECT OF COAL/ REAGENT TEMPERATURE ON MULLABILITY											
Lab No	Ash	Mois.	Reagent Dose	Size	Temperature		Uniformity Test Results				
					Coal	Reagent	+ 6M	6M x 14M	14M x 28M	28M x 0	Hand. Index
019-2B	10.96	23	2	28M x 0	Amb	Amb	10.32	37.91	37.02	14.75	51.77
019-11	10.96	23	2	28M x 0	50° F	Amb	8.45	23.03	42.61	25.91	68.52
019-2A	10.96	23	2	28M x 0	40° F	Amb	2.77	46.04	40.91	10.28	51.19
019-3	10.96	23	2	28M x 0	100° F	Amb	4.05	22.16	59.15	14.64	73.79
019-4A	10.96	23	2	28M x 0	Amb	40° F	1.59	18.25	54.56	25.6	80.16
019-4B	10.96	23	2	28M x 0	Amb	100° F	4.73	37.43	48.39	9.45	57.84