

RECOVERY OF FINE-SIZE WASTE COAL

**MASTER**

FINAL TECHNICAL REPORT  
AS OF  
MAY 1978

JAMES S. BROWNING

THE UNIVERSITY OF ALABAMA  
UNIVERSITY, ALABAMA 35486

DATE PUBLISHED - NOVEMBER 1978  
Prepared Under  
Contract No. - U.S.D.O.E. ET-76-G-01-9005  
(formerly U.S.B.M. G0166073)

US DEPARTMENT OF ENERGY  
Assistant Secretary for Energy Technology  
Division of Fossil Fuel Extraction  
Mining Research and Development

## **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.**

---

## **DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

### NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, 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, mark, 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.

Available from:

National Technical Information Service (NTIS)  
U.S. Department of Commerce  
5285 Port Royal Road  
Springfield, Virginia 22161

Price: Printed copy:  
Microfiche: \$3.00

## Foreword

This report was prepared by the Mineral Resources Institute of The University of Alabama, University, Alabama, under Department of Energy Contract Number ET-76-G-01-9005 (formerly U.S. Bureau of Mines Contract Number G0166073). The contract was administered under the technical direction of Mr. A. W. Deurbrouck, Chief, Coal Preparation and Analysis Group, Pittsburgh, Pennsylvania, who was the Technical Project Officer.

The report summarizes work completed during the period March 22, 1976 to March 31, 1978.

## CONTENTS

	Page
ABSTRACT .....	1
ACKNOWLEDGMENTS .....	2
INTRODUCTION .....	3
DESCRIPTION OF SAMPLES .....	4
EXPERIMENTAL RESULTS .....	11
Float-Sink Analysis of Samples .....	11
The Humphreys Spiral .....	30
Laboratory Batch Tests .....	32
Continuous Tests .....	36
CONCLUSIONS .....	45
REFERENCES .....	46

## FIGURES

1. Location Map of Samples from Alabama Surface and Under-ground Mining Preparation Plants .....	5
2. Humphreys Spiral Test Unit .....	31
3. Single Stage Spiral Concentration Flowsheet .....	37
4. Two-Stage Spiral Concentration Flowsheet .....	38
5. Materials Balance Flowsheet for Continuous Spiral Concentration of Black Creek (B) Seam Sample .....	39

TABLES

	Page
1. Analysis of Fine-Size Waste Coal Samples From Alabama Strip Mining Operations .....	7
2. Analysis of Fine-Size Waste Coal Samples From Alabama Underground Mining Operations .....	8
3. Summarized Results of Screen Analyses of Samples of Surface Mine Waste Fines .....	9
4. Summarized Results of Screen Analyses of Samples of Underground Mine Waste Fines .....	10
5. Float-Sink Analysis of Sample of Waste Fines From America, Pratt, and Nickel Plate Seams .....	12
6. Float-Sink Analysis of Sample of Waste Fines From Black Creek (A) Seam .....	13
7. Float-Sink Analysis of Sample of Waste Fines From Black Creek (B) Seam .....	14
8. Float-Sink Analysis of Sample of Waste Fines From Black Creek (C) and Jefferson Seams .....	15
9. Float-Sink Analysis of Sample of Waste Fines From Blue Creek Seam .....	16
10. Float-Sink Analysis of Sample of Waste Fines From Carter, Milldale, Johnson, and Brookwood Seams .....	17
11. Float-Sink Analysis of Sample of Waste Fines From Clements Seam .....	18
12. Float-Sink Analysis of Sample of Waste Fines From Gwin Seam .....	19
13. Float-Sink Analysis of Sample of Waste Fines From Woodstock Seam .....	20
14. Float-Sink Analysis of Sample of Waste Fines From America (A) Seam .....	21
15. Float-Sink Analysis of Sample of Waste Fines From America (B) Seam .....	22
16. Float-Sink Analysis of Sample of Waste Fines From America (C) and Mary Lee Seams .....	23
17. Float-Sink Analysis of Sample of Waste Fines From Blue Creek Seam .....	24
18. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (D) Seam .....	25
19. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (E) Seam .....	26
20. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (F) Seam .....	27
21. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (G) Seam .....	28

	Page
22. Float-Sink Analysis of Sample of Waste Fines From Pratt Seam .....	29
23. Results of Laboratory Batch Spiral Tests of Surface Mine Waste Fines .....	33
24. Results of Laboratory Batch Spiral Tests of Underground Mine Waste Fines .....	34
25. Results of Continuous Spiral Test on America-Pratt-Nickel Plate Seams Composite .....	40
26. Results of Continuous Spiral Test on Blue Creek Seam Sample .....	41
27. Results of Continuous Spiral Test on Black Creek (B) Seam Sample .....	42
28. Results of Continuous Spiral Test on America (A) Seam Sample .....	43
29. Results of Continuous Spiral Test on Mary Lee (E) Seam Sample .....	44

## ABSTRACT

The Mineral Resources Institute and State Mine Experiment Station of The University of Alabama surveyed existing waste impoundments in Alabama to determine their location, the approximate quantity of coal in each waste pond, and the amount of recoverable coal based on washability tests of representative samples of the waste.

Humphreys spiral tests were conducted on Alabama fine coal waste from nine preparation plants of surface mining operations, and from nine preparation plants of underground mining operations. The ash in the samples ranged from 9 to 51 percent, and the total sulfur ranged from 0.54 to 2.39 percent.

Continuous laboratory tests using a Humphreys spiral gave good recovery of the coal with excellent rejection of the ash and pyritic sulfur. Ash content of the clean coal products fell within a range of 5 to 12 percent, with a total sulfur content of 0.42 to 1.29 percent. Coal recoveries (float 1.60 specific gravity) of 84 to 98 percent were achieved from the different samples. In quality, the products were comparable or superior to those now being shipped from the preparation plants.

## ACKNOWLEDGMENTS

The research was funded by a grant from the U.S. Bureau of Mines under contract Number G0166073 (currently Department of Energy Number ET-76-G-01-9005). The author expresses his appreciation to the U.S. Bureau of Mines and the U.S. Department of Energy for their support of the research.

The author also expresses his appreciation to the following companies that provided samples and information regarding their operations: Alabama By-Products Corporation, Alabama Power Company, Bankhead Mining Company, Black Diamond Coal Mining Company, Brilliant Coal Company, Jim Walter Resources, Inc., Peabody Coal Company, The Drummond Company, and U.S. Steel Corporation.

## INTRODUCTION

Approximately 15 million tons of coal were produced by strip mining methods in Alabama during 1976. About 8 million tons were produced by underground mining during the same period. Surface mined coal is expected to continue at about 14 million tons per year through 1980, and underground coal mining will increase to about 25 million tons by that time. The washing and cleaning of coal at various operations in the State results in a loss of 10 to 15 percent of the fine-size coal. Thus, at least two million tons of fine-size coal are lost each year.

The primary objective of this research is to survey existing waste impoundments in Alabama to determine their location, the approximate quantity of coal in each waste pond and the amount of recoverable coal based on washability tests of representative samples of the waste. If the preliminary studies demonstrate that an acceptable grade of coal can be recovered from the wastes in Alabama, a complete inventory of impounded waste coals will be made.

The fine-size waste coal that is currently impounded creates a number of environmental problems, including stream pollution by acid water drainage from the ponds. Reclamation of the fine-size waste could eliminate the environmental problems, and result in the conservation and development of additional natural resources in Alabama. Recovery of the waste coal could potentially increase Alabama's coal production by several million tons per year.

The use of Humphreys spirals to concentrate fine coal was practiced as early as 1947. At that time the Hudson Coal Company (2) used spirals to concentrate anthracite fines. In 1950, the use of spirals to treat fine-size bituminous coal (3), was investigated. In 1976, the use of spirals was investigated for removing pyrite from fine-sized coal (5). These investigations, however, involved tests of freshly mined coal and not impounded coal of past operations. As part of the current investigation, results have been reported on the use of Humphreys spirals for treating the fine-size waste from surface mined coal in Alabama (1).

This investigation is part of a coal research program conducted by the Mineral Resources Institute and State Mine Experiment Station of The University of Alabama to investigate the feasibility of recovering fine-size coal from impounded coal wastes in Alabama.

## DESCRIPTION OF SAMPLES

Samples of fine waste coal were collected from the preparation plants of nine strip mining operations and nine underground mining operations. Each impoundment area, which is identified by the coal seam being mined, was sampled by drilling a number of 3-inch auger holes to depths of 5 to 10 feet. The material was composited into a single sample which averaged about 500 pounds. These composite samples were used in the preliminary tests. Later in the investigation 2-ton samples of several of the waste impoundments were obtained for the larger scale tests. A location map of the samples is shown in Figure 1. The strip mined wastes ranged from about 9 to over 51 percent ash, and from 0.54 to 2.39 percent total sulfur as shown in Table 1. The underground mined waste ranged from 19 to about 39 percent ash, and from 0.70 to 1.53 percent total sulfur as shown in Table 2. Screen analyses, as summarized in Tables 3 and 4 indicated that, in many cases, the ash was concentrated in the finer screen sizes, and that the minus 200-mesh fractions had a low coal content and could be discarded with minimal loss of coal.

The amount of fine coal waste in each storage area is estimated to be from 350,000 to over 1,000,000 tons.

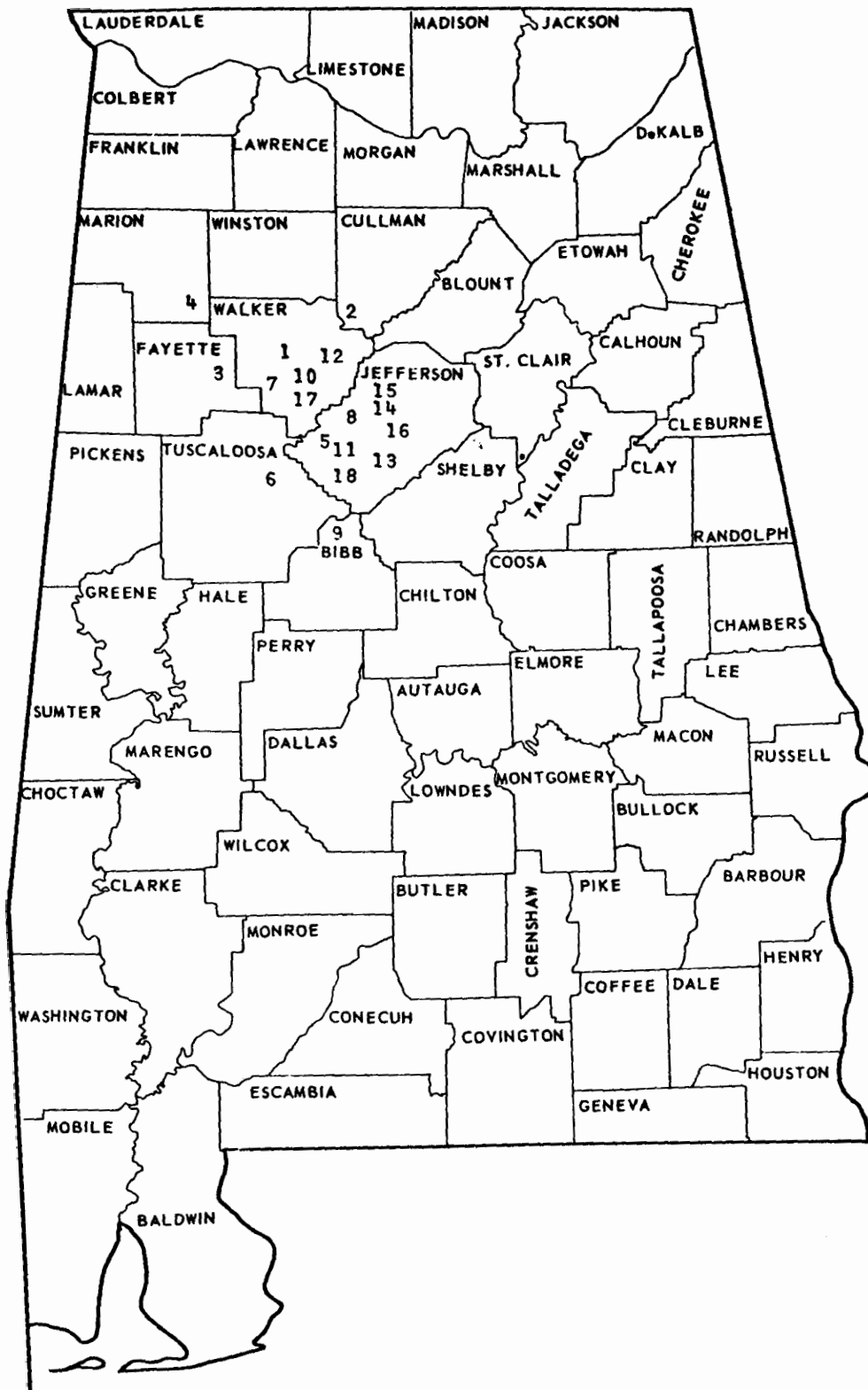


Figure 1. Location Map of Samples from Alabama Surface and Underground Mining Preparation Plants.

## LIST OF WASTE FINES COAL SEAMS

### Surface Mined

1. America-Pratt-Nickel Plate
2. Black Creek (A)
3. Black Creek (B)
4. Black Creek, Jefferson (C)
5. Blue Creek
6. Carter-Milldale, Johnson
7. Clements
8. Gwin
9. Woodstock

### Underground Mines

10. America (A)
11. America (B)
12. America-Mary Lee (C)
13. Blue Creek
14. Mary Lee (D)
15. Mary Lee (E)
16. Mary Lee (F)
17. Mary Lee (G)
18. Pratt

Figure 1. Location Map of Samples from Alabama Surface and Underground Mining Preparation Plants--(Con.)

TABLE 1. Analysis of Fine-Size Waste Coal Samples  
From Alabama Strip Mining Operations

Coal Seam	Analysis, Percent	
	Ash	Total Sulfur
America, Pratt, Nickel Plate	32.3	1.12
Black Creek (A)	29.8	1.15
Black Creek (B)	29.6	1.10
Black Creek, Jefferson (C)	18.0	0.62
Blue Creek	40.6	0.60
Carter, Milldale, Johnson, Brookwood	28.2	2.05
Clements	51.4	2.39
Gwin	16.2	1.48
Woodstock	9.3	0.54

TABLE 2. Analysis of Fine-Size Waste Coal Samples From Alabama Underground Mining Operations

Coal Seam	Analysis, Percent	
	Ash	Total Sulfur
America (A)	29.5	1.53
America (B)	21.1	1.34
America, Mary Lee (C)	38.6	1.04
Blue Creek	38.5	0.90
Mary Lee (D)	20.9	0.70
Mary Lee (E)	19.3	0.87
Mary Lee (F)	29.5	0.87
Mary Lee (G)	25.3	0.74
Pratt	30.9	0.76

TABLE 3. Summarized Results of Screen Analyses of Samples of Surface Mine Waste Fines

Coal Seam	Screen	Weight Percent	Analysis, Percent	Distribution, Percent
	Size, Mesh		Float 1.60 Specific Gravity (Coal)	Float 1.60 Specific Gravity (Coal)
America-Pratt-Nickel Plate Composite	Plus 200	81.7	70.5	99.4
	Minus 200	18.3	2.0	0.6
	Composite	100.0	58.0	100.0
Black Creek (A)	Plus 200	91.2	62.3	99.7
	Minus 200	8.8	2.0	0.3
	Composite	100.0	57.0	100.0
Black Creek (B)	Plus 200	85.3	77.8	99.5
	Minus 200	14.7	2.1	0.5
	Composite	100.0	66.7	100.0
Black Creek Jefferson (C)	Plus 200	83.7	86.5	96.8
	Minus 200	16.3	14.8	3.2
	Composite	100.0	74.8	100.0
Blue Creek	Plus 200	48.7	72.0	94.5
	Minus 200	51.3	4.0	5.5
	Composite	100.0	37.1	100.0
Carter, Milldale and Johnson Composite	Plus 200	83.8	68.1	95.8
	Minus 200	16.2	15.6	4.2
	Composite	100.0	59.6	100.0
Clements	Plus 200	95.4	29.0	99.8
	Minus 200	4.6	1.5	.2
	Composite	100.0	27.7	100.0
Gwin	Plus 200	86.3	85.5	96.3
	Minus 200	13.7	20.8	3.7
	Composite	100.0	76.6	100.0
Woodstock	Plus 200	92.6	92.0	97.5
	Minus 200	7.4	29.8	2.5
	Composite	100.0	87.4	100.0

TABLE 4. Summarized Results of Screen Analyses of Samples of Underground Mine Waste Fines

Coal Seam	Screen	Weight Percent	Analysis, Percent	Distribution, Percent
	Size, Mesh		Float 1.60 Specific gravity (Coal)	Float 1.60 Specific gravity (Coal)
America (A)	Plus 200	74.9	62.0	98.0
	Minus 200	25.1	3.7	2.0
	Composite	100.0	47.4	100.0
America (B)	Plus 200	59.7	82.0	89.1
	Minus 200	40.3	14.9	10.9
	Composite	100.0	55.0	100.0
America Mary Lee (C)	Plus 200	26.8	72.5	86.3
	Minus 200	73.2	4.2	13.7
	Composite	100.0	22.5	100.0
Blue Creek	Plus 200	57.4	69.0	95.9
	Minus 200	42.6	4.0	4.1
	Composite	100.0	41.3	100.0
Mary Lee (D)	Plus 200	83.5	80.5	98.1
	Minus 200	16.5	7.9	1.9
	Composite	100.0	68.5	100.0
Mary Lee (E)	Plus 200	87.8	78.8	99.6
	Minus 200	12.2	2.0	0.4
	Composite	100.0	69.4	100.0
Mary Lee (F)	Plus 200	39.5	79.5	76.6
	Minus 200	60.5	15.9	23.4
	Composite	100.0	41.0	100.0
Mary Lee (G)	Plus 200	45.1	74.0	79.0
	Minus 200	54.9	16.2	21.0
	Composite	100.0	42.3	100.0
Pratt	Plus 200	86.5	52.0	99.2
	Minus 200	13.5	2.8	.8
	Composite	100.0	45.4	100.0

## EXPERIMENTAL RESULTS

### Float-Sink Analysis of Samples

Representative samples of the fine coal waste were screened at 50 mesh. The plus 50-mesh and minus 50-mesh fractions of the samples were float-sink tested at 1.30, 1.40, 1.50, and 1.60 specific gravities. The results of the tests are shown in Tables 5 through 22. The results indicate that gravity separation will yield products low in ash and sulfur, with excellent recoveries of the coal.

The results of the float-sink analyses indicated the feasibility of gravity separation for processing the fine-size waste coal to produce commercially acceptable coal products.

TABLE 5. Float-Sink Analysis of Sample of Waste Fines From America, Pratt, and Nickel Plate Seams

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	6.6	2.9	0.94	0.6	5.5
1.30-1.40	25.8	5.9	1.07	4.7	24.5
1.40-1.50	6.1	14.2	1.21	2.6	6.6
1.50-1.60	3.7	55.4	1.19	6.3	3.9
Sink-1.60	12.3	65.8	1.05	25.0	11.4
Total	54.5	23.3	1.07	39.2	51.9
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.1	2.9	0.93	0.1	-
1.30-1.40	8.6	4.9	1.00	1.3	7.6
1.40-1.50	5.7	9.4	1.08	1.6	5.4
1.50-1.60	3.3	15.6	1.17	1.6	3.4
Sink-1.60	27.8	65.5	1.29	56.2	31.7
Total	45.5	43.2	1.19	60.8	48.1
Composite	100.0	32.3	1.12	100.0	100.0

TABLE 6. Float-Sink Analysis of Sample of Waste Fines From Black Creek (A) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	14.5	3.0	0.76	1.4	9.9
1.30-1.40	13.4	8.0	0.91	3.6	10.9
1.40-1.50	4.4	17.8	0.86	2.6	4.2
1.50-1.60	1.5	21.7	1.23	1.1	1.7
Sink-1.60	15.1	66.4	1.79	33.5	24.3
<b>Total</b>	<b>48.9</b>	<b>25.8</b>	<b>1.1</b>	<b>42.2</b>	<b>51.0</b>
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	3.7	2.7	0.80	0.3	2.3
1.30-1.40	17.8	13.3	0.81	7.9	12.9
1.40-1.50	7.9	15.8	0.86	4.2	6.2
1.50-1.60	2.5	29.4	0.87	2.5	1.9
Sink-1.60	19.2	66.7	1.49	42.9	25.7
<b>Total</b>	<b>51.1</b>	<b>33.6</b>	<b>1.1</b>	<b>57.8</b>	<b>49.0</b>
<b>Composite</b>	<b>100.0</b>	<b>29.8</b>	<b>1.1</b>	<b>100.0</b>	<b>100.0</b>

TABLE 7. Float-Sink Analysis of Sample of Wastes Fines From  
Black Creek (B) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	20.8	2.2	0.78	1.5	14.8
1.30-1.40	27.5	3.9	0.91	3.6	22.8
1.40-1.50	4.1	12.0	0.85	1.6	3.1
1.50-1.60	1.6	22.1	1.25	1.2	1.8
Sink-1.60	8.1	68.1	1.69	18.5	12.4
Total	62.1	12.7	0.96	26.4	54.9
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	1.0	2.3	0.90	0.1	0.8
1.30-1.40	7.7	3.8	0.85	1.0	6.0
1.40-1.50	2.6	8.8	0.89	0.8	2.1
1.50-1.60	1.2	15.3	0.90	0.6	0.9
Sink-1.60	25.4	83.1	1.52	71.1	35.3
Total	37.9	57.4	1.30	73.6	45.1
Composite	100.0	29.6	1.10	100.0	100.0

TABLE 8. Float-Sink Analysis of Sample of Waste Fines From Black Creek (C) and Jefferson Seams

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	16.5	3.7	0.77	3.4	20.6
1.30-1.40	21.2	3.2	0.77	3.8	26.5
1.40-1.50	4.5	10.3	0.68	2.5	4.9
1.50-1.60	0.4	12.2	0.62	0.2	0.3
Sink-1.60	7.4	41.9	0.43	17.2	5.0
<b>Total</b>	<b>50.0</b>	<b>9.8</b>	<b>0.71</b>	<b>27.1</b>	<b>57.3</b>
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.4	3.7	0.76	0.1	0.5
1.30-1.40	9.2	4.8	0.70	2.4	10.4
1.40-1.50	9.2	7.7	0.67	3.9	9.9
1.50-1.60	4.5	12.2	0.52	3.2	3.7
Sink-1.60	26.7	42.7	0.42	63.3	18.2
<b>Total</b>	<b>50.0</b>	<b>26.2</b>	<b>0.52</b>	<b>72.9</b>	<b>42.7</b>
<b>Composite</b>	<b>100.0</b>	<b>18.0</b>	<b>0.62</b>	<b>100.0</b>	<b>100.0</b>

TABLE 9. Float-Sink Analysis of Sample of Waste Fines From  
Blue Creek Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	6.1	4.0	0.69	0.6	7.0
1.30-1.40	4.6	9.8	0.70	1.1	5.3
1.40-1.50	3.9	22.1	0.67	2.1	4.3
1.50-1.60	1.5	24.2	0.61	0.9	1.5
Sink-1.60	25.6	61.3	0.55	38.7	23.4
<b>Total</b>	<b>41.7</b>	<b>42.2</b>	<b>0.59</b>	<b>43.4</b>	<b>41.5</b>
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	1.1	4.8	0.68	0.1	1.2
1.30-1.40	14.3	13.2	0.71	4.6	16.9
1.40-1.50	8.6	11.8	0.74	2.5	10.5
1.50-1.60	0.4	23.8	0.70	0.2	0.5
Sink-1.60	33.9	58.9	0.52	49.2	29.4
<b>Total</b>	<b>58.3</b>	<b>39.4</b>	<b>0.60</b>	<b>56.6</b>	<b>58.5</b>
<b>Composite</b>	<b>100.0</b>	<b>40.6</b>	<b>0.60</b>	<b>100.0</b>	<b>100.0</b>

TABLE 10. Float-Sink Analysis of Sample of Waste Fines From  
Carter, Milldale, Johnson, and Brookwood Seams

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	6.3	2.7	0.88	0.6	2.7
1.30-1.40	9.1	9.5	1.21	3.0	5.4
1.40-1.50	4.9	19.6	1.80	3.4	4.3
1.50-1.60	4.2	24.1	1.81	3.6	3.7
Sink-1.60	9.6	51.1	1.42	17.4	6.6
Total	34.1	23.2	1.36	28.0	22.7
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	6.2	4.3	0.91	0.9	2.7
1.30-1.40	18.7	8.6	1.03	5.7	9.4
1.40-1.50	5.9	14.3	1.37	3.0	3.9
1.50-1.60	9.0	17.1	2.52	5.5	11.0
Sink-1.60	26.1	61.5	3.96	56.9	50.3
Total	65.9	30.8	2.40	72.0	77.3
Composite	100.0	28.2	2.05	100.0	100.0

TABLE 11. Float-Sink Analysis of Sample of Waste Fines From Clements Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.2	14.5	1.62	0.1	0.1
1.30-1.40	9.5	7.8	1.58	1.4	6.3
1.40-1.50	13.0	14.9	2.27	3.8	12.3
1.50-1.60	5.6	22.4	2.86	2.4	6.7
Sink-1.60	39.7	65.6	2.14	50.6	35.5
Total	68.0	44.1	2.14	58.3	60.9
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.05	14.5	1.62	0.05	0.3
1.30-1.40	0.05	7.8	1.63	0.05	0.3
1.40-1.50	0.7	14.7	2.26	0.2	0.6
1.50-1.60	1.1	22.1	2.88	0.5	1.3
Sink-1.60	30.1	69.7	2.90	40.9	36.6
Total	32.0	66.8	2.92	41.7	39.1
Composite	100.0	51.4	2.39	100.0	100.0

TABLE 12. Float-Sink Analysis of Sample of Waste Fines From Gwin Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	15.5	3.6	1.18	3.4	12.3
1.30-1.40	22.7	9.0	1.48	12.6	22.6
1.40-1.50	7.0	15.9	1.58	6.9	7.2
1.50-1.60	3.3	19.8	1.47	4.0	3.3
Sink-1.60	2.3	40.0	2.33	5.7	3.7
Total	50.8	10.4	1.43	32.6	49.1
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	4.8	3.4	1.04	1.0	3.3
1.30-1.40	15.9	7.6	1.43	7.6	15.3
1.40-1.50	9.6	13.9	1.58	8.2	10.2
1.50-1.60	5.3	18.9	1.47	6.2	5.2
Sink-1.60	13.6	52.8	1.84	44.4	16.9
Total	49.2	22.1	1.53	67.4	50.9
Composite	100.0	16.2	1.48	100.0	100.0

TABLE 13. Float-Sink Analysis of Sample of Waste Fines From Woodstock Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	48.4	2.2	0.53	11.4	47.0
1.30-1.40	15.3	6.1	0.60	9.9	16.0
1.40-1.50	4.3	15.9	0.76	7.3	5.9
1.50-1.60	1.5	25.7	0.75	4.1	2.0
Sink-1.60	1.6	43.4	0.70	7.4	2.0
Total	71.1	5.3	0.56	40.1	73.6
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	3.1	2.4	0.51	0.9	2.7
1.30-1.40	12.6	4.7	0.53	6.3	12.1
1.40-1.50	4.8	10.5	0.56	5.3	4.8
1.50-1.60	1.6	17.7	0.58	3.0	1.6
Sink-1.60	6.8	61.1	0.42	44.4	5.2
Total	28.9	19.3	0.49	59.9	26.4
Composite	100.0	9.3	0.54	100.0	100.0

TABLE 14. Float-Sink Analysis of Sample of Waste Fines From America (A) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	5.6	2.7	0.97	0.6	3.5
1.30-1.40	11.3	6.2	1.46	2.6	10.7
1.40-1.50	1.6	16.2	1.77	1.0	1.8
1.50-1.60	0.9	27.8	1.78	0.9	1.0
Sink-1.60	2.2	45.7	1.80	3.8	2.6
<b>Total</b>	<b>21.6</b>	<b>10.9</b>	<b>1.39</b>	<b>8.9</b>	<b>19.6</b>
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	-	-	-	-	-
1.30-1.40	24.6	5.1	1.19	4.7	19.1
1.40-1.50	11.2	12.0	1.47	5.1	10.8
1.50-1.60	1.9	29.2	1.62	2.1	2.0
Sink-1.60	40.7	51.6	1.82	79.2	48.5
<b>Total</b>	<b>78.4</b>	<b>30.8</b>	<b>1.56</b>	<b>91.1</b>	<b>80.4</b>
<b>Composite</b>	<b>100.0</b>	<b>26.5</b>	<b>1.53</b>	<b>100.0</b>	<b>100.0</b>

TABLE 15. Float-Sink Analysis of Sample of Waste Fines From America (B) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	3.2	2.7	1.01	0.4	2.4
1.30-1.40	2.5	9.3	1.17	1.1	2.2
1.40-1.50	1.6	12.6	1.15	1.0	1.3
1.50-1.60	1.9	18.9	1.22	1.7	1.7
Sink-1.60	2.7	36.4	1.32	4.6	2.6
Total	11.9	15.6	1.15	8.8	10.2
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	-	-	-	-	-
1.30-1.40	14.8	4.4	1.24	3.1	13.6
1.40-1.50	6.9	8.4	1.28	2.7	6.6
1.50-1.60	4.7	22.4	1.32	5.0	4.6
Sink-1.60	61.6	27.6	1.42	80.4	65.0
Total	88.1	21.9	1.37	91.2	89.8
Composite	100.0	21.1	1.34	100.0	100.0

TABLE 16. Float-Sink Analysis of Sample of Wastes Fines From America (C) and Mary Lee Seams

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.7	3.0	0.75	0.1	0.5
1.30-1.40	1.5	10.9	0.96	0.4	1.3
1.40-1.50	0.4	17.6	1.33	0.2	0.5
1.50-1.60	0.1	25.0	1.40	0.1	0.1
Sink-1.60	2.8	80.8	1.42	5.8	3.8
Total	5.5	46.2	1.16	6.6	6.2
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	-	-	-	-	-
1.30-1.40	-	-	-	-	-
1.40-1.50	-	-	-	-	-
1.50-1.60	3.8	14.5	0.74	1.4	2.7
Sink-1.60	90.7	39.1	1.04	92.0	91.1
Total	94.5	38.1	1.03	93.4	93.8
Composite	100.0	38.6	1.04	100.0	100.0

TABLE 17. Float-Sink Analysis of Sample of Waste Fines From  
Blue Creek Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	6.6	2.5	0.75	0.4	5.4
1.30-1.40	5.1	7.9	0.80	1.0	4.4
1.40-1.50	2.6	15.5	0.90	1.1	2.5
1.50-1.60	1.6	24.3	1.03	1.0	1.7
Sink-1.60	11.1	54.2	1.13	15.6	13.9
<b>Total</b>	<b>27.0</b>	<b>27.3</b>	<b>0.93</b>	<b>19.1</b>	<b>27.9</b>
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	-	-	-	-	-
1.30-1.40	1.5	8.1	0.70	0.3	1.1
1.40-1.50	13.5	9.9	0.74	3.5	11.0
1.50-1.60	4.4	18.9	0.88	2.2	4.2
Sink-1.60	53.6	53.8	0.94	74.9	55.8
<b>Total</b>	<b>73.0</b>	<b>42.6</b>	<b>0.89</b>	<b>80.9</b>	<b>72.1</b>
<b>Composite</b>	<b>100.0</b>	<b>38.5</b>	<b>0.90</b>	<b>100.0</b>	<b>100.0</b>

TABLE 18. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (D) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	18.2	3.5	0.76	3.0	19.5
1.30-1.40	17.5	8.1	0.79	6.7	19.5
1.40-1.50	5.1	17.5	0.70	4.2	5.0
1.50-1.60	0.7	21.5	0.62	0.7	0.6
Sink-1.60	4.0	44.4	0.61	8.5	3.4
Total	45.5	10.6	0.74	23.1	48.0
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.7	3.4	0.73	0.1	0.7
1.30-1.40	7.3	4.4	0.75	1.5	7.7
1.40-1.50	8.7	8.9	0.73	3.7	8.9
1.50-1.60	1.8	20.6	0.62	1.8	1.6
Sink-1.60	36.0	40.6	0.65	69.8	33.1
Total	54.5	29.5	0.67	76.9	52.0
Composite	100.0	20.9	0.70	100.0	100.0

TABLE 19. Float-Sink Analysis of Sample of Waste Fines From  
Mary Lee (E) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	27.7	2.8	0.70	4.0	22.2
1.30-1.40	16.3	7.6	0.82	6.4	15.3
1.40-1.50	8.3	14.8	0.91	6.3	8.6
1.50-1.60	3.2	22.3	1.04	3.7	3.8
Sink-1.60	9.0	54.8	1.22	25.5	12.6
Total	64.5	13.7	0.84	45.9	62.5
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	1.4	2.5	0.70	0.2	1.0
1.30-1.40	9.2	4.4	0.75	2.1	7.9
1.40-1.50	7.2	11.5	0.92	4.3	7.6
1.50-1.60	1.8	19.5	0.98	1.8	2.0
Sink-1.60	15.9	55.6	1.04	45.7	19.0
Total	35.5	29.4	0.91	54.1	37.5
Composite	100.0	19.3	0.87	100.0	100.0

TABLE 20. Float-Sink Analysis of Sample of Waste Fines From  
Mary Lee (F) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	2.2	3.2	0.70	0.3	1.7
1.30-1.40	2.2	10.2	0.75	0.7	1.8
1.40-1.50	1.0	19.0	0.96	0.6	1.0
1.50-1.60	0.8	28.0	1.33	0.7	1.3
Sink-1.60	6.8	73.0	1.40	16.8	11.1
Total	13.0	43.6	1.12	19.1	16.9
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	1.4	5.6	0.65	0.3	1.3
1.30-1.40	29.1	13.8	0.76	13.6	25.5
1.40-1.50	18.8	24.2	0.74	15.4	16.1
1.50-1.60	13.6	24.4	0.74	11.2	11.6
Sink-1.60	24.1	49.4	1.04	40.4	28.9
Total	87.0	27.4	0.82	80.9	83.1
Composite	100.0	29.5	0.87	100.0	100.0

TABLE 21. Float-Sink Analysis of Sample of Waste Fines From Mary Lee (G) Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	3.0	3.0	0.68	0.4	2.7
1.30-1.40	1.7	8.5	0.72	0.6	1.6
1.40-1.50	0.8	16.4	0.79	0.5	0.8
1.50-1.60	2.0	24.8	0.81	1.9	2.2
Sink-1.60	3.5	34.6	0.88	4.8	4.2
Total	11.0	18.8	0.77	8.2	11.5
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	-	-	-	-	-
1.30-1.40	26.9	6.8	0.71	7.2	25.9
1.40-1.50	15.7	15.9	0.75	9.9	15.8
1.50-1.60	2.8	31.2	0.69	3.4	2.6
Sink-1.60	43.6	41.4	0.75	71.3	44.2
Total	89.0	26.1	0.73	91.8	88.5
Composite	100.0	25.3	0.74	100.0	100.0

TABLE 22. Float-Sink Analysis of Sample of Waste Fines From Pratt Seam

Plus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	13.4	2.1	0.52	0.9	9.0
1.30-1.40	3.2	6.8	0.66	0.7	2.7
1.40-1.50	1.4	16.6	0.78	0.7	1.3
1.50-1.60	0.5	16.7	0.80	0.3	0.5
Sink-1.60	4.2	52.4	0.90	7.1	4.9
Total	22.7	13.3	0.62	9.7	18.4
Minus 50 Mesh					
Specific Gravity Fraction	Weight, Percent	Analysis, Percent		Distribution, Percent	
		Ash	Total Sulfur	Ash	Total Sulfur
Float-1.30	0.5	4.4	0.42	0.1	0.2
1.30-1.40	3.7	4.5	0.55	0.5	2.6
1.40-1.50	6.9	5.1	0.62	1.1	5.5
1.50-1.60	1.4	8.2	0.71	0.4	1.2
Sink-1.60	64.8	42.1	0.85	88.2	72.1
Total	77.3	36.1	0.80	90.3	81.6
Composite	100.0	30.9	0.76	100.0	100.0

### The Humphreys Spiral

The Humphreys coal spiral consists of six turns of troughing, with a cross section roughly following the quadrant of a circle 24 inches in diameter (4). Each spiral turn consists of three 120° sections and each section has a circular refuse port at the lowest point of the channel cross section. The refuse ports, which are 2 inches in diameter, can be blanked off or opened to various degrees by means of an adjustable disk. The spiral has a vertical height of five feet and an outside diameter of two feet. Since this is a commercial-size unit, the test data obtained are directly indicative of results that can be achieved in plant operation. The spiral test unit is shown in Figure 2. A sampling device was installed to permit collection of the clean coal, middlings, and refuse products simultaneously.

In action, the spiral combines centrifugal action and sluicing to achieve a separation of the different mineral constituents. The heavier particles stratify in a band along the inner edge of the spiral and are removed through the refuse ports. The lighter specific gravity particles stratify along the outer edge of the spiral stream. The stream discharging from the lower end of the spiral can be split into two products by an adjustable splitter to obtain a clean coal product (outer coal) and a middling (inner coal).



FIGURE 2. Humphreys Spiral Test Unit

### Laboratory Batch Tests

Laboratory screen size analyses and float-sink tests using heavy liquid were made on each of the samples to determine the effectiveness of gravity concentration for separating clean coal from the pyrite and other gangue constituents. The tests indicated that gravity separation of the plus 200-mesh screen fractions of the different samples, under optimum conditions, could be expected to yield clean coal products containing 5 to 10 percent ash and 0.40 to 1.30 percent total sulfur.

Using the float-sink analyses as a guide, tests were made with the Humphreys spiral on each sample by a procedure in which a 200 to 300 pound portion of the refuse was recycled over the spiral until equilibrium conditions were reached, after which a concentrate and tailing were obtained. The tests were made on feeds from which the minus 200-mesh material had been removed. Results of these tests for the surface mined and underground mined waste fines are shown in tables 23 and 24 respectively.

The batch tests of the different samples demonstrated that under simulated continuous operating conditions it was possible to recover clean coal concentrates containing 4.6 to 12.6 percent ash, with coal recoveries ranging from 80.5 to 99.5 percent.

TABLE 23. Results of Laboratory Batch Spiral Tests of Surface Mine Waste Fines

Coal Seam	Product	Weight Percent	Analysis, Percent			Distribution, Percent		
			Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
America-Pratt-Nickel Plate Composite	Clean Coal	67.2	98.0	8.1	0.97	94.4	24.3	64.4
	Tailing	32.8	12.0	51.8	1.10	5.6	75.7	35.6
	Composite	100.0	69.8	22.4	1.01	100.0	100.0	100.0
Black Creek (A)	Clean Coal	51.7	96.4	10.6	0.94	80.5	19.2	41.8
	Tailing	48.3	25.0	47.8	1.40	19.5	80.8	58.2
	Composite	100.0	61.9	28.6	1.16	100.0	100.0	100.0
Black Creek (B)	Clean Coal	69.8	97.0	7.0	0.81	87.2	27.4	51.0
	Tailing	30.2	33.0	42.9	1.80	12.8	72.6	49.0
	Composite	100.0	77.7	17.8	1.10	100.0	100.0	100.0
Black Creek, Jefferson (C)	Clean Coal	76.5	97.4	4.6	0.62	88.3	32.3	70.6
	Tailing	23.5	42.0	25.4	0.84	11.7	67.7	29.4
	Composite	100.0	84.4	9.5	0.67	100.0	100.0	100.0
Blue Creek	Clean Coal	70.6	92.7	8.8	0.60	89.4	31.7	67.3
	Tailing	29.4	26.5	45.5	0.70	10.6	68.3	32.7
	Composite	100.0	73.2	19.6	0.63	100.0	100.0	100.0
Carter, Milldale, and Johnson Composite	Clean Coal	59.8	90.6	12.6	1.20	81.5	31.6	40.2
	Tailing	40.2	30.5	40.5	2.65	18.5	68.4	59.8
	Composite	100.0	66.4	23.8	1.78	100.0	100.0	100.0
Clements	Clean Coal	27.8	89.8	12.2	2.00	81.2	7.6	22.3
	Tailing	72.2	8.0	56.9	2.68	18.8	92.4	77.7
	Composite	100.0	30.7	44.5	2.49	100.0	100.0	100.0
Gwin	Clean Coal	79.3	91.3	10.9	1.20	90.2	56.1	73.2
	Tailing	20.7	38.0	32.7	1.68	9.8	43.9	26.8
	Composite	100.0	80.3	15.4	1.30	100.0	100.0	100.0
Woodstock	Clean Coal	89.2	98.2	5.2	0.42	95.4	51.8	85.9
	Tailing	10.8	39.5	39.9	0.57	4.6	48.2	14.1
	Composite	100.0	91.9	8.9	0.44	100.0	100.0	100.0

Test Conditions: Solids in feed - 25 percent Feed rate - 1.5 tons per hour

TABLE 24. Results of Laboratory Batch Spiral Tests of Underground Mine Waste Fines

Coal Seam	Product	Weight Percent	Analysis, Percent			Distribution, Percent		
			Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
America (A)	Clean Coal	72.9	97.5	7.3	1.29	98.2	25.4	71.1
	Tailing	27.1	4.9	57.7	1.41	1.8	74.6	28.9
	Composite	100.0	72.4	21.0	1.32	100.0	100.0	100.0
America (B)	Clean Coal	83.7	98.5	5.4	1.14	97.2	35.1	82.9
	Tailing	16.3	14.6	51.2	1.21	2.8	64.9	17.1
	Composite	100.0	84.8	12.9	1.15	100.0	100.0	100.0
America, Mary Lee (C)	Clean Coal	73.9	96.7	8.0	1.02	99.5	25.4	75.2
	Tailing	26.1	1.5	66.4	0.95	0.5	74.6	24.8
	Composite	100.0	71.9	23.2	1.00	100.0	100.0	100.0
Blue Creek	Clean Coal	73.7	96.2	7.8	0.60	96.9	32.9	67.2
	Tailing	26.3	8.7	44.6	0.82	3.1	67.1	32.8
	Composite	100.0	73.2	17.5	0.66	100.0	100.0	100.0
Mary Lee (D)	Clean Coal	83.8	95.3	6.2	0.62	99.2	36.5	82.3
	Tailing	16.2	3.9	55.8	0.69	0.8	63.5	17.7
	Composite	100.0	80.5	14.2	0.63	100.0	100.0	100.0
Mary Lee (E)	Clean Coal	81.9	94.4	7.1	0.81	99.0	36.0	71.0
	Tailing	18.1	4.1	57.2	1.50	1.0	64.0	29.0
	Composite	100.0	78.1	16.2	0.93	100.0	100.0	100.0
Mary Lee (F)	Clean Coal	79.4	96.2	7.2	0.78	99.1	34.6	70.5
	Tailing	20.6	3.2	52.4	1.26	0.9	65.4	29.5
	Composite	100.0	77.0	16.5	0.88	100.0	100.0	100.0

TABLE 24. (Con't)

Coal Seam	Product	Weight Percent	Analysis, Percent			Distribution, Percent		
			Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
Mary Lee (G)	Clean Coal	72.9	95.7	8.7	0.60	96.3	31.2	68.9
	Tailing	27.1	9.8	51.6	0.73	3.7	68.8	31.1
	Composite	100.0	72.4	20.3	0.63	100.0	100.0	100.0
Pratt	Clean Coal	52.6	95.4	6.1	0.62	96.7	11.4	48.9
	Tailing	47.4	3.6	52.8	0.72	3.3	88.6	51.1
	Composite	100.0	51.9	28.2	0.67	100.0	100.0	100.0

Test Conditions : Solids in feed - 25 percent      Feed rate - 1.5 tons per hour

### Continuous Tests

With the preliminary spiral tests as a guide, continuous runs were made in the spiral on 2-ton samples from five of the waste impoundments to determine the effect of recycling the middlings on the grade and recovery of the clean coal. Two different flowsheets were used in treating the wastes. These are shown in figures 3 and 4. Only the plus 200-mesh screen fraction of each sample was treated in the spiral. The minus 200-mesh undersize was discarded because of its low coal content.

The America-Pratt-Nickel Plate, Black Creek (B), and Mary Lee (E) were processed by a single stage procedure (Figure 3), whereas the Blue Creek and America (A) samples, because of somewhat higher ash content, required treatment in a two stage circuit (Figure 4). Results of the tests are shown in Tables 25 through 29.

The America-Pratt-Nickel Plate sample produced a clean coal concentrate containing 8.7 percent ash and 0.90 percent total sulfur, and had a BTU value of 13,250 per pound. Coal recovery was 90.7 percent.

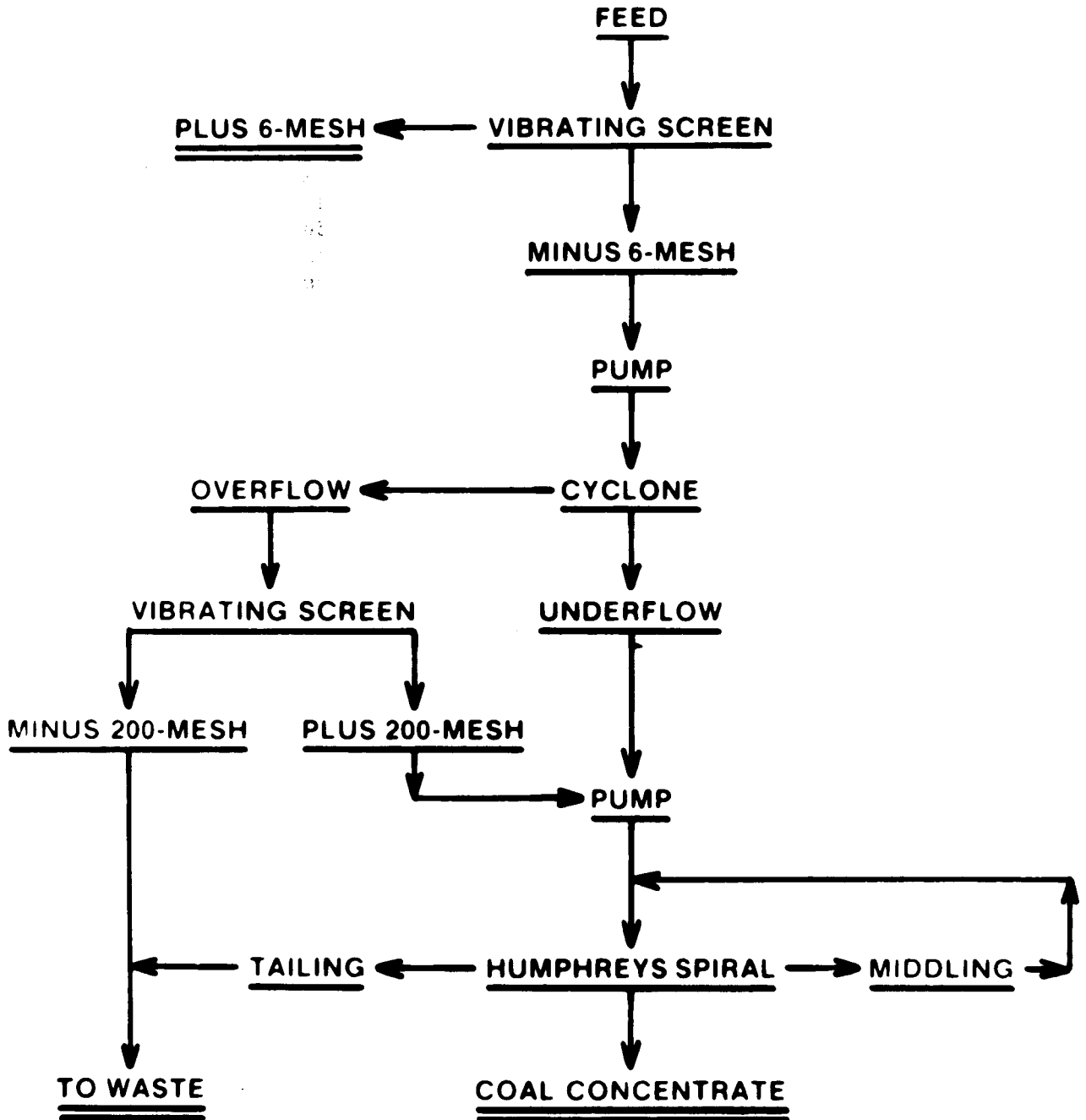
The Blue Creek sample produced a clean coal concentrate containing 8.8 percent ash and 0.62 percent total sulfur, and had a BTU value of 13,580 per pound. The coal recovery was 83.6 percent.

The Black Creek (B) sample contained an appreciable quantity of clean coal coarser than 6 mesh in size. This was not passed over the spiral but was subsequently combined with the spiral concentrate from treatment of the minus 6- plus 200-mesh fraction. The combined clean coal spiral concentrate and 6-mesh screen oversize product contained 5.0 percent ash and 0.83 percent total sulfur, and had a heat value of 13,140 BTU per pound. Coal recovery was 94.1 percent. A materials balance flowsheet for the Black Creek (B) sample is shown in Figure 5.

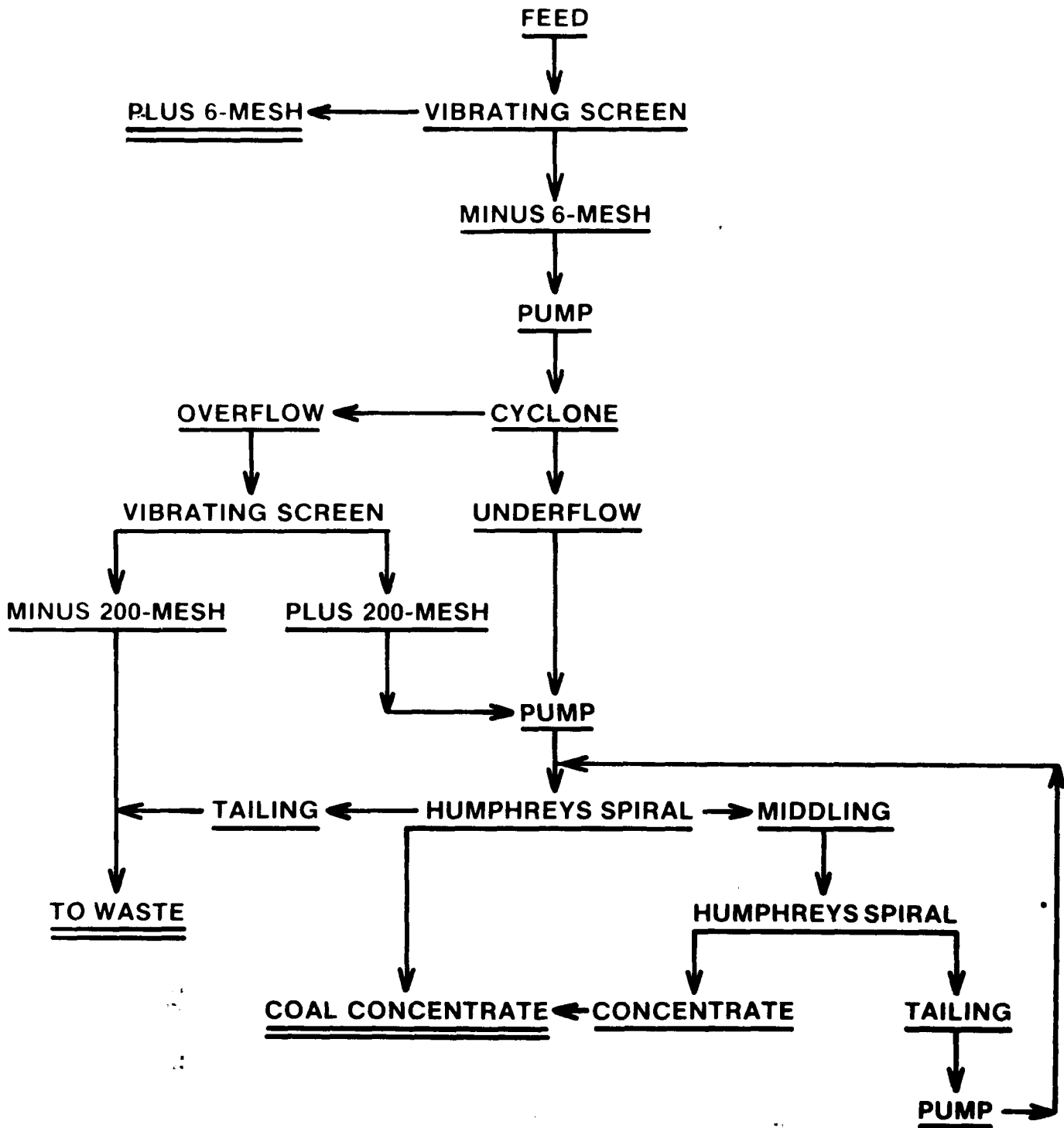
Treatment of the America (A) sample in the two stage circuit gave good results. The clean coal concentrate contained 8.7 percent ash and 1.20 percent total sulfur, and had a heat value of 13,694 BTU per pound. Coal recovery was 95.6 percent.

The Mary Lee (E) sample produced a clean coal concentrate containing 8.1 percent ash and 0.81 percent total sulfur, and had a heat value of 13,976 BTU per pound. Coal recovery was 97.5 percent.

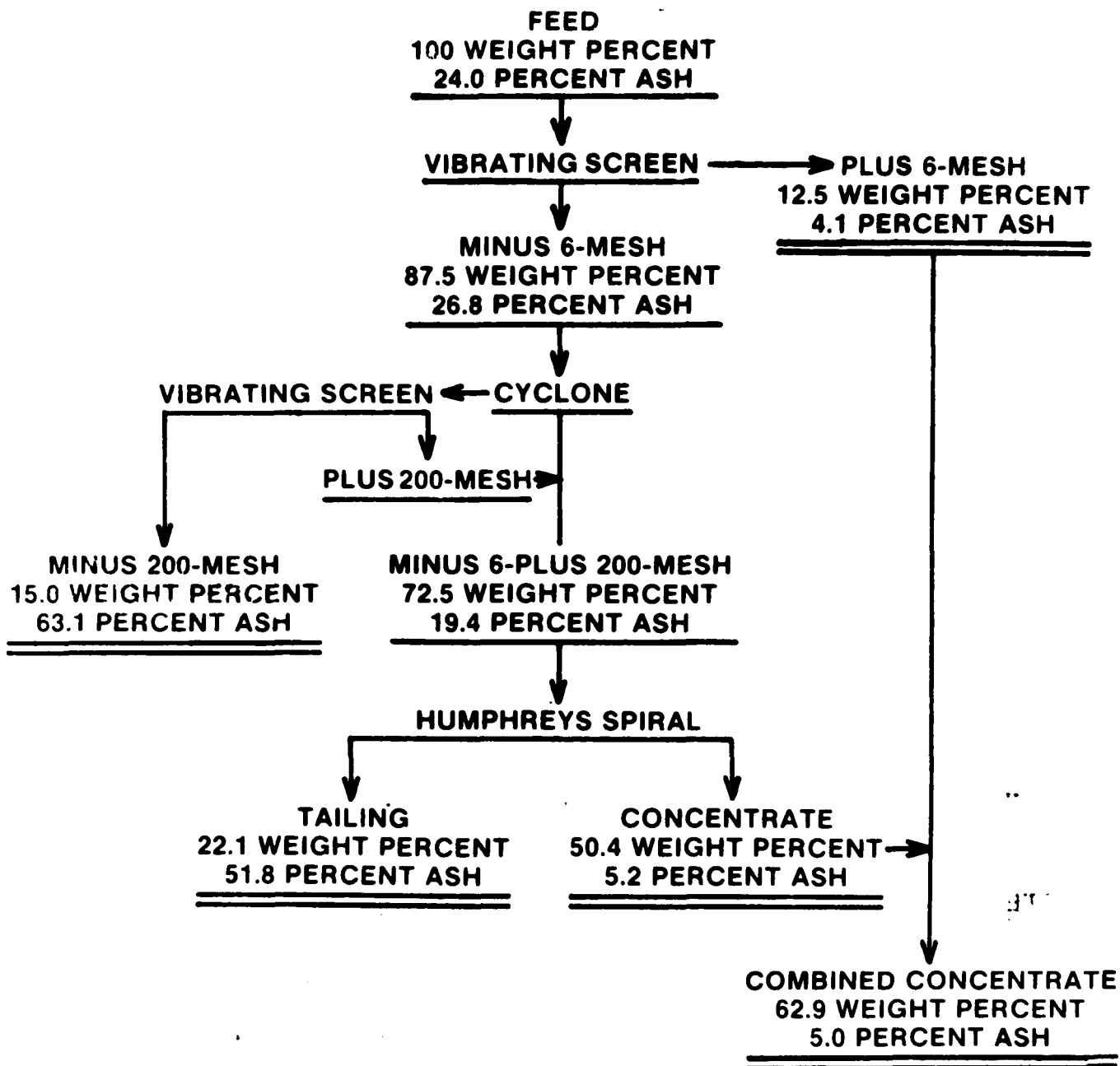
The coal research program has resulted in the development of a simple efficient method for recovering fine size coal using Humphreys spirals. The process has been tested on a continuous laboratory basis on a wide variety of fine-size coal from a number of Alabama coal seams. Results of the research indicated that it is possible to achieve a very high recovery of the coal in products that are comparable or superior to those now being shipped from the preparation plants.



**FIGURE 3** – SINGLE STAGE SPIRAL CONCENTRATION FLOWSHEET



**FIGURE 4** –TWO-STAGE SPIRAL CONCENTRATION FLOWSHEET



**FIGURE 5 - MATERIALS BALANCE FLOWSHEET FOR CONTINUOUS SPIRAL CONCENTRATION OF BLACK CREEK (B) SEAM SAMPLE**

TABLE 25. Results of Continuous Spiral Test On  
America-Pratt-Nickel Plate Seams  
Composite

Product	Weight Percent	Analysis, Percent				Distribution, Percent		
		Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	BTU/lb.	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
Spiral Concentrate	58.4	92.0	8.7	0.90	13,250	90.7	17.9	57.3
Spiral Tailing	22.8	22.4	44.2	0.80		8.6	35.6	19.9
Minus 200- Mesh Slimes	18.8	2.3	70.1	1.11		0.7	46.5	22.8
Composite Feed	100.0	59.3	28.3	.92		100.0	100.0	100.0

TABLE 26. Results of Continuous Spiral Test On  
Blue Creek Seam Sample

Product	Weight Percent	Analysis, Percent				Distribution, Percent		
		Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	BTU/lb.	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
Spiral Concentrate	35.6	91.7	8.8	0.62	13,580	83.6	8.4	33.2
Spiral Tailing	13.1	33.3	48.9	0.52		11.2	17.1	10.3
Minus 200- Mesh Slimes	51.3	4.0	54.5	0.73		5.2	74.5	56.5
Composite Feed	100.0	39.1	37.5	0.66		100.0	100.0	100.0

TABLE 27. Results of Continuous Spiral Test On  
Black Creek (B) Seam Sample

Product	Weight Percent	Analysis, Percent				Distribution, Percent		
		Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur	BTU/lb.	Float 1.60 Specific Gravity (Coal)	Ash	Total Sulfur
Plus 6-mesh Spiral Concentrate	12.5	98.1	4.1	1.10	12,900	18.9	2.1	12.5
	50.4	97.5	5.2	0.77	13,200	75.6	10.9	35.3
Composite Concentrate	62.9	97.6	5.0	0.84	13,140	94.5	13.1	47.8
Spiral Tailing	22.1	15.5	51.8	1.65		5.3	47.6	33.1
Minus 200- Mesh Slimes	15.0	1.0	63.1	1.41		0.2	39.3	19.1
Composite Feed	100.0	65.0	24.0	1.10		100.0	100.0	100.0

TABLE 28. Results of Continuous Spiral Test on America (A) Seam Sample

Product	Weight, Percent	Analysis, Percent				Distribution, Percent		
		Float 1.60 Specific gravity (Coal)	Ash	Total Sulfur	BTU/lb	Float 1.60 Specific gravity (Coal)	Ash	Total Sulfur
Spiral Concentrate	50.2	94.3	8.7	1.20	13,694	95.6	13.5	44.9
Spiral Secondary Tailing	7.1	6.0	52.8	1.45		0.8	11.6	7.7
Spiral Primary Tailing	14.5	5.0	54.8	1.70		1.5	24.6	18.4
Minus 200-mesh Slimes	28.2	3.7	57.4	1.38		2.1	50.3	29.0
Composite Feed	100.0	49.5	32.2	1.34		100.0	100.0	100.0

TABLE 29. Results of Continuous Spiral Test  
on Mary Lee (E) Seam Sample

Product	Weight, Percent	Analysis, Percent				Distribution, Percent		
		Float 1.60 Specific gravity (Coal)	Ash	Total Sulfur	BTU/lb	Float 1.60 Specific gravity (Coal)	Ash	Total Sulfur
Spiral Concentrate	70.2	95.2	8.1	0.81	13,976	97.5	28.9	55.8
Spiral Tailing	16.8	8.6	44.5	1.75		2.1	38.0	28.9
Minus 200-mesh Slimes	13.0	2.0	50.0	1.20		0.4	33.1	15.3
Composite Feed	100.0	68.5	19.7	1.02		100.0	100.0	100.0

## CONCLUSIONS

The batch laboratory and continuous tests in the Humphreys spiral demonstrated the technical feasibility of processing high-ash waste fines to recover high quality clean coal products that meet or exceed common commercial specifications for BTU value, and ash and sulfur content. Clean coal products containing as little as 5 percent to as much as 13 percent ash were obtained from the nine surface mine washer reject samples. Clean coal products containing 5 to 9 percent ash were obtained from the nine underground mine washer reject samples. Fine coal which has been wasted in the past can be readily recovered as clean commercial-grade coal products using simple gravity concentration circuits.

## REFERENCES

1. Browning, James S., "Recovering Fine-Size Coal From Alabama Surface Mine Washer Wastes Using The Humphreys Spiral." Mineral Resources Institute of The University of Alabama. Technical Report No. 2, 11 pp., 1977.
2. Demmer, W. L. and Wilson, V. H., "Cleaning Anthracite Silt for Boiler Fuel with Humphreys Spiral Separator." American Institute of Mining and Metallurgical Engineers TP2479, 15 pp., 1948.
3. Hubbard, Judson S., Brown, Whitman E. and Walker, Merrill, "The Humphreys Spiral Concentrator for Cleaning Minus 1/4 Inch Coal." The Humphreys Engineering Company, Denver, Colo., 1951.
4. Pryor, E. J., "Mineral Processing." Elsevier Publishing Company, London, pp. 342-344, 1965.
5. Zeilinger, J. E. and Deurbrouck, A. W., "Physical Desulfurization of Fine-Size Coals on a Spiral Concentrator." U.S. Bureau of Mines, Report of Investigations 8152, 18 pp., 1976.