DOE/PC/90314--T13

HYDROCARBON-OIL ENCAPSULATE BUBBLE FLOTATION OF FINE COAL

**Technical Progress Report for the Twelfth Quarter
(The period of July 1 to September 30, 1993)**

DE-FG22-90PC90314

RECEIVED

APR 29 1996

OSTI

by

**Felicia F. Peng
Principal Investigator
Department of Mineral Processing Engineering
West Virginia University
Morgantown, West Virginia 26506-6070**

MASTER

Program Officer

**Thomas J. Feeley
U.S. Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236**

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

CHAPTER 1

HYDROCARBON-OIL ENCAPSULATED BUBBLE FLOTATION

OF FINE COAL USING 3-IN. ID FLOTATION COLUMN 1

1. Experiment 1

2. Results 3

2.1 Recovery-Grade Curves for Gasified Collector

and Direct Liquid Collector Flotation 3

2.2 Separation Efficiency and Ash Rejection

or Sulfur Rejection 11

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.

CHAPER 1
HYDROCARBON-OIL ENCAPSULATED BUBBLE FLOTATION
OF FINE COAL USING 3-IN. ID FLOTATION COLUMN
(CONTINUED)

Two modes of collector addition techniques including gasified collector transported in gas phase and direct collector addition techniques were applied in the column flotation to demonstrate the selectivity of utilizing the hydrocarbon-oil encapsulated air bubbles in the fine coal flotation process. A 3-in. floatation column was used to evaluate two modes of collector dispersion and addition techniques on the recovery and grade of fine coals using various ranks of coal.

1. EXPERIMENT

Five different coal samples were used in the column flotation test program. They are Mammoth, Lower Kittanning, Upper Freeport, Pittsburgh No.8, and Illinois No.6 seam coals, which correspond to anthracite-, low volatile-, medium volatile-, and high volatile-seam coals, respectively. The sample preparation for column flotation was described in previous quarterly report. In this quarterly report, the test results for the Upper Freeport seam coal and Pittsburgh No. 8 seam coal are reported. Table 1 and 2 are the typical size distributions of Holmes mill products for Upper Freeport seam coal and Pittsburgh seam coal, respectively. The coal samples were diluted to the desired solid concentration and reagents were added according to

the specifications of experimental design.

Table 1 Size Analysis of Raw Coal for Upper Freeport
Seam, Indiana Co., PA

Size, μm	Wt %	% Passing
+150	6.3	100.0
-150 + 75	20.3	93.7
-75 + 38	58.0	73.4
-38	15.4	15.4

Table 2 Size Analysis of Raw Coal for Pittsburgh No.8
Seam, Belmont Co., OH

Size, μm	Wt %	% Passing
+150	3.69	100.0
-150 + 75	30.50	96.31
-75 + 38	50.13	65.81
- 38	15.68	15.68

The operating of 3-in. ID flotation column was described in previous quarterly report. The feed, froth, and tailing products were collected for ash analysis. The yield, Y_c , and combustible recovery, R_c , were then calculated according to the following expression:

$$\text{Yield \%} = \frac{\text{tailing ash} - \text{feed ash}}{\text{tailing ash} - \text{clean coal ash}} \times 100\% \quad (1)$$

$$\text{Recovery \%} = Y_c \frac{(100 - A_c)}{(100 - A_f)} \quad (2)$$

The amount of collector used in the flotation tests are varied from 0.05 - 0.7 lb kerosene/ton coal for Upper Freeport seam coal and 0.2 to 4.3 lb kerosene/ton of coal for Pittsburgh No. 8 seam coal, while the operating conditions were adjusted to achieve the maximum combustible recovery at high ash rejection.

2. RESULTS

2.1 Recovery-Grade Curves for Gasified Collector Flotation and Direct Liquid Collector Flotation

The flotation test results for gasified collector flotation and direct liquid addition flotation using 3-in. ID flotation column are given in Figure 1 and Figure 2 for the Upper Freeport seam coal and Pittsburgh No. 8 seam coal, respectively. The numerical results are presented in Table 3 to Table 6. The test results show that 90 to 95 percent of combustible recovery with 6.0 - 6.8 percent of ash content can be achieved by gasification of kerosene coal flotation using 3-in. ID flotation column, while the combustible recovery of 90 percent with 7.5 percent of ash content was recovered by using the direct liquid addition to the coal slurry. The results indicate that both techniques can be used to achieved high combustible recovery. However, column flotation using the hydrocarbon-encapsulated bubbles produce lower ash content in the clean coal products than that of direct collector addition to the feed stream. These results also demonstrate the potential of producing deep clean coal selectively by using gasification of collector transported into an air stream to produce hydrocarbon encapsulated bubbles. The Pittsburgh No. 8 seam

coal is a high volatile bituminous coal, while the Upper Freeport seam coal is medium volatile bituminous coal. The floatability of Pittsburgh No. 8 seam coal is more amenable by the collector than that of medium volatile bituminous coal such as Upper Freeport seam coal. The Pittsburgh No. 8 coal particles required more kerosene to achieve the higher combustible recovery, compared with the Upper Freeport coal particles. The high recovery and high selectivity of hydrocarbon-oil encapsulated bubble flotation can be explained by the reduction of induction time for the bubble-particle attachment due to the oil-coated bubble. The oil-coated air bubbles are preferentially adsorbed on the hydrophobic sites of the coal particles.

For medium volatile Upper Freeport seam coals, 80 - 85 percent of combustible recovery was obtained with 7.6 - 10.0 percent of ash content by using gasified collector flotation, whereas 80 - 85 percent of combustible recovery with 9.5 - 12.0 percent of ash content by using direct liquid collector addition flotation was achieved. This coal has high natural floatability, but they may contain high middling which are difficult to separate than the high volatile coals. It should be noticed that the ash contents of the raw coals used in this testing program are ranging from 8 - 12 percent for the Upper Freeport seam coals, while as high as 18 - 21 percent for the Pittsburgh No. 8 seam coal. Both coals tested give high percentage of ash rejection. Thus, there is a potential to produce super clean coal product with flotation column by applying the gasified collector coated air bubbles and starting with lower ash content of feed slurry.

Figure 1

Relationship of combustible recovery and ash content of clean coal product using 3-in. ID flotation column for Upper Freeport seam coal, Indiana Co., PA

Figure 2

Relationship of combustible recovery and ash content of clean coal product using 3-in. ID flotation column for Pittsburgh No.8 seam coal, Belmont Co., OH

Table 1 Hydrocarbon-Oil Encapsulated Bubble Flotation for Upper Freeport
Seam Coal, Indiana Co., PA Using a 3-in.ID Flotation Column

Collector Dosage (lb/ton)	Ash (%)			Yield (%)	Recovery (%)	Ash Rejection (%)	Separation Efficiency (%)
	Feed	Clean Coal	Tailing				
0.596	19.20	8.50	47.50	72.56	82.17	67.88	50.05
	19.20	8.10	48.10	72.25	82.18	69.52	51.69
0.61	18.90	7.90	45.70	70.90	80.52	70.36	50.88
	18.90	8.10	44.60	70.41	79.79	69.82	49.61
0.592	21.10	7.80	55.30	72.00	84.14	73.38	57.52
	21.10	7.60	56.90	72.62	85.04	73.84	58.89
0.501	19.50	5.90	39.70	59.76	69.86	81.92	51.78
	19.50	6.20	40.40	61.11	71.21	80.57	51.78
0.62	21.10	5.90	37.10	51.28	61.16	85.66	46.82
	21.10	6.20	36.30	50.50	60.03	85.16	45.20
0.7	19.70	10.10	62.00	81.50	91.25	58.21	49.46
	19.70	11.50	57.30	82.10	90.48	52.08	42.56
0.612	20.30	11.10	58.40	80.55	89.85	55.96	45.80
	20.30	11.90	58.80	82.09	90.74	51.88	42.62

Table 2 Direct Liquid Addition Flotation for Upper Freeport Seam Coal,
Indiana Co., PA Using a 3-in.ID Flotation Column

Collector Dosage (lb/ton)	Ash (%)			Yield (%)	Recovery (%)	Ash Rejection (%)	Separation Efficiency (%)
	Feed	Clean Coal	Tailing				
0.596	19.50	9.50	45.20	71.99	80.93	64.93	45.86
0.596	19.50	9.30	44.80	71.27	80.30	66.01	46.31
0.61	19.10	8.90	48.20	74.05	83.38	65.50	48.88
0.61	19.10	9.10	47.10	73.68	82.79	64.89	47.69
0.592	20.60	9.60	45.80	69.61	79.26	67.56	46.82
0.592	20.60	9.90	46.50	70.77	80.30	65.99	46.29
0.501	19.70	9.00	43.40	68.90	78.08	68.52	46.60
0.501	19.70	9.50	44.90	71.19	80.23	65.67	45.90
0.62	20.20	7.30	39.60	60.06	69.77	78.29	48.07
0.62	20.20	7.50	40.80	61.86	71.71	77.03	48.74
0.7	20.80	7.10	38.20	55.95	65.63	80.90	46.53
0.7	20.80	7.50	37.30	55.37	64.67	80.04	44.70
0.612	21.20	11.70	56.90	78.98	88.50	56.41	44.91
0.612	21.20	12.30	57.00	80.09	89.14	53.53	42.67

Table 3 Hydrocarbon-Oil Encapsulated Bubble Flotation for Pittsburgh No. 8 Seam Coal, Belmont Co., OH Using a 3-in.ID Flotation Column

Collector Dosage (lb/ton)	Ash (%)			Yield (%)	Recovery (%)	Ash Rejection (%)	Separation Efficiency (%)	Sulfur (%)		Sulfur Rejection (%)	Separation Efficiency (%)
	Feed	Clean Coal	Tailing					Feed	Clean Coal		
0.17	20.02	4.89	35.50	50.57	60.14	75.57	45.45	4.83	3.99	17.39	10.46
0.17	21.04	5.22	50.70	65.22	78.29	75.19	58.87	4.83	3.94	18.43	14.43
3.11	20.54	5.69	57.88	71.55	84.92	72.30	61.40	4.96	4.07	17.94	15.24
0.84	21.07	5.86	72.97	77.34	92.24	72.19	66.59	4.69	3.96	15.57	14.36
7.43	19.61	5.91	65.86	77.15	90.30	69.86	63.09	4.51	4.04	10.42	9.41
7.43	19.12	5.91	76.19	81.20	94.46	69.09	65.26	4.51	4.10	9.09	8.59
0.84	19.60	6.11	72.50	79.68	93.05	68.83	64.04	4.69	4.13	11.94	11.11
1.48	19.30	6.13	75.44	81.00	94.22	68.24	64.29	4.74	4.30	9.28	8.75
4.29	19.99	6.15	73.86	79.56	93.32	69.23	64.61	4.79	4.09	14.61	13.64
4.29	19.75	6.15	65.95	77.26	90.35	68.86	62.22	4.79	4.02	16.08	14.52
1.19	20.23	6.48	72.54	79.19	92.84	67.97	63.10	4.97	4.24	14.69	13.64
2.24	19.29	6.49	76.42	81.70	94.66	66.36	62.81	4.76	4.22	11.34	10.74
1.48	20.79	6.55	76.90	79.76	94.10	68.49	64.45	4.74	4.48	5.49	5.16
3.95	20.21	6.67	75.74	80.40	94.04	67.00	63.00	5.18	4.27	17.57	16.52
4.10	23.35	6.82	73.85	75.34	91.59	70.79	64.84	-	-	-	-
2.24	20.55	6.83	77.49	80.58	94.50	66.76	63.09	4.76	4.37	8.19	7.74
3.95	21.64	6.86	78.67	79.42	94.40	68.30	64.47	5.18	4.45	14.09	13.30
4.10	19.69	6.94	74.49	81.13	94.01	64.75	60.87	-	-	-	-
2.88	17.67	7.36	77.21	85.24	95.91	58.35	55.96	4.47	4.36	2.46	2.36
2.88	17.47	7.76	77.13	86.00	96.12	55.58	53.42	4.47	4.34	2.91	2.80

Note: - not available

Table 4 Direct liquid Addition Flotation for Pittsburgh No. 8 Seam Coal,
Belmont Co., OH Using a 3-in. ID flotation column

Collector Dosage (lb/ton)	Ash (%)			Yield (%)	Recovery (%)	Ash Rejection (%)	Separation Efficiency (%)	Sulfur (%)		Sulfur Rejection (%)	Separation Efficiency (%)
	Feed	Clean Coal	Tailing					Feed	Clean Coal		
0.50	23.89	5.79	53.26	61.87	76.58	75.76	58.02	4.74	4.27	9.92	7.59
0.25	19.85	5.99	41.68	61.17	71.75	69.82	50.10	5.00	4.12	17.60	12.63
1.00	18.76	6.05	51.35	71.94	83.20	67.75	56.37	4.88	4.24	13.11	10.91
0.25	20.04	6.07	50.47	68.54	80.51	69.71	56.12	5.00	4.04	19.20	15.46
0.75	20.27	6.08	50.72	68.21	80.35	70.00	56.25	4.98	4.14	16.87	13.55
1.00	20.00	6.10	57.14	72.77	85.41	69.50	59.36	4.88	4.26	12.70	10.85
2.00	18.31	6.65	47.31	71.32	81.50	63.68	51.90	4.75	4.10	13.68	11.15
1.48	16.79	6.69	43.69	72.70	81.53	60.15	49.04	4.04	4.04	0.00	0.00
2.64	19.48	6.72	58.25	75.24	87.16	65.50	57.09	4.76	4.15	12.82	11.17
3.00	18.79	6.75	60.91	77.77	89.30	64.08	57.22	4.70	4.36	7.23	6.46
2.00	18.86	6.83	56.28	75.67	86.89	63.79	55.42	4.75	4.19	11.79	10.24
3.00	19.06	7.01	59.07	76.85	88.29	63.22	55.82	4.70	4.34	7.66	6.76
2.00	19.34	7.52	62.59	78.54	90.05	61.12	55.04	-	-	-	-
3.00	18.39	7.67	50.62	75.04	84.90	58.29	49.49	-	-	-	-

Note: - not available

2.2 Separation Efficiency and Ash Rejection or Sulfur Rejection

The separation of mineral matters from fine coal in column flotation were evaluated by using separation efficiency and ash rejection and/or sulfur rejection. They were defined and calculated according to Equations (4) and (5) as shown below. The numerical results are also included in Table 1 to Table 4 for the Upper Freeport seam coal and Pittsburgh No. 8 seam coal, respectively.

$$\text{Ash Rejection \%} = \frac{(100 A_f - Y_c A_c)}{A_f} \quad (3)$$

$$\begin{aligned} \text{Separation Efficiency \%} &= Y_c \left[\frac{100 - A_c}{100 - A_f} - \frac{A_c}{A_f} \right] \\ &= R_c - (100 - A_{rej}) \end{aligned} \quad (4)$$

The separation efficiency versus ash rejection from column flotation of fine coal using gasified collector is plotted in Figure 3 and Figure 4. Figure 3 and Figure 4 are for the Upper Freeport seam coal and Pittsburgh No. 8 seam coal, respectively. For both coals show the maximum separation efficiency as the ash rejection or sulfur rejection ranging from zero percent to 100 percent. The maximum separation efficiencies for the Upper Freeport and Pittsburgh seam coals are at the ash rejection of 70 percent and 80 percent, respectively. The maximum values of the separation efficiency based on the ash rejections are corresponding to the sharp turning points (or bend) of the recovery-grade curves on the Upper Freeport seam coal and Pittsburgh No. 8 seam coal, which are exhibited in Figure 1 and Figure 2. The separation efficiency based on the sulfur rejection for Pittsburgh No. 8 is also included in Figure 4. The maximum separation efficiency is 70 percent which gives the sulfur rejection of 30 percent. These results suggested that the operating conditions for the column flotation of fine coal may be set to achieve the maximum value of separation efficiency for optimum combustible recovery.

The next quarterly report will include the results of column flotation for the Illinois No. 6 seam coal using both gasified collector and direct liquid collector techniques.

Figure 3 Separation Efficiency Versus Ash Rejection Using Gasified Collector Flotation for Upper Freeport Seam Coal

Figure 4

Separation efficiency versus ash rejection and
sulfur rejection for Pittsburgh No. 8 seam coal,
Belmont Co., OH

DISCLAIMER

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