ABSTRACT

This project was developed to install a small commercial size Deister column beside the existing sub-aeration flotation cells at Kerr-McGee's Galatia Plant so that a comparison of the flotation results could be made. A representative split of the fines which normally goes to sub-aeration cells was diverted to the column for continuous side by side flotation testing over an extended period.

After the column was installed, time was spent in learning to operate the unit. Variables included feed rate, reagent selection and rates, quantity of air and water into the bubble generators, and froth height, washing, and removal. A series of twenty three tests were conducted in which concentrate grades averaged over 13400 Btu/pound, ash in the concentrates was 8.2%, total sulfur rejection was 56%, pyritic sulfur rejection was 75%, ash rejection was 92% and Btu recovery was 82%. A similar plant test yielded 12,700 btu with 11.7% ash, total sulfur rejection was 51%, ash rejection was 92% and Btu recovery was 79%.

Significant differences in operation between column tests and the plant were the following 1) more reagent was used in the column tests than was normally used in the plant; 2) more connected power per ton of feed is required in the sub-a machines, than is required for the column; 3) the retention time in the sub-a machines is 2.7 minutes while the retention time in the column was 10.7 minutes. The froth to surface area ratio in the plant is 90.5 pounds of froth (dry basis) per square foot per hour while the column generates 99.5lb/sqft/hr.

Summarizing, the column provided equal or better froth concentrate quality and recovery than the sub-a flotation machines on similar coal slurry feeds. The column tests were not optimized in the time available, and test results indicate that the column is no particularly sensitive to charges in grade of the feed nor to the source of the feed. This insensitivity to feed composition means that the column would operate well within the broad range of feed that is often delivered at a plant.

(This project is funded by the Illinois Department of Energy and Natural Resources as part of its cost-shared program with the U. S. Department of Energy.)
EXECUTIVE SUMMARY

The project was developed to install a small commercial size Deister column beside the existing sub-aeration flotation cells at Kerr-McGee's Galatia (Illinois) plant so that a comparison of flotation results could be made. A representative split of the feeds which normally goes to the sub-a cells was diverted to the column for continuous side by side flotation testing.

An early meeting was held at Galatia with Kerr-McGee operators, Deister engineers, and ISGS representatives during which the location of the machine and the size of the machine was selected. Methods for accurate sampling of feed, tailing, and concentrate were developed. In addition, a technique was developed to supply a representative feed to the column as well as a method to control and measure the feed rate.

After the column was installed, time was spent learning to operate the unit. Variables included feed rate, reagent selection, and rates, quantity of air and water to the bubble generators, and froth height, wash, and removal.

A short period of time was utilized with debugging the column operation. Uncontrollable flow rates caused by inadequate venting of the feedline was solved by installing a vent. A faulty signal response by the Clarkson valve which controls the flotation level of the cell was caused by contamination in the house air. A clean instrument air was connected to the Clarkson valve to avoid reoccurrence of that problem.

A series of twenty-three tests were conducted varying in time from thirty minutes to 14 hours. the column concentrate grades averaged over 13,400 btu/pound; ash in the concentrate was 8.2%; total sulfur rejection was 56% pyritic sulfur rejection was 75%, ash rejection was 92% and Btu recovery was over 82%. A plant test using the sub-a flotation machines yielded 12,700 Btu/pound with 11.7% ash, total sulfur rejection of 51%, ash rejection of 92% and a Btu recovery of 79%.

The significant differences in operation between column tests and the plant were the following: 1) more reagent per ton was used in the column tests than was used in the sub-a operation; 2) more connected horsepower per ton of feed is required in the sub-a machines than for the column; 3) the retention time in the sub-a machine is 2.7 minutes while the retention time in the column varied between 10.7 and 16.5 minutes depending upon feed rate.

One of the features of column flotation is that of froth washing. A spray of water is directed upon the rising froth causing the pyrite and ash minerals which are mechanically attached to the bubbles to be washed off resulting in a cleaner concentrate; this is at a sacrifice of several percent recovery of coal.

The results of this exploratory testing program are summarized as
follows: 1) the column provided equal or better froth concentrate quality and recovery than the sub-a flotation machines on similar coal slurry feeds; 2) the column was easily adjusted to accommodate for changes in grade in the feed or for feeds from different seams; thus, the column would be expected to operate well within a broad range of feed that may be common in a plant.

The cooperation between the Kerr-McGee hosts the Deister and ISGS visitors was key to the success of this project. This cooperation resulted in a highly productive, and professional successful testing program. Now that the column is set up and operating efficiently, additional reagents should be tested.
PROJECT DESCRIPTION

Background

During the 1989-1990 contract year, a project entitled "Column vs. Sub-Aeration Cells for the flotation of Fine Coal from Plant Waste" was completed. A number of goals were achieved by batch flotation in the sub-a laboratory machines, the 40 lb/hour continuous flow unit, also a sub-a machine and with a 10 lb/hour 3" diameter Deister Flotaire column flotation cell.

The tests showed that similar products could be made by each flotation system and that concentrates over 13,000 Btu/lb were normal, ash content near 8.0% was made in a number of tests while rejecting over 90% of the ash and pyritic sulfur rejection was near 70% on tests with good Btu recovery.

The tests were made from a sample of 48 drums of plant waste (plant flotation feed) which was nearly a year old at the time the last tests on were completed. It was felt that it would be advisable to conduct tests on identical fresh material so that effect of aging, if any, would be the same on both the column and the sub-a flotation machines.

Goals and Objectives

The objective of this project was to compare results from a small commercially sized Deister Flotaire column flotation cell with the sub-aeration cells at Kerr-McGee's Galatia plant during side by side testing of feed splits from the same sources. Typical cell criteria for both cells are included in the appendix. The project involved the activities of three organizations: the Kerr-McGee Coal Corporation, the Deister Concentrator Company, and the Illinois State Geological Survey. Their roles were as follows: Kerr-McGee installed the Deister column with sample splitter and tailings volume measuring cell in the Galatia Coal Preparation Plant to treat a representative split of their flotation feed; Deister provided a 30" diameter x 35' high Deister Flotaire Column Flotation Cell capable of treating nominally one ton per hour or slightly over 1% of the plant feed. Deister additionally provided the sample splitter and the tailings volume measuring cell. ISGS personnel worked with both companies on the installation, conducted laboratory tests to direct the early plant test reagent practice, attended all of the plant runs cutting representative samples of feed, measuring slurry and reagent flows, preparing samples and writing reports.

EXPERIMENTAL PROCEDURES

Early in the contract year a meeting was held at Kerr-McGee's coal preparation pant near Galatia, Illinois. Deister, Kerr-McGee, and ISGS personnel agreed on the scope of the contract, what size column would be applicable where it would be located within the plant and how the individual products would be sampled and measured.
Deister designed an effective sample splitter from which variable amounts of slurry from their "A" bank of cyclones could be diverted into the column, and a tailings tank with a quick-opening valve for volume measurement. They delivered this equipment along with the 30" diameter x 35' high column, control panel, and provided their latest version of bubble generators.

Kerr-McGee erected the column, set the splitter and tailings tank, made all of the connectors of slurry, water, air, and power to run the unit from the control panel adjacent the flotation cell on the plant flotation floor and provided easily accessible sampling stations for feed, concentrate and tailing. Deister provided technical assistance during installation. Mr. John Amos, Vice President of Deister was present during installation and start-up. ISGS was represented during the planning, erection, start-up and operation of the test program.

Several weeks were spent running familiarization tests so that the testing personnel felt adept in monitoring feed rate, reagent rates, froth flow, wash water flow and froth removal techniques. The control panel which controls froth depth, air and water rates to the bubble generators, and the Clarkson valve which maintains cell volume with respect to desired froth height was also built and tested.

A series of small start-up problems were discovered and resolved with the three principles working together. When the actual testing program began we were able to run several tests per day varying feed rate, collector rate, frother type and quantity and froth column height.

Delays were encountered between tests; as the rule of thumb of 10 volume changes was considered the standard to reach equilibrium. With a cell volume of 1285 gallons and feed rates varying from 78 gpm to 120 gpm this meant equilibrium times of 164 minutes to 107 minutes between tests. When only froth column height was being changed (no feed rate, nor reagent rates) these times were reduced to about 5 volume changes.

Tests were conducted on slurries from coals from the No. 5 and No. 6 seams, with varying amounts of fuel oil collector, and with varying amounts and types of frothers as well as varying rates of product feed. The frothers investigated were MIBC, 2 ethylhexanol, Nalco 9847 (which is being used in the plant). Betz M-150, Dow froth 1263, and Ore prep No. 507, all of which were provided by their manufacturers. As each test was completed the samples of feed, concentrate, and tailings were filtered and dried in Kerr-McGee's Galatia laboratory.

Some of the products were analyzed at Galatia, but most were returned to ISGS Minerals Engineering Laboratory. This was done since ISGS routinely runs varieties of sulfur while Kerr-McGee's analyses are concerned with total sulfur only for their shipping specification.
RESULTS AND DISCUSSION

Twenty three plant tests were run on the Deister column 3 not reported as they were exploratory, 14 on No. 6 seam coal, and 6 on No. 5 seam coal. Table 1 summarizes the results and test sheets. Nos 4 through 23 inclusive and a similar test sheet showing an extended plant test on No. 6 coal are included in the appendix.

Wash water

The Deister column is designed to have small spray of wash water running countercurrent to the froth; that is, it sprays on the top of the froth, washing away the pyrite and ash minerals which are mechanically attached to the bubble, but not really bonded to the bubble as the coal particles. Tests 5 and 6 were conducted without spray water, the ash content and pyrite grades and recoveries were noticeably higher than in those tests in which the spray water was included. It is worthy of note that the Btu recoveries were also higher.

Froth height

It would be expected that the deeper froth column would give a higher grade concentrate at a sacrifice of recovery. Averages of the tests run on No. 6 seam show grade and recovery flow froth height (12") to high froth height (16-18") as 13309 and 80.0 with 13295 and 80.5 respectively, or virtually no difference. Additional testing with lower reagent rates might clarify these comparisons.

Reagent rate

The first tests utilized low reagent rates as the plant uses in their sub-a cells. The grades were excellent, but recoveries were very low. It is believed that additional collector is required in a column because of its relatively quiescent condition as compared to a sub-a machine in which the slurry and reagent are mixed four times in a 4-cell machine. High collector loading was used in subsequent tests with excellent results. The collector was not optimized during this series of tests nor was the frother rate.

Frother selection

Each of the frothers examined in these tests, MIBC, 2-ethylhexanol, Nalco 9847, Betz M-150, Dow froth 1263, and Ore Prep 507 all provided an acceptable froth. They were not quantified against a preferred collection amount because of lack of time to complete this type of work in the time frame allowed.

Feed rate

The column has a nominal feed rate of 1 ton of dry solids per hour, and an auxiliary feed rate of 100 gallons per minute. With 3.4% solids and a nominal specific gravity of 1.6 for the solids going to flotation 1
ton of dry solids is equal to 116 gallons per minute. Most of the tests took the more conservative approach of less than 100 gpm although several tests were conducted at 1.04 tph. No significant observation was made at either extreme.

Froth rate

Taking the work from one of the laboratory tests in 1989-90, a low feed rate column test (test 7). A high feed rate column test (test 23) and a plant test of some hours duration, we developed the following table comparing froth rate and grades. It should be noted that each test was conducted under different feed conditions but the pounds of concentrate per square feet of flotation surface per hour is quite close.

<table>
<thead>
<tr>
<th>Method</th>
<th>Chemical Analyses</th>
<th>Feed</th>
<th>Concentrate</th>
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<tr>
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<td>TPH feed</td>
<td>Ash</td>
<td>T/S</td>
</tr>
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</tr>
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<td>0.67</td>
<td>8.1</td>
<td>2.25</td>
</tr>
<tr>
<td>Deister 30&quot; column high feed</td>
<td>1.04</td>
<td>9.7</td>
<td>1.92</td>
</tr>
<tr>
<td>Denver 4x500 cuft cells</td>
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<td>Coal Seam</td>
<td>Feed Analyses</td>
<td>Conct Analyses</td>
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<td>-----------</td>
<td>---------------</td>
<td>----------------</td>
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<td></td>
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Cooperation

This project included teams from Kerr-McGee, from Deister, and for ISGS. The hospitality and cooperation shown by the Kerr-McGee operating personnel, both management and hourly was outstanding. We were working in an area where their daily production standard was of great importance yet, this project was aided in more ways than can be acknowledged to get the job done. Particular support was given by Mr. Dale W. Norris, Plant Manager, Mr. Robert M. Sterner, Operations Manager, and Mr. Charles M. Dietzel, Maintenance Manager all at Galatia, and Mr. Renan O. Jauregui, Staff Engineer with Kerr-McGee in Oklahoma City for his encouragement and support.

The Deister Concentrator Company was represented by Mr. John D. Stephenson and Mr. Donald Zipperian during planning and Mr. John Amos and Mr. Zipperian during testing. Their skills in resolving small, but important problems helped make the project a success.

The ISGS was represented by Henry Ehrlinger and David Rapp during testing in Galatia and by John M. Lytle, Lawrence Kohlenberger and the Analytical Section in Champaign.

CONCLUSIONS

After working with the Deister Flotaire column cell for most of several months it has been determined that column flotation is a technology worthy of consideration for installation in coal plants of the recovery of coal and the rejection of ash and pyrite.

This test work did not optimize collector quantity nor frother type and quantity, but the average of the series of tests completed yielded higher grades, better recoveries and improved rejection of sulfur and ash than the Sub-A flotation machine treating the same slurry. Higher reagent consumption and lower power consumption were noted using the column.

Suggested Additional Work

Items which were not optimized during this test program were 1) feed rate-frother rate-collector rate on both No. 5 and No. 6 coals, 2) effect of surfactants and dispersents, and combining these to provide the best conditions for the machines.
# ISGS Coal Plant Test Data Sheet

**Test No.** 4  
**Date:** 6/7/91

| Product     | %Wt | Ash | T/S | P/S | O/S | Btu | %SO₂ | MMBTU | Ash | T/S | P/S | O/S | Btu |
|-------------|-----|-----|-----|-----|-----|-----|------|-------|-----|-----|-----|-----|-----|-----|
| Feed        | 100.0 | 52.2 | 2.02 | 1.31 | 0.71 | 6424 | 6.29 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Concentrate | 41.13 | 8.3  | 2.19 | 0.83 | 1.36 | 13420 | 3.26 | 6.5   | 44.6 | 26.1 | 78.5 | 85.9 |
| Tailing     | 58.87 | 82.8 | 1.90 | 1.64 | 0.26 | 1536 | 93.5 | 55.4  | 73.9 | 21.5 | 14.1  |

**Conditions:**

- **Collector:** No. 2 fuel oil, 3.02 #/ton
- **Wash Water:** Yes
- **Frother:** MIBC, 1.59 #/ton
- **Froth Push:** Yes (5)
- **Froth Depth:** 12"
- **Upper Air:** 14 cfm
- **Feed Rate:** 0.67 tph
- **Lower Air:** 9 cfm
- **Feed Rate:** 78.28 gpm
- **Upper Water:** 2.5 gpm
- **Tailings Rate:** 83.87 gpm
- **Lower Water:** 2.0 gpm
- **Coal Seam:** IL No. 6
ISGS COAL PLANT TEST DATA SHEET

TEST NO. 5  
DATE: 6/7/91

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<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO₂</th>
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<td>T/S</td>
<td>P/S</td>
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<td>Feed</td>
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<td>1.17</td>
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</table>

Conditions:

Collector: No. 2 Fuel Oil, 3.02 #/ton  
Frother: MIBC, 1.59 #/ton  
Upper Air: 14 cfm  
Lower Air: 8 cfm  
Upper Water: 2.7 gpm  
Lower Water: 2.3 gpm  
Wash Water: off  
Froth Push: yes (5)  
Froth Depth: 12 "  
Feed Rate: 0.67 tph  
Feed Rate: 78.28 gpm  
Tailings Rate: 76.25 gpm  
Coal Seam: Ill. No. 6
### ISGS Coal Plant Test Data Sheet

**Test No.**: 6  
**Date**: 6/7/91

| Product | %Wt  | Ash | T/S | P/S | O/S | Btu | #SO₂, NMMBTU | Ash | T/S | P/S | O/S | Btu |
|---------|------|-----|-----|-----|-----|-----|--------------|-----|-----|-----|-----|-----|-----|
| Feed    | 100.0| 51.4| 1.89| 1.21| 0.68| 6527| 5.79         | 100.0| 100.0| 100.0| 100.0| 100.0|
| Conc    | 46.31| 12.5| 2.13| 0.83| 1.30| 12719| 3.35         | 11.3 | 52.1 | 31.9 | 87.5 | 90.2 |
| Tailing | 53.69| 85.0| 1.69| 1.53| 0.16| 1186| 88.7         | 47.9 | 68.1 | 12.5 | 9.8  | "   |

**Conditions:**

- **Collector**: No. 2 Fuel Oil, 3.02 #/ton
- **Wash Water**: off
- **Frother**: MIBC, 1.59 #/ton
- **Froth Push**: on (5)
- **Froth Depth**: 17 "
- **Upper Air**: 14 cfm
- **Feed Rate**: 0.67 tph
- **Lower Air**: 8 cfm
- **Feed Rate**: 78.28 gpm
- **Upper Water**: 2.5 gpm
- **Tailings Rate**: 76.25 gpm
- **Lower Water**: 2.2 gpm
- **Coal Seam**: IL No. 6
ISGS COAL PLANT TEST DATA SHEET

TEST NO. 7
DATE: 6/7/91

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<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
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<tr>
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Conditions:

Collector | No. 2 Fuel Oil, 3.02 #/ton
Frother    | MIBC, 1.59 #/ton
Other      | __________________, _________ #/ton
Upper Air  | 15 cfm
Lower Air  | 9 cfm
Upper Water| 2.3 gpm
Lower Water| 2.0 gpm

Wash Water  | on
Froth Push | yes (5)
Froth Depth| 16 "
Feed Rate  | 0.67 tph
Feed Rate  | 78.28 gpm
Tailings Rate| 83.87 gpm
Coal Seam  | IL No. 6
# ISGS Coal Plant Test Data Sheet

**TEST NO.:** 8  
**DATE:** 6/11/91

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<th>Product</th>
<th>%Wt</th>
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<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
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<td>57.0</td>
<td>49.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector**: No. 2 Fuel Oil, 2.77 #/ton*
- **Frother**: 2 ethyl hexanol, 1.36 #/ton
- **Other**: __________, __________ #/ton
- **Upper Air**: 10 cfm
- **Lower Air**: 15 cfm
- **Upper Water**: 2.0 gpm
- **Lower Water**: 3.0 gpm
- **Wash Water**: __________ on __________
- **Froth Push**: yes (5)
- **Froth Depth**: 12 "
- **Feed Rate**: 0.73 tph
- **Feed Rate**: 85.09 gpm
- **Tailings Rate**: 90.32 gpm
- **Coal Seam**: IL No. 6

*Collector off part of test
ISGS COAL PLANT TEST DATA SHEET

TEST NO. 9  
DATE: 6/12/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO₂, MMBTU</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100.0</td>
<td>46.5</td>
<td>1.78</td>
<td>0.95</td>
</tr>
<tr>
<td>Conc</td>
<td>43.17</td>
<td>6.7</td>
<td>1.89</td>
<td>0.49</td>
</tr>
<tr>
<td>Tailing</td>
<td>56.83</td>
<td>76.7</td>
<td>1.70</td>
<td>1.30</td>
</tr>
</tbody>
</table>

Conditions:

- Collector: No. 2 Fuel Oil, 2.68 #/ton
- Frother: 2-ethyl hexanol, 1.13 #/ton
- Other: 
- Upper Air: 10 cfm
- Lower Air: 15 cfm
- Upper Water: 2.25 gpm
- Lower Water: 2.75 gpm
- Wash Water: on
- Froth Push: yes (5)
- Froth Depth: 12 "
- Feed Rate: 0.67 tph
- Feed Rate: 78.28 gpm
- Tailings Rate: 87.63 gpm
- Coal Seam: IL No. 6
# ISGS Coal Plant Test Data Sheet

**Test No.:** 10  
**Date:** 6/12/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>MMBTU</th>
<th>#SO&lt;sub&gt;2&lt;/sub&gt;</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
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<td>0.84</td>
<td>7779</td>
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<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td></td>
</tr>
<tr>
<td>Conct</td>
<td>46.09</td>
<td>6.8</td>
<td>1.76</td>
<td>0.38</td>
<td>1.38</td>
<td>13185</td>
<td>2.67</td>
<td>7.4</td>
<td>45.0</td>
<td>18.3</td>
<td>75.2</td>
<td>78.1</td>
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</tr>
<tr>
<td>Tailing</td>
<td>53.91</td>
<td>73.1</td>
<td>1.84</td>
<td>1.45</td>
<td>0.39</td>
<td>3157</td>
<td>92.6</td>
<td>55.0</td>
<td>81.7</td>
<td>24.8</td>
<td>21.9</td>
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</table>

**Conditions:**

<table>
<thead>
<tr>
<th>Collectors</th>
<th>No. 2 Fuel Oil, 3.02 #/ton</th>
<th>Frother</th>
<th>2 ethyl hexanol, 1.23 #/ton</th>
<th>Other</th>
<th>Wash Water</th>
<th>yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Froth Push</td>
<td>On (5)</td>
<td>Froth Depth</td>
<td>18 ''</td>
<td>Feed Rate</td>
<td>0.67</td>
<td>tph</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>78.28 gpm</td>
<td>Tailings Rate</td>
<td>86.34 gpm</td>
<td>Coal Seam</td>
<td>IL No. 6</td>
<td></td>
</tr>
<tr>
<td>Lower Water</td>
<td>2.4 gpm</td>
<td>Lower Water</td>
<td>2.8 gpm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Air</td>
<td>9 cfm</td>
<td>Upper Air</td>
<td>15 cfm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Water</td>
<td>2.4 gpm</td>
<td>Upper Water</td>
<td>2.4 gpm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# ISGS Coal Plant Test Data Sheet

**TEST NO.:** 11  
**DATE:** 6/12/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash</td>
<td>T/S</td>
</tr>
<tr>
<td>Feed</td>
<td>100.0</td>
<td>48.6</td>
<td>1.82</td>
</tr>
<tr>
<td>Conct</td>
<td>37.66</td>
<td>7.0</td>
<td>1.85</td>
</tr>
<tr>
<td>Tailing</td>
<td>62.34</td>
<td>73.8</td>
<td>1.80</td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector**  No. 2 Fuel Oil, 2.68 #/ton  
- **Frother**  Nalco 9847, 1.59 #/ton  
- **Other**  
- **Upper Air**  10 cfm  
- **Lower Air**  15 cfm  
- **Upper Water**  2.0 gpm  
- **Lower Water**  2.6 gpm  
- **Wash Water** on  
- **Froth Push** yes (5)  
- **Froth Depth** 12 "  
- **Feed Rate**  0.67 tph  
- **Feed Rate**  78.28 gpm  
- **Tailings Rate**  83.87 gpm  
- **Coal Seam**  IL No. 6
<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100.0</td>
<td>40.6</td>
<td>1.79</td>
<td>0.90</td>
<td>0.89</td>
<td>8312</td>
<td>4.31</td>
<td>100.0</td>
</tr>
<tr>
<td>Conct</td>
<td>45.43</td>
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<td>0.39</td>
<td>1.37</td>
<td>13808</td>
<td>2.55</td>
<td>7.2</td>
</tr>
<tr>
<td>Tailing</td>
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<td>69.0</td>
<td>1.82</td>
<td>1.32</td>
<td>0.50</td>
<td>3736</td>
<td>92.8</td>
<td>55.4</td>
</tr>
</tbody>
</table>

**Conditions:**

- Collector: No. 2 Fuel Oil, 2.51 lb/ton
- Frother: Nalco 9847, 1.59 lb/ton
- Other: 
- Wash Water: on
- Froth Push: yes (5)
- Froth Depth: 18
- Upper Air: 10 cfm
- Lower Air: 15 cfm
- Upper Water: 2.2 gpm
- Lower Water: 2.6 gpm
- Feed Rate: 0.67 tph
- Feed Rate: 78.28 gpm
- Tailings Rate: 83.87 gpm
- Coal Seam: IL No. 6
## ISGS Coal Plant Test Data Sheet

**TEST NO.** 13  
**DATE:** 6/18/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>%SO₂</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100.0</td>
<td>31.0</td>
<td>1.18</td>
<td>0.73</td>
<td>0.45</td>
<td>9874</td>
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<td>Conct</td>
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<td>1.05</td>
<td>0.46</td>
<td>0.59</td>
<td>13698</td>
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<td>53.1</td>
</tr>
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<td>Tailing</td>
<td>40.38</td>
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<td>1.14</td>
<td>0.23</td>
<td>4227</td>
<td>85.6</td>
<td>46.9</td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector**: No. 2 Fuel Oil, 2.35 #/ton  
- **Frother**: Betz M-150, 0.92 #/ton  
- **Other**:  
- **Upper Air**: 9 cfm  
- **Lower Air**: 15 cfm  
- **Upper Water**: 2.0 gpm  
- **Lower Water**: 3.0 gpm  
- **Wash Water**: on  
- **Froth Push**: yes (5)  
- **Froth Depth**: 12 "  
- **Feed Rate**: 0.78 tph  
- **Feed Rate**: 90.32 gpm  
- **Tailings Rate**: 106.75 gpm  
- **Coal Seam**: IL No. 5
<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
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<td>31.2</td>
<td>1.23</td>
<td>0.76</td>
<td>0.47</td>
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<tr>
<td>Conct</td>
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<td>1.06</td>
<td>0.45</td>
<td>0.61</td>
<td>13852</td>
<td>1.53</td>
<td>11.0</td>
<td>48.4</td>
<td>33.4</td>
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<td>80.0</td>
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<td>Tailing</td>
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<td>63.5</td>
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<td>66.6</td>
<td>27.6</td>
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</tr>
</tbody>
</table>

Conditions:

- Collector: No. 2 Fuel Oil, 2.59 #/ton
- Wash Water: on
- Frother: Betz M-150, 0.92 #/ton
- Froth Push: yes (5)
- Froth Depth: 12 "
- Upper Air: 9 cfm
- Feed Rate: 0.78 tph
- Lower Air: 15 cfm
- Feed Rate: 90.32 gpm
- Upper Water: 2.0 gpm
- Tailings Rate: 112.91 gpm
- Lower Water: 3.0 gpm
- Coal Seam: IL No. 5
**ISGS COAL PLANT TEST DATA SHEET**

**TEST NO.** 15  
**DATE:** 6/18/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO, MMBTU</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash</td>
<td>T/S</td>
<td>P/S</td>
</tr>
<tr>
<td>Feed</td>
<td>100.00</td>
<td>31.9</td>
<td>1.10</td>
<td>0.64</td>
</tr>
<tr>
<td>Conct</td>
<td>59.34</td>
<td>6.1</td>
<td>1.10</td>
<td>0.48</td>
</tr>
<tr>
<td>Tailing</td>
<td>40.66</td>
<td>69.5</td>
<td>1.10</td>
<td>0.87</td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector** No. 2 Fuel Oil, 2.59#/ton
- **Frother** Betz M-150, 0.92#/ton
- **Other** 
- **Upper Air** 0 cfm
- **Lower Air** 15 cfm
- **Upper Water** 0 gpm
- **Lower Water** 5 gpm
- **Wash Water** on
- **Froth Push** yes (5)
- **Froth Depth** 18
- **Feed Rate** 0.78 tph
- **Feed Rate** 90.32 gpm
- **Tailings Rate** 117.42 gpm
- **Coal Seam** Il No. 5
<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
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<td>Conc</td>
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<td>0.60</td>
<td>13890</td>
<td>1.60</td>
<td>6.5</td>
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<tr>
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<td>47.5</td>
<td>1.60</td>
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<td>7023</td>
<td>93.5</td>
<td>68.8</td>
<td>77.6</td>
<td>53.5</td>
<td>43.7</td>
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<td></td>
</tr>
</tbody>
</table>

Conditions:

- Collector: No. 2 Fuel Oil, 2.30 #/ton
- Frother: Dowfroth 1263, 1.41 #/ton
- Other: ---, --- #/ton
- Upper Air: 0 cfm
- Lower Air: 15 cfm
- Upper Water: 0 gpm
- Lower Water: 5 gpm
- Wash Water: on
- Froth Push: yes (5)
- Froth Depth: 18"
- Feed Rate: 0.78 tph
- Feed Rate: 90.32 gpm
- Tailings Rate: 103.00 gpm
- Coal Seam: IL No. 5
# ISGS Coal Plant Test Data Sheet

**Test No.:** 17  
**Date:** 6/19/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO₂</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash</td>
<td>T/S</td>
<td>P/S</td>
</tr>
<tr>
<td>Feed</td>
<td>100.0</td>
<td>57.2</td>
<td>1.91</td>
<td>1.24</td>
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<tr>
<td>Coct</td>
<td>33.92</td>
<td>9.0</td>
<td>2.00</td>
<td>0.63</td>
</tr>
<tr>
<td>Tailing</td>
<td>66.08</td>
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<td>1.87</td>
<td>1.55</td>
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</tbody>
</table>

**Conditions:**

- **Collector** No. 2 Fuel Oil, 2.01 #/ton
- **Frother** Dowfroth 1263, 1.31 #/ton
- **Wash Water** on
- **Froth Push** yes (5)
- **Other**
- **Froth Depth** 12"
- **Upper Air** 9 cfm
- **Feed Rate** 0.84 tph
- **Lower Air** 14 cfm
- **Feed Rate** 97.85 gpm
- **Upper Water** 2.0 gpm
- **Tailings Rate** 112.91 gpm
- **Lower Water** 2.3 gpm
- **Coal Seam** Il No. 6
# ISGS Coal Plant Test Data Sheet

## Conditions:

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector</td>
<td>No. 2 Fuel Oil, 2.01 #/ton</td>
</tr>
<tr>
<td>Frother</td>
<td>Betz M-150, 0.85 #/ton</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Upper Air</td>
<td>8.0 cfm</td>
</tr>
<tr>
<td>Lower Air</td>
<td>15.0 cfm</td>
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<tr>
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</tr>
<tr>
<td>Lower Water</td>
<td>2.1 gpm</td>
</tr>
<tr>
<td>Wash Water</td>
<td>on</td>
</tr>
<tr>
<td>Froth Push</td>
<td>yes (5)</td>
</tr>
<tr>
<td>Froth Depth</td>
<td>12</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>0.84 tph</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>97.85 gpm</td>
</tr>
<tr>
<td>Tailings Rate</td>
<td>112.91 gpm</td>
</tr>
<tr>
<td>Coal Seam</td>
<td>Il No. 6</td>
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</tbody>
</table>
## ISGS COAL PLANT TEST DATA SHEET

**TEST NO.** 19  
**DATE:** 6/19/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO₂</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash T/S P/S O/S Btu</td>
<td>MMBTU Ash T/S P/S O/S Btu</td>
<td></td>
</tr>
<tr>
<td>Feed</td>
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</tr>
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<td>Conct</td>
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<td>6.1 40.5 20.7 78.2 84.3</td>
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</tr>
<tr>
<td>Tailing</td>
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<td>93.9 59.5 79.3 21.8 15.7</td>
<td></td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector** No. 2 Fuel Oil, 2.01#/ton
- **Frother** Ore Prep 507, 0.91#/ton
- **Other**
- **Upper Air** 9 cfm
- **Lower Air** 15 cfm
- **Upper Water** 2.0 gpm
- **Lower Water** 2.5 gpm
- **Wash Water** on
- **Froth Push** yes (5)
- **Froth Depth** 12"
- **Feed Rate** 0.84 tph
- **Feed Rate** 97.85 gpm
- **Tailings Rate** 112.91 gpm
- **Coal Seam** Il No. 6
### ISGS Coal Plant Test Data Sheet

**TEST NO.:** 20  
**DATE:** 6/19/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
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<td>2.09</td>
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<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>Conct</td>
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<td>0.78</td>
<td>1.37</td>
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<td>11.4</td>
<td>48.0</td>
<td>27.2</td>
<td>85.1</td>
<td>89.9</td>
<td></td>
</tr>
<tr>
<td>Tailing</td>
<td>53.27</td>
<td>84.6</td>
<td>2.04</td>
<td>1.83</td>
<td>0.21</td>
<td>1266</td>
<td>88.6</td>
<td>52.0</td>
<td>72.8</td>
<td>14.9</td>
<td>10.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector:** No. 2 Fuel Oil, 3.02 #/ton  
- **Frother:** Ore Prep. 507, 0.93 #/ton  
- **Wash Water:** on  
- **Froth Push:** yes (5)  
- **Froth Depth:** 12"  
- **Upper Air:** 9 cfm  
- **Lower Air:** 15 cfm  
- **Upper Water:** 2.0 gpm  
- **Lower Water:** 2.5 gpm  
- **Feed Rate:** 0.67 tph  
- **Feed Rate:** 78.28 gpm  
- **Tailings Rate:** 76.25 gpm  
- **Coal Seam:** Ill No. 6
<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100</td>
<td>34.14</td>
<td>1.22</td>
<td></td>
<td></td>
<td>8910</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conct</td>
<td>23.88</td>
<td>8.74</td>
<td>1.15</td>
<td></td>
<td></td>
<td>13409</td>
<td>6.1</td>
<td>22.5</td>
<td>35.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tailing</td>
<td>76.12</td>
<td>42.10</td>
<td>1.24</td>
<td></td>
<td></td>
<td>7499</td>
<td>93.9</td>
<td>77.5</td>
<td>64.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector**: Fuel Oil, 1.88#/ton
- **Wash Water**: on
- **Frother**: 2 ethyl hexanol, 1.28#/ton
- **Froth Push**: yes (5)
- **Other**: 
- **Froth Depth**: 14 - 16
- **Upper Air**: 11 cfm
- **Feed Rate**: 1.04 tph
- **Lower Air**: 16 cfm
- **Feed Rate**: 120 gpm
- **Upper Water**: 2 gpm
- **Tailings Rate**: 137 gpm
- **Lower Water**: 2 gpm
- **Coal Seam**: #5, high sulfur

Test 5 hours
## ISGS COAL PLANT TEST DATA SHEET

### Test No. 22
**Date:** 8/14/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Analyses</th>
<th>#SO₂</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ash</td>
<td>T/S</td>
<td>P/S</td>
</tr>
<tr>
<td>Feed</td>
<td>100.00</td>
<td>39.45</td>
<td>0.92</td>
<td></td>
</tr>
<tr>
<td>Conct</td>
<td>40.11</td>
<td>7.23</td>
<td>1.02</td>
<td></td>
</tr>
<tr>
<td>Tailing</td>
<td>59.89</td>
<td>61.04</td>
<td>0.86</td>
<td></td>
</tr>
</tbody>
</table>

### Conditions:
- Collector: Fuel Oil, 1.88 #/ton
- Frother: 2 ethyl hexanol, 1.28 #/ton
- Other: ____________, ____________ #/ton
- Wash Water: on
- Froth Push: yes (5)
- Froth Depth: 18"
- Upper Air: 14 cfm
- Lower Air: 14 cfm
- Upper Water: 2.5 gpm
- Lower Water: 2.5 gpm
- Feed Rate: 1.04 tph
- Feed Rate: 120 gpm
- Tailings Rate: 137 gpm
- Coal Seam: #5, low sulfur

Test 9 hours
### ISGS Coal Plant Test Data Sheet

**Test No.:** 23  
**Date:** 8/14-15/91

<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
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<td>60.80</td>
<td>1.45</td>
<td></td>
<td></td>
<td>5101</td>
<td>100.00</td>
<td>100.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.00</td>
</tr>
<tr>
<td>Conct</td>
<td>28.86</td>
<td>9.65</td>
<td>1.92</td>
<td></td>
<td></td>
<td>13313</td>
<td>4.6</td>
<td>38.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75.3</td>
</tr>
<tr>
<td>Tailing</td>
<td>71.14</td>
<td>81.55</td>
<td>1.26</td>
<td></td>
<td></td>
<td>1775</td>
<td>95.4</td>
<td>61.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24.7</td>
</tr>
</tbody>
</table>

**Conditions:**

- **Collector:** Fuel Oil, 1.88 #/ton
- **Frother:** 2 ethyl hexanol, 1.28 #/ton
- **Other:**
- **Wash Water:** on
- **Froth Push:** yes (5)
- **Froth Depth:** 18"
- **Upper Air:** 14 cfm
- **Lower Air:** 14 cfm
- **Upper Water:** 2.5 gpm
- **Lower Water:** 2.5 gpm
- **Feed Rate:** 1.04 tph
- **Feed Rate:** 120 gpm
- **Tailings Rate:** 137 gpm
- **Coal Seam:** #6

Test 14 hours
<table>
<thead>
<tr>
<th>Product</th>
<th>%Wt</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
<th>#SO₂</th>
<th>MMBTU</th>
<th>Ash</th>
<th>T/S</th>
<th>P/S</th>
<th>O/S</th>
<th>Btu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>100.00</td>
<td>56.48</td>
<td>2.12</td>
<td></td>
<td></td>
<td>5726</td>
<td>100.00</td>
<td>100.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.00</td>
</tr>
<tr>
<td>Conct</td>
<td>35.75</td>
<td>11.73</td>
<td>2.88</td>
<td></td>
<td></td>
<td>12695</td>
<td>7.4</td>
<td>48.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tailing</td>
<td>64.25</td>
<td>81.38</td>
<td>1.70</td>
<td></td>
<td></td>
<td>1848</td>
<td>92.6</td>
<td>20.7</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conditions:

Collector ___________, _______#/ton
Frother ___________, _______#/ton
Other ___________, _______#/ton
Wash Water ___________
Froth Push ___________ (5)
Froth Depth ___________
Upper Air ___________ cfm
Lower Air ___________ cfm
Upper Water ___________ gpm
Lower Water ___________ gpm
Feed Rate ___________ tph
Feed Rate ___________ gpm
Tailings Rate ___________ gpm
Coal Seam ___________ #6
Cell-to-Cell Sub A™ Flotation: An alternative for cleaning coal fines.

In addition to the D-R™ Flotation Machine, Denver Equipment Division also offers the Cell-to-Cell Sub-A™ Flotation Machine which we originated in 1924. It's proving to be one of the most efficient and most economical methods of cleaning coal fines. Cell-to-cell flotation lowers the ash content to acceptable levels, recovering coal that might otherwise have been wasted. Return on your capital investment is fast and positive.

Because of its high selectivity, cell-to-cell flotation is particularly well-suited for floating coal fines. Bubbles slowly raise the coal concentrate to the top of the machine while raising or lowering the weirs controls the slurry level in the cell. The coal slurry passes from cell to cell repeating the flotation process until all of the recoverable coal is floated away and the refuse is discharged to waste.

Designed for simplicity of operation, the Standard DENVER Cell-to-Cell Sub-A Machine has three principal parts — a tank, a weir gate assembly, and a suspended impeller mechanism. Each of these parts can be easily removed for maintenance.

Cell-to-Cell Sub A Mechanism.

### Large Cell-to-Cell Flotation Machines for Coal

<table>
<thead>
<tr>
<th>Size</th>
<th>Vol/Cell</th>
<th>HP/Cell</th>
<th>T.P.H.*</th>
<th>Tank Width (inside)</th>
<th>Cell Depth</th>
<th>Weight/Cell approx. shipping (lbs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>180 C-C</td>
<td>180</td>
<td>30</td>
<td>15/30</td>
<td>1.00</td>
<td>6 0&quot;</td>
<td>6 8*</td>
</tr>
<tr>
<td>300 C-C</td>
<td>300</td>
<td>40</td>
<td>25/50</td>
<td>1.60</td>
<td>7 4&quot;</td>
<td>6 0*</td>
</tr>
<tr>
<td>500 C-C</td>
<td>500</td>
<td>50</td>
<td>43/85</td>
<td>2.00</td>
<td>8 10&quot;</td>
<td>6 6&quot;</td>
</tr>
</tbody>
</table>

*These figures are based on the following assumptions:
- A 4-Cell machine
- S.G. of 1.6
- 12% Solids for Coarse Coal
- and 8% Solids for Fine Coal
- 5 minutes retention time

Denver #300 Cell-to-Cell unit in assembly.
You already know that column flotation makes good sense, improving performance in many applications. And when you use a Deister Flotaire Column Flotation Cell, you get over 10 years of R&D in column flotation. Flotaire are installed in copper, molybdenum, gold, lithium, coal, phosphate, lead, zinc, iron, mica and other minerals worldwide. The Flotaire is also patented around the world. Here are the exclusive features that make Flotaire the right choice in column flotation:

1. **Automatic Pulp Level Control**
   Basic control scheme provides automatic pulp level control at computer - or operator - maintained set point. Preassembled/panel mounted level controller, level sensor, filters, regulators and pressure gauges are provided to position a tailings valve.

2. **Sight Tube**
   Calibrated external sight tube measures internal pulp level for visual operator observance or remote readout and control. Sight tube is self cleaning and can be used for remote signal processing.

3. **Modular Construction**
   The column cell is manufactured in modular sections containing bolted flanges for precise and rapid stacking field assembly.

4. **Deister Micro Bubble Generator**
   For maximum recovery performance, at least 50% of the total aeration is provided as less than 1.0 micron (0.00004 in.) dia. air bubbles. These bubbles are generated externally and all maintenance to this system can be performed without disrupting cell operation. Optimum bubble size control requires 1 GPM of less than 50 dynes/cm. surface tension water for 4 SCFM air at 40 PSIG.