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# Damp Coal Screening—Effect of Screen Size and Coal Surface Moisture on Fines Removal Efficiency

Vanston R. Brantley    William A. Thomas



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## GLOSSARY OF TERMS

| | |
|---|---|
| Coarse material — | Particles larger than the size at which separation is desired. |
| Cut point — | Size at which separation is desired. |
| Damp yield fraction — | Weight fraction of feed reporting to the product stream of interest as measured at time of testing (before drying). |
| Fines — | Particles smaller than the size at which separation is desired. |
| Overflow — | Material which does not pass through the screen cloth, regardless of its particle size. |
| Overflow efficiency — | Percent of coarse material which reports to the screen overflow. |
| Underflow — | Material which passes through the screen cloth. |
| Underflow burden — | Ratio of total underflow to fines in the underflow. |
| Underflow efficiency — | Percent of feed fines which reports to the screen underflow. |

# DAMP COAL SCREENING — EFFECT OF SCREEN SIZE AND COAL SURFACE MOISTURE ON FINES REMOVAL EFFICIENCY

Vanston R. Brantley* William A. Thomas†

## ABSTRACT

The efficiency of fines (−28 mesh) removal over a range of screen openings and surface moistures was determined for a western Kentucky coal. Three test series were conducted, two at manufacturers' test sites and one at the Oak Ridge National Laboratory (ORNL). Wet and dry sieve analyses were performed on products from three exploratory tests at ORNL to evaluate the suitability of each method for the purposes of this investigation. While wet sieve analyses consistently produced a higher percentage of fines than did the dry sieve analyses, approximately the same screen underflow efficiency was calculated for each test with wet sieve and dry sieve data. Dry sieve analyses were therefore judged to be suitable for the screening performance evaluations.

Graphs depicting the efficiency of fines removal as a function of screen opening and surface moisture were plotted for each test series. Graphs were also prepared which show the ratio of total underflow to fines in the underflow, here called underflow burden, as a function of screen opening and surface moisture. For a given screen opening, efficiency of fines removal decreases as surface moisture increases; underflow burden generally increases as surface moisture increases. For a given surface moisture level, both fines removal efficiency and underflow burden decrease as screen opening decreases. For a fixed fines removal efficiency, underflow burden increases as surface moisture level increases due to the larger screen opening required.

## 1. INTRODUCTION

Magnetic beneficiation of coal, a process developed at the Oak Ridge National Laboratory (ORNL), has been demonstrated in laboratory and pilot plant scale experiments to be an effective means for reducing the ash and sulfur content of fine (−28 mesh) coal. Although the magnetic beneficiation can be performed either wet or dry, there are strong economic incentives for dry processing to avoid subsequent dewatering of the product and

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refuse as required in a wet process. An impediment to the widespread use of dry magnetic beneficiation is the lack of an efficient means of preparing dry fine feedstock from damp run-of-mine coal. A screen testing program was initiated to investigate the effect of screen opening size and coal surface moisture level on fine coal removal. This program was jointly developed and implemented by ORNL and the Tennessee Valley Authority (TVA), with funding provided by the Energy Demonstrations and Technology Division of TVA.

Interest in damp coal screening is not limited to dry magnetic beneficiation. In some cases, a preparation plant may produce a satisfactory product without washing the fines. In order to maximize the capital and operating cost savings of this type of operation, the fines must be economically removed from the plant feed stream and blended back with the washed coal. The results of this damp coal screening investigation, while initiated to provide design data for an unconventional dry beneficiation process, are therefore applicable to conventional wet beneficiation processes as well.

## 2. SCREEN TESTING PROCEDURE

Tests were conducted at ORNL's Screen Test Facility and at two manufacturers' test sites, Midwestern Industries in Ohio and Krebs Engineers in California. Twelve drums of coal, four of each moisture level, were shipped to each manufacturer's site, and twelve were retained at ORNL. Table 2.1 lists the size and type of openings in the screen cloths used at the three sites.

Surface moisture level is here defined as the air dry weight loss. A sample of damp coal was weighed, spread on the floor to dry, and reweighed when there was no visual difference between coal on the top and on the bottom of the 3 to 6 in. layer on the floor. Drying time varied from 16 to 72 hours depending on moisture level, ambient temperature, and relative humdity. Surface moisture was calculated thusly:

$$\text{Surface moisture (\%)} = \frac{100 \times [(\text{damp coal weight}) - (\text{dry coal weight})]}{(\text{dry coal weight})}$$

All of the ORNL tests were conducted in a single-deck mode* of operation, yielding an overflow and an underflow product for each test. Three exploratory tests were conducted using coal from the Y-12 Steam Plant coal yard; these tests were run on the 3/4-in. screen cloth. Nine tests were run using the Paradise coal, with three surface moisture level coals being run over three sizes of screen cloth. Feed and products were weighed for all twelve tests. Feed and product samples of the exploratory tests were air dried and sieved at ORNL while products of the Paradise coal tests were sent to TVA's Power Service Center (PSC) in Chattanooga for sieve analysis.

At Midwestern Industries, a five-deck screen was used for the Paradise coal screening. Overflow from each of the five decks and the underflow from the bottom deck were collected and weighed separately, thus yielding six products per test. One drum of each moisture level was screened and a portion of each product air-dried and sieved at the test

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*As opposed to multi-deck mode, where two or more screen cloths with different screen openings are stacked to effect separation at two or more sizes.

Table 2.1. Screen openings in the decks used for damp coal screen tests

| Krebs Engineers | Midwestern Industries | ORNL |
|---|---|---|
| 0.5 in. (12.7 mm) square | 1.125 in. (28.6 mm) square | 0.75 in. (19.1 mm) square |
| 0.236 in. (6 mm) wide slot | 0.5 in. (12.7 mm) wide slot | 0.313 in. (7.9 mm) square |
| 0.098 in. (2.5 mm) wide slot | 0.25 in. (6.4 mm) wide slot | 0.1 in. (2.5 mm) square |
| | 0.125 in. (3.2 mm) wide slot | |
| | 0.05 in. (1.3 mm) wide slot | |

site. Two drums of each moisture level were screened and the resultant eighteen products sent to the PSC in Chattanooga for sieve analysis.

The Krebs Engineers screen was operated in the single-deck mode, but the feed for the smallest screen opening was first scalped using the largest opening screen cloth for a scalp cut. Two drums of each moisture level were run using the largest and the intermediate size opening screen cloth, weighing the feed and the two products from each test. One drum of each moisture level was then run using the largest opening cloth, and the underflow from this operation was used as feed for the three tests with the smallest opening cloth. The twenty-one products thus obtained were shipped to ORNL for sieve analysis.

## 2.1 Screen Test Equipment

Three different screens were utilized for the test program. A Derrick model K18-120A-25DD machine was set up at ORNL. This is an inclined vibrating screen, which Derrick engineers did not recommend for this damp coal screening. However, it was available and the opportunity for first-hand experience outweighed its design deficiencies. The Derrick staff provided every assistance in the form of manuals, test data, and advice. Since the machine was not the one they would have recommended for this service, however, the test results should not be interpreted as representative of Derrick equipment performance.

For the Midwestern tests, a five-deck screen marketed as the Multi-Vib was used for testing. Each deck is curved from the feed end to the discharge end, with the discharge end having the greatest vertical slope. The five-deck arrangement was especially advantageous for this particular test program, since five screen openings could be tested simultaneously. Midwestern uses a step-down transformer to provide low-voltage high-amperage current to heat the screen cloths to minimize blinding by damp materials. Another feature which minimizes blinding is the optional use of rubber-coated steel bars beneath the screen cloth. Dubbed Harmono-Vib Deck, these bars set up a harmonic vibration which tends to keep fines knocked loose from the screen cloth. Both of these features were used for the tests with the intermediate and high surface moisture level feed coal.

Krebs Industries specializes in cyclones, but they are also the North American distributor for the Liwell screen. This is a device which uses reciprocating action to flex the inclined nonrigid polyurethane deck panels. The resultant "flip-flow" action of the screen deck makes it possible to screen materials which would blind a more conventional screen. Tests at both Midwestern and Krebs were performed with the assistance of their staff, while tests at ORNL were conducted solely by the ORNL and TVA researchers.

## 2.2 Feed Coal

Coal used for the bulk of the screening tests was recently mined Kentucky No. 9 coal from the TVA Paradise complex. Over seven tons of coal were collected at Paradise for these tests. Fifty-five gallon drums were filled and shipped to ORNL for processing. As-received surface moisture was measured, and more water was added to two-thirds of the drums so as to make three discrete surface moisture levels for testing.

These moisture levels were:

| | |
|---|---|
| Low (as-received) | 5.0% |
| Intermediate | 9.5% |
| High | 11.5%. |

Three exploratory tests were run at ORNL with Y-12 Steam Plant coal on an as-received basis. Surface moisture level for these tests was measured but no attempt was made to control the degree of moisture. Surface moisture levels for the exploratory tests were 3.6%, 6.5%, and 8.6%. Sieve analyses for the Y-12 Steam Plant coal and the Paradise Kentucky No. 9 coal appear in Tables 3.1 and 3.3, respectively.

## 3. EVALUATION OF EXPERIMENTAL DATA

Since it is not feasible for most industrial screening processes to accurately weigh total feed and products, a procedure has been developed by the screening industry for evaluating the performance of process screens using sieve data from the feed and product streams. This procedure is as follows:

1. Sieve analyses are performed on representative samples of feed and products.
2. Underflow yield is defined as the fraction of feed reporting to the underflow and is calculated:

$$Y_u = \frac{\text{feed fines (\%)} - \text{overflow fines (\%)}}{\text{underflow fines (\%)} - \text{overflow fines (\%)}} \; .$$

3. Underflow efficiency is defined as the percent feed fines reporting to the underflow and is calculated:

$$E_u = \frac{100 \times Y_u \times \text{underflow fines (\%)}}{\text{feed fines (\%)}}$$

Percent fines misplaced = 100 − $E_u$

4. Overflow efficiency is defined as the percent coarse material in the feed which reports to the overflow and is calculated:

$$E_o = \frac{100 \times (1.0 - Y_u) \times \text{overflow coarse (\%)}}{\text{feed coarse (\%)}}$$

Percent coarse misplaced = 100 − $E_o$.

When filling the drums at Paradise, efforts were made to ensure that the size consist of each drum of coal for the damp screening work was uniform. Thus a sieve analysis on one or two drums could be used as the feed size consist for all tests and the procedure outlined above could be used for screen performance calculations. However, the equipment configurations and test procedures at all three test sites permitted weighing the total overflow and underflow products. With these measured yield fractions and the size consist data from product sieve analyses, a reconstituted feed size consist was calculated for each test. All of the results on screen efficiency and misplaced material for the Paradise coal tests were derived using this reconstituted feed. Prior investigations have shown that 500 μm (~28 mesh) is a reasonable top size for feed material to a magnetic beneficiation process. Thus, 28 mesh was chosen as the point at which screening performance was evaluated.

### 3.1 Sieve Analysis Procedure

The damp screen test products were double bagged in polyethylene bags and labeled at the test site before being loaded in drums for shipment to PSC and to ORNL. Some of the test products were processed in their entirely, but most had to be reduced in bulk to produce a sample size appropriate to the available equipment and manpower. Representative samples were obtained by pouring the contents of a bag into two side-by-side containers with a back and forth motion. Some of the test products were divided in this manner two or more times, depending on the initial bulk and the top size of the material. The authors performed all of the sample division.

Samples for sieve analysis were air-dried and then sieved on a Gilson model TS-1 laboratory test screen. Screen surfaces in the trays for this machine are about 14.5 in. wide by 22.5 in. long; up to five screen trays can be stacked in the machine. Number of trays and size of screen opening were determined by the weight and top size of the sample to be sieved. A 28 mesh screen tray was always used on the bottom. Run time was typically four to five minutes for each machine loading. The −28 mesh fraction of each sample was riffled down to about 150g for sieving on a Ro Tap machine to determine the plus and minus 100 mesh fractions. Results of these analyses are reported in the appendix.

There was some concern during program plan development that dry sieve analyses would not be appropriate for this investigation. Surface moisture allows fines to either agglomerate or become cemented to larger particles during a wet/dry cycle; these fines are not easily restored to their original condition after drying. Three exploratory tests were conducted at the ORNL screen test facility to determine the advisability of performing wet sieve analyses on all screen test products. Screen opening for these tests was 0.75 in.: Y-12 Steam Plant coal was used for the feed. Samples of feed and product streams from these tests were air dried and sieved. After the dry sieving operation, each size fraction was washed over a 28 mesh screen. The washed fractions were weighed after air drying, and the difference in sample weight before and after washing was taken to be −28 mesh fines which were not properly accounted for in the dry sieve method. Table 3.1 presents the results of this work.

Table 3.1. Size consist of ORNL screen test feed and products, Y-12 steam plant coal

| Test | Sample | Cumulative weight percent retained on | | | | | | Damp yield fraction[c] |
|---|---|---|---|---|---|---|---|---|
| | | 1 1/2 in. | 3/4 in. | 1/2 in. | 1/4 in. | 28 mesh | PAN | |
| | | | | Dry Sieve Analysis | | | | |
| ST1[a] | Feed (actual) | 1.7 | 20.2 | 33.2 | 55.1 | 87.0 | 100.0 | |
| | Feed (reconstituted)[b] | 1.6 | 19.2 | 30.7 | 53.0 | 87.3 | 100.0 | |
| | Overflow | 5.5 | 64.6 | 80.0 | 90.5 | 93.6 | 100.0 | 0.2969 |
| | Underflow | | | 9.9 | 37.1 | 84.7 | 100.0 | 0.7031 |
| ST2[a] | Feed (actual) | 2.3 | 17.6 | 31.2 | 54.8 | 88.1 | 100.0 | |
| | Feed (reconstituted)[b] | 2.7 | 15.8 | 29.4 | 53.3 | 88.4 | 100.0 | |
| | Overflow | 8.3 | 48.7 | 82.6 | 94.4 | 95.8 | 100.0 | 0.3247 |
| | Underflow | | | 3.8 | 33.5 | 84.9 | 100.0 | 0.6753 |
| ST3[a] | Feed (actual) | 1.2 | 11.5 | 21.9 | 44.4 | 87.5 | 100.0 | |
| | Feed (reconstituted)[b] | 0.6 | 9.9 | 20.6 | 42.4 | 87.5 | 100.0 | |
| | Overflow | 2.5 | 39.0 | 74.2 | 92.5 | 95.9 | 100.0 | 0.2540 |
| | Underflow | | | 2.4 | 25.4 | 84.6 | 100.0 | 0.7460 |
| | | | | Wet Sieve Analysis | | | | |
| ST1[a] | Feed (actual) | 1.7 | 20.2 | 33.1 | 54.7 | 85.5 | 100.0 | |
| | Feed (reconstituted)[b] | 1.6 | 19.2 | 30.6 | 52.6 | 85.8 | 100.0 | |
| | Overflow | 5.5 | 64.6 | 79.9 | 90.3 | 93.3 | 100.0 | 0.2969 |
| | Underflow | | | 9.8 | 36.7 | 82.6 | 100.0 | 0.7031 |
| ST2[a] | Feed (actual) | 2.3 | 17.6 | 31.2 | 54.5 | 86.5 | 100.0 | |
| | Feed (reconstituted)[b] | 2.7 | 15.8 | 29.3 | 52.9 | 86.8 | 100.0 | |
| | Overflow | 8.3 | 48.7 | 82.4 | 94.0 | 95.4 | 100.0 | 0.3247 |
| | Underflow | | | 3.8 | 33.1 | 82.6 | 100.0 | 0.6753 |
| ST3[a] | Feed (actual) | 1.2 | 11.5 | 21.8 | 44.2 | 85.7 | 100.0 | |
| | Feed (reconstituted)[b] | 0.6 | 9.9 | 20.5 | 42.4 | 85.5 | 100.0 | |
| | Overflow | 2.5 | 38.8 | 73.7 | 91.8 | 95.0 | 100.0 | 0.2540 |
| | Underflow | | | 2.4 | 25.3 | 82.3 | 100.0 | 0.7460 |

[a]Difference Of −28 mesh fines in actual feed by wet sieve vs dry sieve method:
ST1 − $\Delta$ = 100 x (87.0−85.5)/(100−87.0) = 11.5%
ST2 − $\Delta$ = 100 x (88.1−86.5)/(100−88.1) = 13.4%
ST3 − $\Delta$ = 100 x (87.5−85.7)/(100−87.5) = 14.4%

[b]Reconstituted feed calculated from product sieve analyses and measured damp yield fraction.

[c]Damp yield fraction = weight fraction of feed reporting to that product stream as measured at the time of testing (before drying).

The amount of −28 mesh feed fines differed by as much as 14.4% for the wet sieve versus the dry sieve method. Using the computational procedure outlined at the beginning of Section 3, no appreciable difference in fines removal efficiency was calculated using the wet sieve data as opposed to using the dry sieve data. Efficiency of fines removal was also calculated using a reconstituted feed size consist obtained from the product sieve analyses and the damp product yield measurements. These calculations are presented in Table 3.2. The differences among the six sets of

Table 3.2. Comparison of fines (−28 mesh) removal efficiency calculations using wet and dry sieve data and two computational procedures

| Test | $EU_1^a$ (%) | $EU_2^b$ (%) | $EU_3^c$ (%) | $EU_4^d$ (%) | $EU_5^e$ (%) | $EU_6^f$ (%) |
|---|---|---|---|---|---|---|
| ST1 | 87.3 | 87.5 | 85.0 | 86.0 | 84.7 | 86.2 |
| ST2 | 89.6 | 89.6 | 88.2 | 88.7 | 87.9 | 89.0 |
| ST3 | 91.6 | 90.6 | 91.7 | 91.2 | 91.9 | 91.1 |

[a]$EU_1$: dry sieve data, actual feed size consist, computational method outlined at the beginning of Section 3.

[b]$EU_2$: wet sieve data, actual feed size consist, computational method outlined at the beginning of Section 3.

[c]$EU_3$: dry sieve data, reconstituted feed size consist, computational method outlined at the beginning of Section 3.

[d]$EU_4$: wet sieve data, reconstituted feed size consist, computational method outlined at the beginning of Section 3.

[e]$EU_5$: dry sieve data, reconstituted feed size consist, computational method –

$$EU = 100 \times \frac{\text{(underflow damp yield fraction)} \times \text{(percent fines in underflow)}}{\text{(percent fines in feed)}}$$

[f]$EU_6$: wet sieve data, reconstituted feed size consist, computational method –

$$EU = 100 \times \frac{\text{(underflow damp yield fraction)} \times \text{(percent fines in underflow)}}{\text{(percent fines in feed)}}$$

underflow efficiencies for each test are considered within the range of experimental error, so any consistent combination of sieve method and efficiency calculation was judged to be adequate for the screen performance evaluations.

Wet and dry sieve analyses were also performed on a sample of the Kentucky No. 9 coal from Paradise. These analyses are reported in Table 3.3. Percentage of −28 mesh fines was not appreciably different between the two sieve methods for this coal. From these experiments, it was concluded that dry sieve analyses were valid for the purposes of this investigation.

Table 3.3. Size consist of Paradise Kentucky No. 9 coal prepared for damp coal screen tests

| Screen size | Cumulative weight percent retained | |
|---|---|---|
| | Dry sieve method[a] | Wet sieve method[a] |
| 1-1/2 in. | 4.6 | 4.6 |
| 3/4 in. | 16.1 | 16.1 |
| 1/2 in. | 26.1 | 26.0 |
| 1/4 in. | 45.8 | 45.5 |
| 9 mesh | 69.0 | 68.4 |
| 28 mesh | 83.5 | 82.5 |
| Pan | 100.0 | 100.0 |

[a]Difference of −28 mesh fines by two methods: $\Delta = 100 \times (83.5 - 82.5)/(100-83.5) = 6.1\%$.

## 3.2 Discussion of Experimental Results

Two indices of screen performance are of major importance. One index is underflow efficiency, or the percent of feed fines correctly reporting to the screen underflow. Fines which are misplaced in the screen overflow are either lost or are sent to the wrong coal cleaning circuit where they will not be properly cleaned. Fines recovery efficiency is plotted as a function of screen opening and coal surface moisture level in Figs. 3.1, 3.2, and 3.3 for the ORNL, Krebs, and Midwestern tests respectively. A second index is the ratio of total underflow to fines in the underflow, here defined as underflow burden. This reflects the magnitude of the load placed on the secondary classification system by oversize material in the damp coal screen underflow. Underflow burden is plotted as a function of screen opening and coal surface moisture level in Figs. 3.4, 3.5, and 3.6 for the ORNL, Krebs, and Midwestern tests respectively.

Except for minor aberrations, underflow efficiency followed two basic trends for all three test series:

- Underflow efficiency decreased with increasing surface moisture for a given screen opening.
- Underflow efficiency increased with increasing screen opening for a given surface moisture.

The first of these trends is inferred to be due to the tendency of fines to agglomerate or stick to larger pieces of coal as surface moisture increases, thus making it less likely for the fine particles to fall through the screen cloth. The second of these trends is a logical consequence of a larger screen opening; more coal, and hence more fine coal, has a greater probability of falling through the screen cloth.

With the exception of the ORNL 11.5% surface moisture tests, underflow burden generally followed two basic trends for all three test series:

- Underflow burden increased with increasing surface moisture for a given screen opening.
- Underflow burden increased with increasing screen opening for a given surface moisture.

The first of these trends is linked with the first trend listed for underflow efficiency; fewer fines fall through the screen cloth as surface moisture increases. The moisture has lesser effect on the size fraction greater than 28 mesh, so roughly the same percentage of this size fraction reports to the underflow for all surface moisture levels at a given screen opening. Thus the ratio of total underflow to underflow fines increases

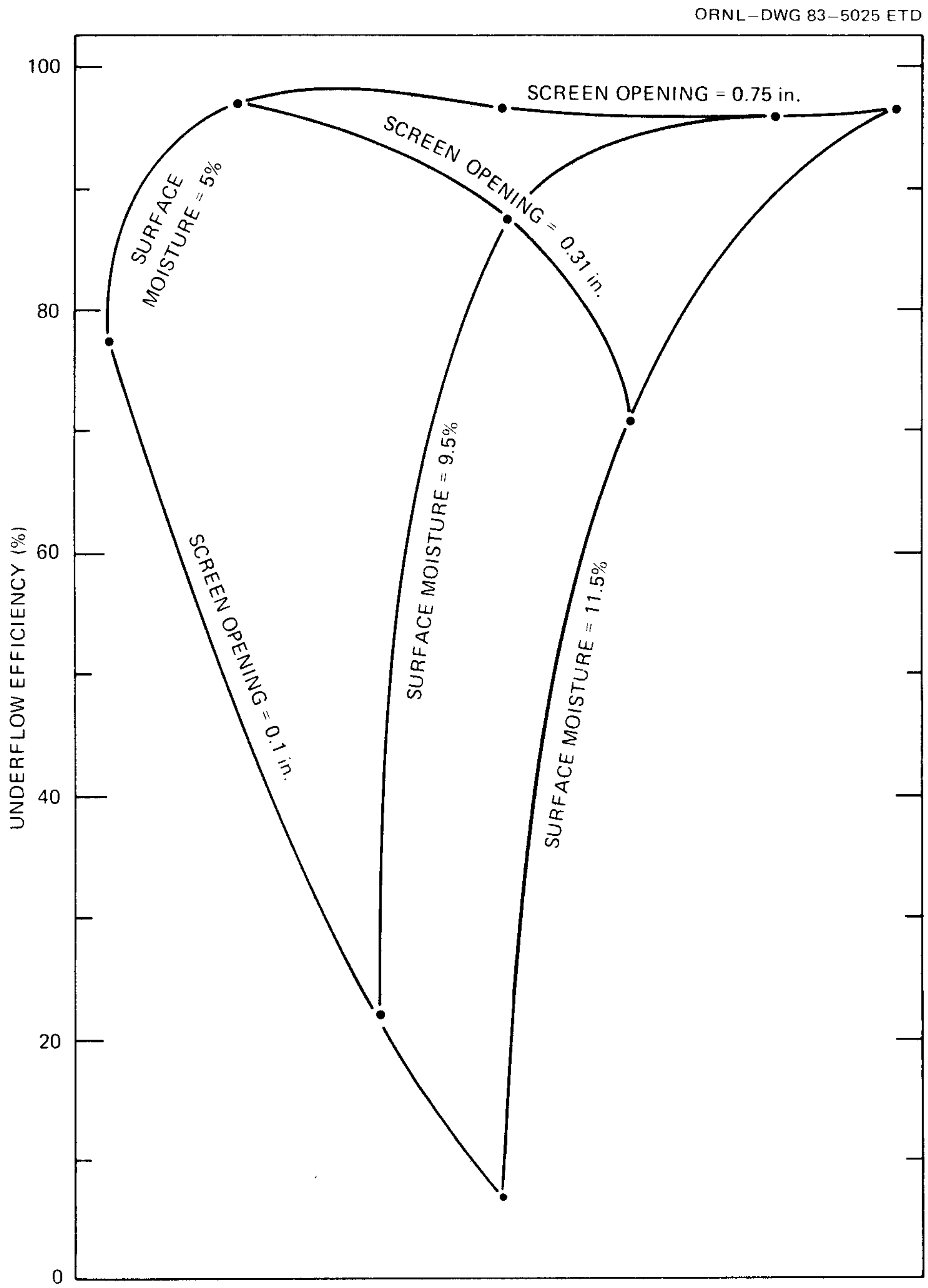


Fig. 3.1. Efficiency of fine (−28 mesh) coal removal as a function of screen opening and surface moisture for the ORNL tests.

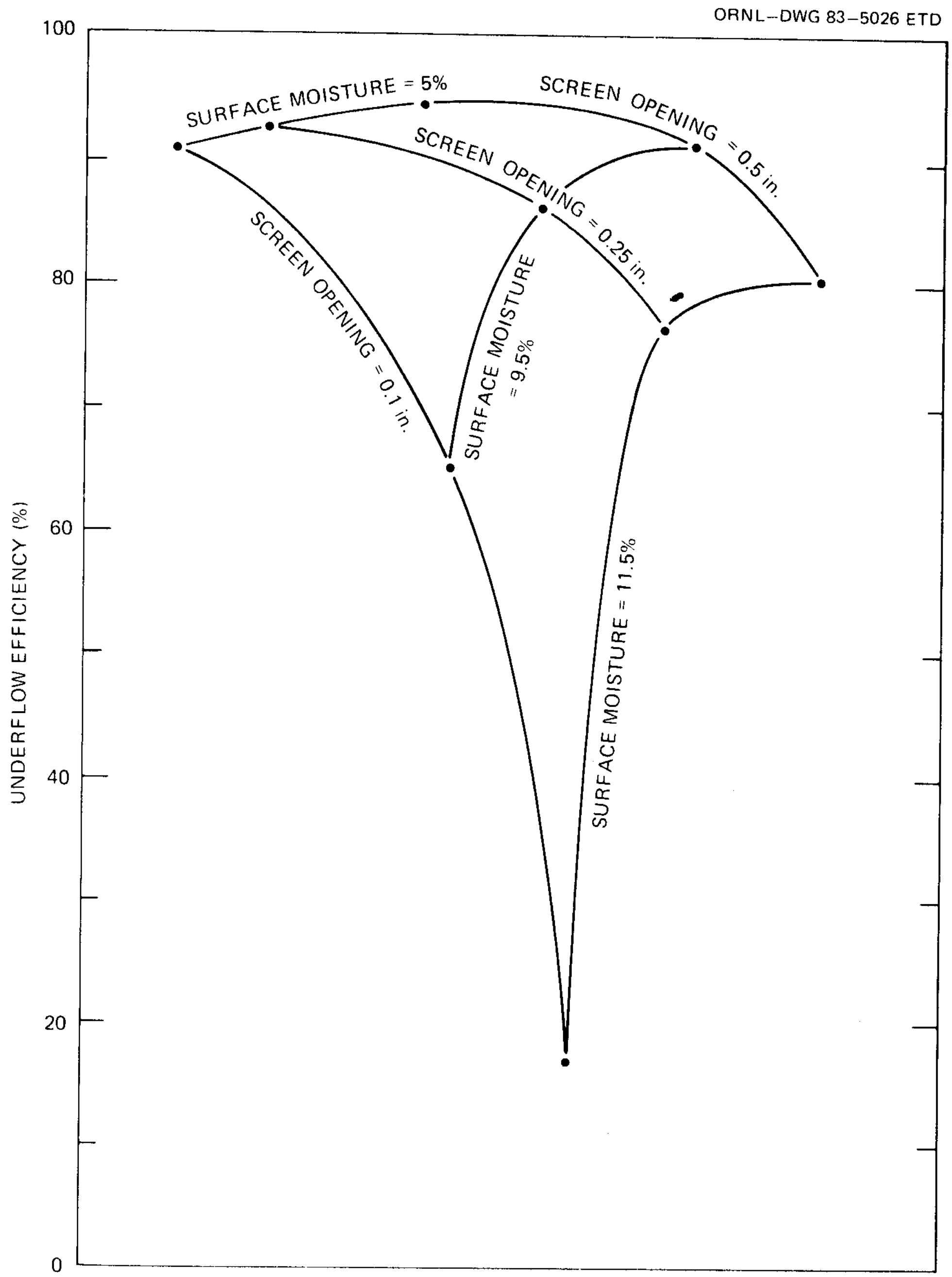


Fig. 3.2. Efficiency of fine (−28 mesh) coal removal as a function of screen opening and surface moisture for the Krebs tests.

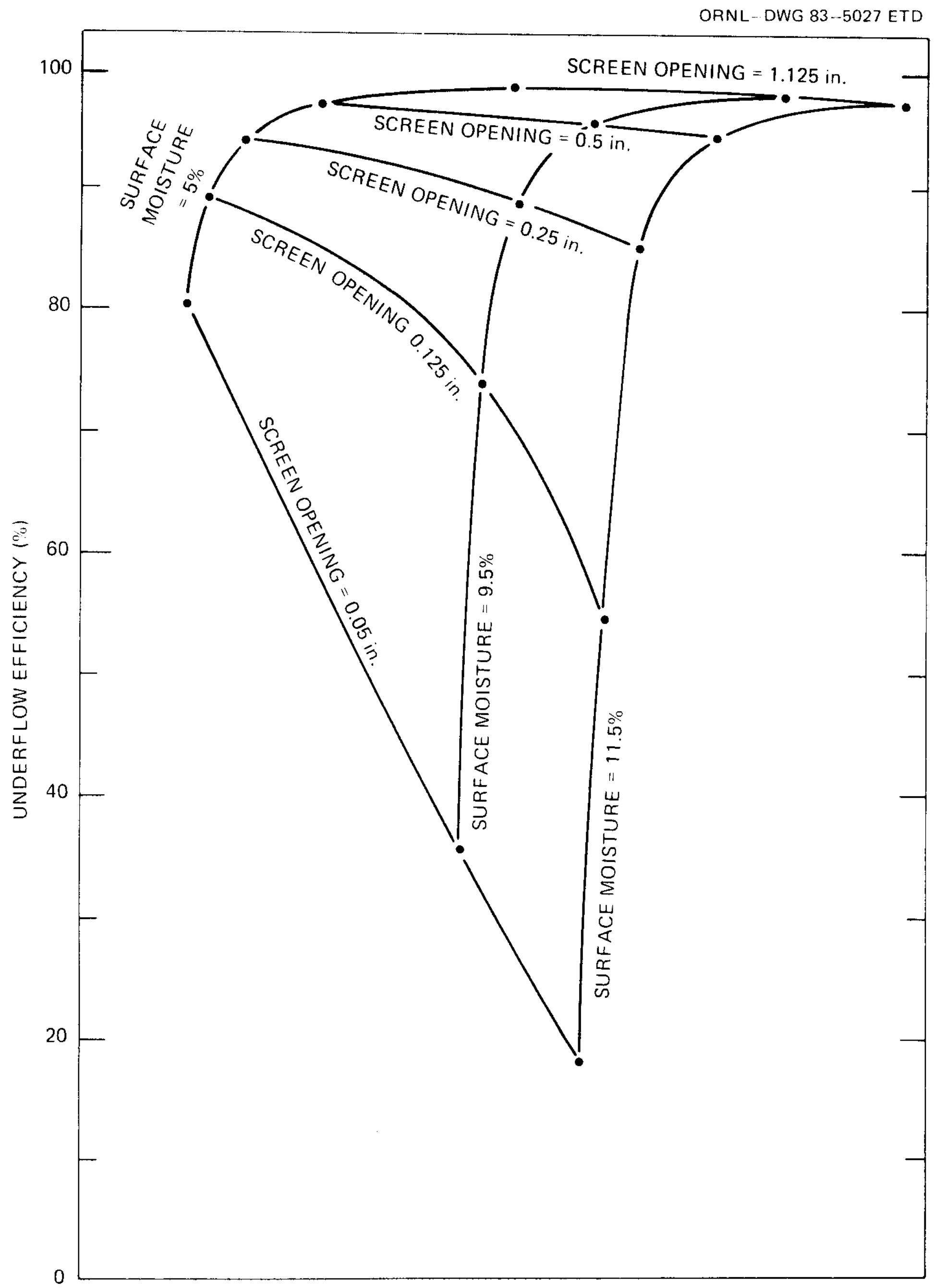


**Fig. 3.3. Efficiency of fine (−28 mesh) coal removal as a function of screen opening and surface moisture for the Midwestern tests.**

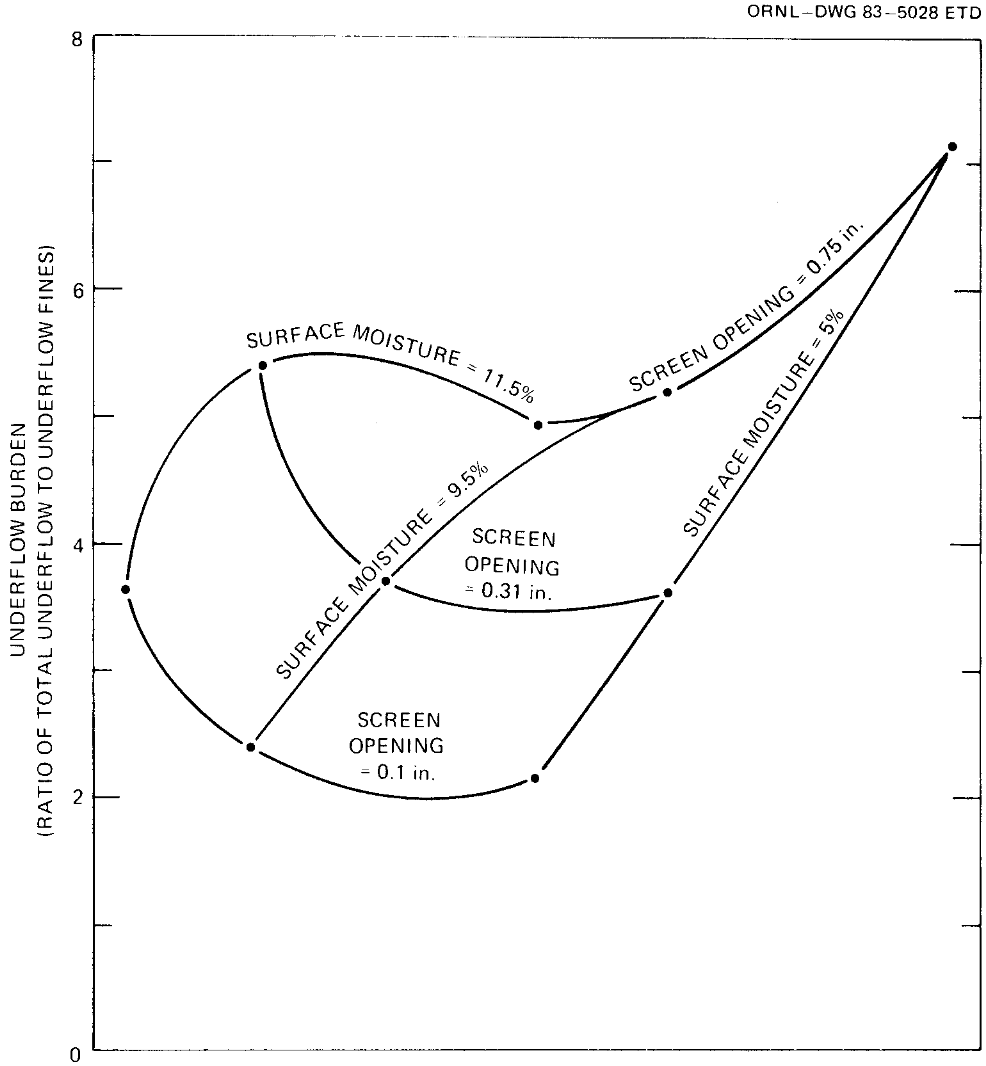


Fig. 3.4. Underflow burden as a function of screen opening and surface moisture for the ORNL tests.

as surface moisture increases. The second of these trends is again a logical consequence of a larger screen opening; more oversize particles are likely to fall through a larger opening than a smaller one.

These graphs clearly illustrate the deleterious effect of surface moisture on fines removal efficiency. Going from a moisture level of 5% to one of 11.5% at a screen opening of 0.1 in., efficiency drops from 77% to 7% for the ORNL tests, from 91% to 17% for the Krebs tests, and from 86% to 44% for the Midwestern tests. In order to achieve a high underflow efficiency at high moisture levels, larger screen openings can be used;

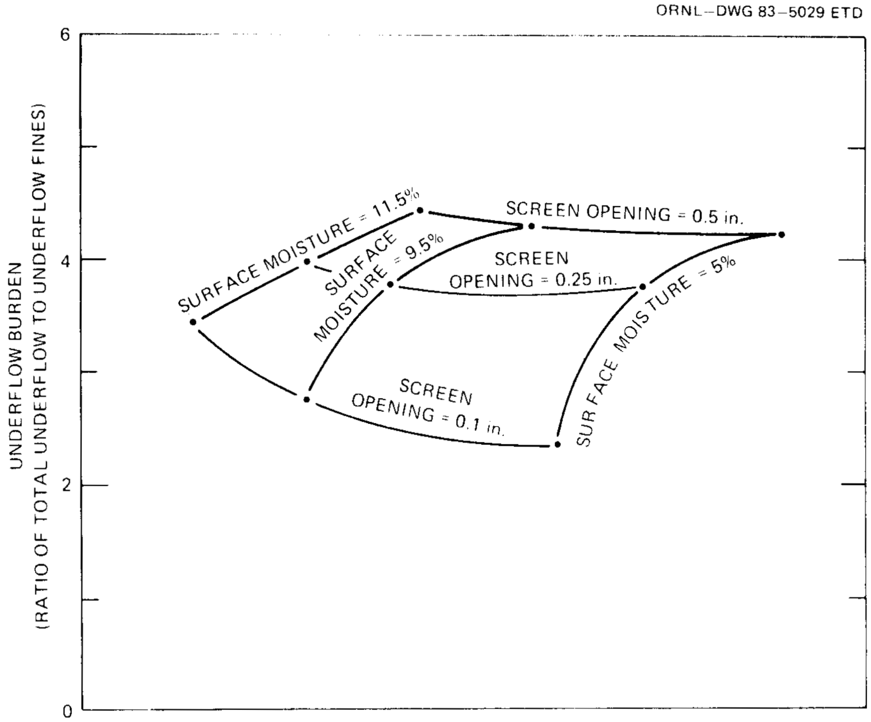


**Fig. 3.5. Underflow burden as a function of screen opening and surface moisture for the Krebs tests.**

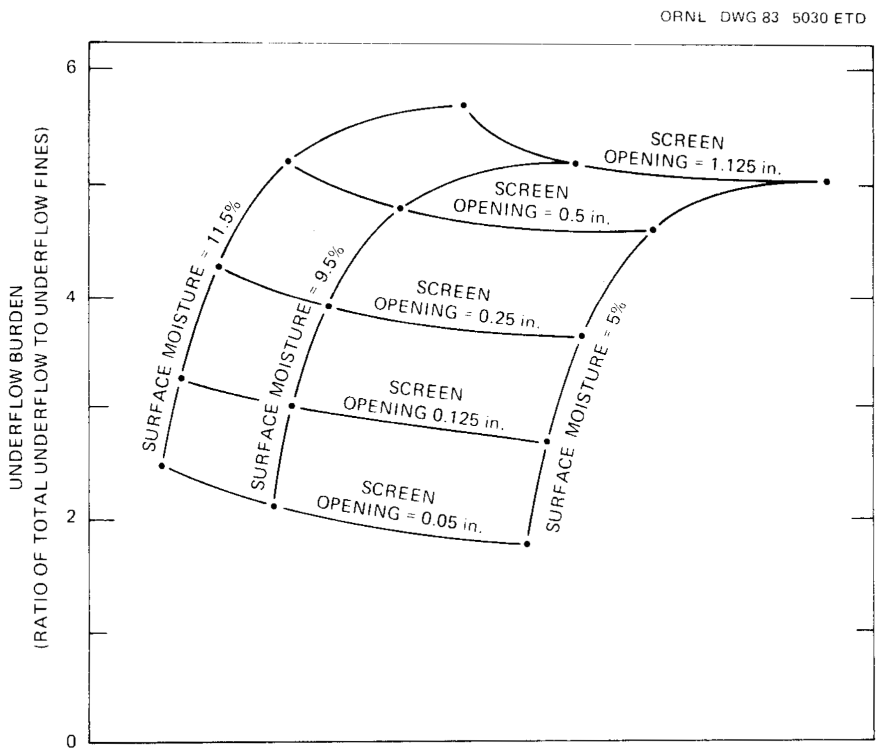


**Fig. 3.6. Underflow burden as a function of screen opening and surface moisture for the Midwestern tests.**

this action, however, will increase the underflow burden. Going from a screen opening of 0.1 in. to one of 0.5 in. at a surface moisture of 9.5% increased the underflow burden from 2.4 to 4.5 for the ORNL tests, from 2.75 to 4.3 for the Krebs tests, and from 2.8 to 4.8 for the Midwestern tests.

### 3.3 Industrial Damp Coal Screening

An industrial damp-coal screening process is in use at a Webster County Coal Company site in Clay, Kentucky. The Dotiki wash plant uses a screen/deduster combination to remove most of the minus 28 mesh fines from the plant feed. Raw coal, roughly 2 x 0 in., is fed to a Tyler double-deck inclined vibrating screen which makes a cut at approximately 1/2 in. Overflow goes to the wash plant, and underflow is fed to a modified Sturtevant air classifier which cuts the 1/2 x 0 in. stream at 28 mesh. Classifier underflow (1/2 in. x 28 mesh) goes to the wash plant, while the overflow (28 mesh x 0) bypasses the wash plant to be blended back with the cleaned coal.

Researchers from ORNL visited this plant and collected stop-belt samples from the plant feed and the screen product streams; sieve analyses were then performed on these samples at ORNL. Copies of sieve analyses performed on screen samples taken when the plant was put on line were obtained from the Dotiki staff as well; these two sets of data are presented in the appendix. Underflow efficiency and underflow burden derived from these two sets of data are given in Table 3.4, along with the feed coal surface moisture.

Referring again to Figs. 3.1 through 3.6, performance of the screening operation at Dotiki can be compared with that of the ORNL-TVA tests. With a nominal screen opening of 1/2 in. and surface moisture of roughly 2%, underflow efficiency on two different dates at Dotiki was 82% and 90%. At a screen opening of 0.5 in and surface moisture of 5%, underflow efficiencies for the ORNL, Krebs, and Midwestern tests were 98%, 95%, and 97% respectively.

A higher specific feed rate at Dotiki is the most probable explanation for this difference in underflow efficiency. For the ORNL-TVA tests,

Table 3.4. Damp coal screen performance at the Dotiki wash plant

| | SM | EU | UB |
|---|---|---|---|
| Start-up data, Oct. 12, 1979 | 1.9 | 82 | 6.25 |
| Stop-belt samples, Aug. 6, 1981 | 2.2 | 90 | 4.88 |

SM = Percent surface moisture

EU = Percent feed fines reporting to underflow

UB = Ratio of total underflow to fines in the underflow.

low specific feed rates were selected to give fine particles ample opportunity to fall through the screen. Table 3.5 presents feed rates for the ORNL-TVA tests and for the Dotiki wash plant. The screen specific feed rate at Dotiki is considerably higher than those selected for the ORNL-TVA tests, and the lesser fines removal efficiency at Dotiki is a logical consequence of this feed rate difference. Underflow efficiency could probably be increased at Dotiki by (a) reducing plant throughput or (b) installing additional screen surface. Neither of these options may be cost

Table 3.5. Specific screen feed rates for the ORNL-TVA tests and the Dotiki wash plant

| | |
|---|---|
| | <u>ORNL tests</u> |
| ST1-ST3 | feed rate = 0.752 TPH/ft$^2$ |
| ST4-ST9 | feed rate = 0.481 TPH/ft$^2$ |
| | <u>Krebs tests</u> |
| K1-K3 | feed rate = 0.832 TPH/ft$^2$ |
| K4-K6 | feed rate = 0.527 TPH/ft$^2$ |
| K7-K9 | feed rate = 0.410 TPH/ft$^2$ |
| | <u>Midwestern tests</u> |
| M2 | feed rate = 1.72 TPH/ft$^2$ |
| M4 | feed rate = 1.25 TPH/ft$^2$ |
| M5 | feed rate = 1.27 TPH/ft$^2$ |
| Dotiki wash plant | feed rate = 3.13 TPH/ft$^2$ |

effective, however, and additional information would be needed to perform a cost-benefit analysis.

The Oct. 12, 1979 Dotiki sampling produced an underflow burden of 6.25, and the Aug. 6, 1981 sampling produced an underflow burden of 4.88. At a screen opening of 0.5 in. and a surface moisture of 5%, underflow burdens for the ORNL, Krebs, and Midwestern tests were 5.05, 4.25, and 4.6 respectively. Because underflow burden is influenced by underflow efficiency, the same comments made above on increasing the underflow efficiency at Dotiki apply as well to decreasing the underflow burden.

## 4. SUMMARY AND CONCLUSIONS

This work has examined the effect of two variables, surface moisture and screen opening, on damp coal screening performance. For the Kentucky No. 9 coal, the effects of these two variables have been quantified in order to provide engineering design information previously unavailable. The results of this endeavor demonstrate the advantages of limiting the surface moisture level of feed coal to a screen:

- At a given screen opening, efficiency of fines removal decreases with increasing feed surface moisture.
- For a fixed fines removal efficiency, ratio of total underflow to fines in the underflow increases with increasing feed surface moisture.

Factors other than surface moisture level and screen opening which affect screening performance are particle size distribution, clay content, and particle shape. Performance curves published here might be used to predict the screening performance of coals with different size distributions by shifting the moisture curves proportional to the ratio of specific surface areas. This approach would be valid only if two assumptions are true:

1. Surface moisture is evenly distributed over all particles.
2. Damp coal screening properties are a function of water film thickness on the finer particles.

Greatest utility of this approximation method would be the ability to limit the range of parameter values which would have to be investigated experimentally before specifying design data for a specific application. For coals whose clay content and particle shape are significantly different from that of the Kentucky No. 9 screen test coal, such a straightforward means of extending the results of this investigation is not apparent.

# APPENDIX

Table A1. Damp coal screening – ORNL tests

| Test No. | FL | SM | SO | EO | EU | YU | UO | UB |
|---|---|---|---|---|---|---|---|---|
| ST-1 | 12.7 | 8.6 | 0.75 | 31.8 | 85.0 | 70.3 | 84.7 | 6.54 |
| ST-2 | 11.6 | 3.6 | 0.75 | 35.2 | 88.2 | 67.5 | 84.9 | 6.62 |
| ST-3 | 12.5 | 6.5 | 0.75 | 27.8 | 91.7 | 74.6 | 84.6 | 6.49 |
| ST-7 | 11.3 | 5.0 | 0.75 | 23.6 | 96.4 | 78.7 | 86.1 | 7.19 |
| ST-8 | 15.9 | 9.5 | 0.75 | 23.9 | 95.8 | 79.2 | 80.8 | 5.21 |
| ST-9 | 17.3 | 11.5 | 0.75 | 20.3 | 96.5 | 82.6 | 79.8 | 4.95 |
| ST-4 | 15.6 | 5.0 | 0.31 | 52.6 | 96.8 | 55.1 | 72.6 | 3.65 |
| ST-5 | 16.8 | 9.5 | 0.31 | 52.6 | 87.4 | 54.1 | 72.9 | 3.69 |
| ST-6 | 12.9 | 11.5 | 0.31 | 54.2 | 70.7 | 49.0 | 81.4 | 5.38 |
| ST-10 | 17.4 | 5.0 | 0.10 | 80.8 | 77.3 | 29.3 | 54.0 | 2.17 |
| ST-11 | 14.2 | 9.5 | 0.10 | 94.9 | 22.0 | 7.5 | 58.3 | 2.40 |
| ST-12 | 15.7 | 11.5 | 0.10 | 96.7 | 6.9 | 3.9 | 72.3 | 3.61 |

FL = Percent fines in feed.
SM = Percent surface moisture.
SO = Screen opening (in.).
EO = Percent feed coarse reporting to overflow = overflow efficiency.
EU = Percent feed fines reporting to underflow = underflow efficiency.
YU = Weight percent of feed reporting to underflow.
UO = Percent underflow which is oversize.
UB = Ratio of total underflow to fines in the underflow.

All screen decks with square openings.

Table A2. Damp coal screening — Krebs tests

| Test No. | FL | SM | SO | EO | EU | YU | UO | UB |
|---|---|---|---|---|---|---|---|---|
| K-1 | 16.5 | 5.0 | 0.50 | 39.3 | 94.7 | 66.3 | 76.4 | 4.24 |
| K-2 | 17.0 | 9.5 | 0.50 | 38.2 | 91.4 | 66.8 | 76.8 | 4.31 |
| K-3 | 16.4 | 11.5 | 0.50 | 45.7 | 80.5 | 58.6 | 77.5 | 4.44 |
| K-4 | 16.4 | 5.0 | 0.25 | 50.0 | 92.6 | 57.0 | 73.4 | 3.76 |
| K-5 | 17.4 | 9.5 | 0.25 | 49.4 | 86.4 | 56.8 | 73.5 | 3.77 |
| K-6 | 17.7 | 11.5 | 0.25 | 51.1 | 76.7 | 53.8 | 74.8 | 3.97 |
| K-7 | 18.3 | 5.0 | 0.10 | 72.7 | 90.8 | 38.9 | 57.4 | 2.35 |
| K-8 | 17.2 | 9.5 | 0.10 | 76.0 | 65.6 | 31.1 | 63.8 | 2.76 |
| K-9 | 17.3 | 11.5 | 0.10 | 91.4 | 16.9 | 10.0 | 70.8 | 3.42 |

FL = Percent fines in feed.
SM = Percent surface moisture.
SO = Screen opening (in.).
EO = Percent feed coarse reporting to overflow = overflow efficiency.
EU = Percent feed fines reporting to underflow = underflow efficiency.
YU = Percent total feed reporting to underflow.
UO = Percent underflow which is oversize.
UB = Ratio of total underflow to fines in the underflow.

Tests 1–3, SO = side dimension square opening.
Tests 4–9, SO = width of slotted opening.

Table A3. Damp coal screening — Midwestern tests

| Deck No. | FL | SM | SO | EO | EU | YU | UO | UB |
|---|---|---|---|---|---|---|---|---|
| 1 | 17.8 | 5.0 | 1.125 | 14.6 | 98.3 | 87.7 | 80.1 | 5.03 |
| 1 | 17.4 | 9.5 | 1.125 | 14.0 | 97.5 | 88.0 | 80.7 | 5.18 |
| 1 | 15.9 | 11.5 | 1.125 | 14.3 | 97.1 | 87.5 | 82.4 | 5.68 |
| 2 | 17.8 | 5.0 | 0.50 | 25.2 | 96.8 | 78.7 | 78.2 | 4.58 |
| 2 | 17.4 | 9.5 | 0.50 | 24.1 | 95.3 | 79.3 | 79.1 | 4.78 |
| 2 | 15.9 | 11.5 | 0.50 | 25.2 | 94.1 | 77.9 | 80.8 | 5.22 |
| 3 | 17.8 | 5.0 | 0.25 | 46.7 | 94.0 | 60.5 | 72.4 | 3.63 |
| 3 | 17.4 | 9.5 | 0.25 | 45.6 | 88.7 | 60.4 | 74.4 | 3.91 |
| 3 | 15.9 | 11.5 | 0.25 | 47.6 | 85.0 | 57.6 | 76.6 | 4.27 |
| 4 | 17.8 | 5.0 | 0.125 | 67.7 | 89.2 | 42.4 | 62.7 | 2.68 |
| 4 | 17.4 | 9.5 | 0.125 | 68.6 | 74.1 | 38.8 | 66.8 | 3.01 |
| 4 | 15.9 | 11.5 | 0.125 | 76.7 | 54.3 | 28.2 | 69.5 | 3.27 |
| 5 | 17.8 | 5.0 | 0.05 | 86.6 | 80.5 | 25.3 | 43.5 | 1.77 |
| 5 | 17.4 | 9.5 | 0.05 | 91.5 | 35.7 | 13.2 | 52.9 | 2.12 |
| 5 | 15.9 | 11.5 | 0.05 | 95.0 | 18.1 | 7.1 | 59.5 | 2.47 |

FL = Percent fines in feed.
SM = Percent surface moisture.
SO = Screen opening (in.).
EO = Percent feed coarse reporting to overflow = overflow efficiency.
EU = Percent feed fines reporting to underflow = underflow efficiency.
YU = Weight percent of feed reporting to underflow.
UO = Percent underflow which is oversize.
UB = Ratio of total underflow to fines in the underflow.

Square opening on Deck 1, SO = side length.
Slotted opening on Decks 2 through 5, SO = slot width.

Table A4. Sieve analyses for Krebs screen tests

| Sample | Cumulative weight percent retained on | | | | | | | Damp yield[a] fraction |
|---|---|---|---|---|---|---|---|---|
| | 1-1/2 in. | 3/4 in. | 1/2 in. | 1/4 in. | 9 mesh | 28 mesh | 100 mesh | |
| K1 OF | 10.1 | 43.2 | 73.4 | 95.1 | | 97.4 | 98.6 | 0.337 |
| K1 UF | | | | 19.0 | 54.3 | 76.4 | 90.0 | 0.663 |
| K2 OF | 12.3 | 43.9 | 73.0 | 93.2 | | 95.6 | 98.0 | 0.332 |
| K2 UF | | | | 18.9 | 54.3 | 76.8 | 89.3 | 0.668 |
| K3 OF | 8.4 | 37.7 | 63.1 | 86.2 | | 92.3 | 96.3 | 0.414 |
| K3 UF | | | | 17.3 | 55.9 | 77.5 | 89.5 | 0.586 |
| K4 OF | 11.3 | 37.2 | 61.4 | 94.7 | | 97.2 | 98.4 | 0.430 |
| K4 UF | | | | 8.9 | 48.3 | 73.4 | 89.0 | 0.570 |
| K5 OF | 3.2 | 31.1 | 54.7 | 91.2 | | 94.5 | 97.3 | 0.432 |
| K5 UF | | | | 7.6 | 47.8 | 73.5 | 88.0 | 0.568 |
| K6 OF | 5.7 | 26.1 | 47.3 | 83.9 | | 91.1 | 95.7 | 0.462 |
| K6 UF | | | | 5.6 | 49.2 | 74.8 | 88.3 | 0.538 |
| K7 OF1 | 5.2 | 41.1 | 76.2 | 94.9 | | 97.4 | 98.6 | 0.296 |
| K7 OF2 | | | | 42.3 | 96.1 | 97.1 | 97.7 | 0.315 |
| K7 UF | | | | | 17.5 | 57.4 | 83.7 | 0.389 |
| K8 OF1 | 11.9 | 44.3 | 73.9 | 93.0 | | 95.7 | 97.9 | 0.307 |
| K8 OF2 | | | | 34.7 | | 88.0 | 93.5 | 0.382 |
| K8 UF | | | | | 15.3 | 63.8 | 84.5 | 0.311 |
| K9 OF1 | 10.8 | 38.9 | 65.9 | 88.0 | | 92.6 | 96.4 | 0.370 |
| K9 OF2 | | | | 21.7 | | 78.1 | 89.6 | 0.530 |
| K9 UF | | | | | 16.6 | 70.8 | 86.3 | 0.100 |

[a]Damp yield fraction = weight fraction of feed reporting to that product stream as measured at the time of testing (before drying).

Table A5. Sieve analyses for Midwestern screen tests

| Sample | Cumulative weight percent retained on | | | | | Damp yield[a] fraction |
|---|---|---|---|---|---|---|
| | 1 in. | 1/2 in. | 1/4 in. | 28 mesh | 100 mesh | |
| M2-1 | 63.4 | 93.6 | 95.5 | 97.5 | 98.9 | 0.123 |
| M2-2 | | 87.6 | 95.4 | 97.2 | 98.4 | 0.090 |
| M2-3 | | 24.0 | 92.7 | 97.2 | 98.2 | 0.182 |
| M2-4 | | | 23.6 | 95.3 | 96.4 | 0.181 |
| M2-5 | | | | 91.0 | 93.7 | 0.171 |
| M2-6 | | | | 43.5 | 80.7 | 0.253 |
| M4-1 | 69.1 | 90.2 | 92.9 | 96.4 | 98.4 | 0.120 |
| M4-2 | | 86.2 | 93.4 | 95.6 | 97.9 | 0.087 |
| M4-3 | | 21.3 | 88.4 | 93.9 | 97.0 | 0.189 |
| M4-4 | | | 19.4 | 88.2 | 94.0 | 0.216 |
| M4-5 | | | | 73.9 | 87.6 | 0.256 |
| M4-6 | | | | 52.9 | 83.4 | 0.132 |
| M5-1 | 65.8 | 90.8 | 93.0 | 96.3 | 98.4 | 0.125 |
| M5-2 | | 87.4 | 92.0 | 95.1 | 97.7 | 0.096 |
| M5-3 | | 21.7 | 86.6 | 92.9 | 96.6 | 0.203 |
| M5-4 | | | 15.0 | 83.4 | 92.5 | 0.294 |
| M5-5 | | | | 72.8 | 83.5 | 0.211 |
| M5-6 | | | | 59.5 | 88.0 | 0.071 |

[a]Damp yield fraction = weight fraction of feed reporting to that product stream as measured at time of testing (before drying).

Table A6. Sieve analyses for ORNL screen tests using Y-12 Steam Plant coal

| Sample | Cumulative weight percent retained on | | | | | Damp yield[a] fraction |
|---|---|---|---|---|---|---|
| | 1-1/2 in. | 3/4 in. | 1/2 in. | 1/4 in. | 28 mesh | |
| ST1 feed | 1.7 | 20.2 | 33.2 | 55.1 | 87.0 | |
| ST1 OF | 5.5 | 64.6 | 95.4 | 90.5 | 93.6 | 0.297 |
| ST1 UF | | | 9.9 | 37.1 | 84.7 | 0.703 |
| ST2 feed | 2.3 | 17.6 | 31.2 | 54.8 | 88.1 | |
| ST2 OF | 8.3 | 48.7 | 82.6 | 94.4 | 95.8 | 0.325 |
| ST2 UF | | | 3.8 | 33.5 | 84.9 | 0.675 |
| ST3 feed | 1.2 | 11.5 | 21.9 | 44.4 | 87.5 | |
| ST3 OF | 2.5 | 39.0 | 74.2 | 92.5 | 95.9 | 0.254 |
| ST3 UF | | | 2.4 | 25.4 | 84.6 | 0.746 |

[a]Damp yield fraction = weight fraction of feed reporting to that product stream as measured at time of testing (before drying).

Table A7. Sieve analyses for ORNL screen tests using Paradise Kentucky No. 9 coal

| Sample | Cumulative weight percent retained on | | | | | | | Damp yield[a] fraction |
|---|---|---|---|---|---|---|---|---|
| | 1 in. | 1/2 in. | 1/4 in. | 6 mesh | 14 mesh | 28 mesh | 100 mesh | |
| ST4 OF | 18.6 | 56.6 | 93.0 | | | 98.9 | 99.4 | 0.449 |
| ST4 UF | | | 3.7 | | | 72.6 | 89.6 | 0.551 |
| ST5 OF | 19.3 | 52.8 | 89.1 | | | 95.4 | 98.0 | 0.459 |
| ST5 UF | | | | 30.8 | | 72.9 | 88.2 | 0.541 |
| ST6 OF | 23.2 | 52.6 | 82.8 | 87.0 | | 92.6 | 96.6 | 0.510 |
| ST6 UF | | | 5.3 | 47.3 | | 81.4 | 91.6 | 0.490 |
| ST7 OF | 37.7 | 91.5 | 96.0 | | | 98.1 | 99.1 | 0.213 |
| ST7 UF | | 5.3 | 29.2 | | | 86.1 | 94.3 | 0.787 |
| ST8 OF | 45.2 | 92.1 | 94.8 | | | 96.8 | 98.7 | 0.208 |
| ST8 UF | | 8.5 | 30.7 | 52.1 | | 80.8 | 91.3 | 0.792 |
| ST9 OF | 40.6 | 91.4 | 94.2 | | | 96.5 | 98.6 | 0.174 |
| ST9 UF | | 6.4 | 28.6 | 50.7 | | 79.8 | 90.7 | 0.826 |
| ST10 OF | 11.5 | 31.7 | 56.5 | | | 94.4 | 97.1 | 0.707 |
| ST10 UF | | | | | 28.2 | 54.0 | 82.9 | 0.293 |
| ST11 OF | 11.6 | 28.5 | 48.5 | 67.4 | | 88.0 | 94.4 | 0.925 |
| ST11 UF | | | | | 28.6 | 58.3 | 83.6 | 0.075 |
| ST12 OF | 7.4 | 22.9 | 42.7 | 61.4 | | 84.8 | 92.8 | 0.961 |
| ST12 UF | | | | | 22.1 | 72.3 | | 0.039 |

[a]Damp yield fraction = weight fraction of feed reporting to that product stream as measured at time of testing (before drying).

Table A8. Sieve analyses of Dotiki screen samples
Start-up data taken on Oct. 12, 1979

| Sieve size | Feed coal | Screen overflow | Screen underflow |
|---|---|---|---|
| | Cumulative percent retained on sieve | | |
| 1.5 in. | 9.4 | 23.2 | |
| 0.5 in. | 41.3 | 85.7 | 5.1 |
| 0.25 in. | 59.1 | | 31.0 |
| 8 mesh | 73.6 | | 54.5 |
| 28 mesh | 89.3 | | 84.0 |
| PAN | 100.0 | 100.0 | 100.0 |

Stop-Belt samples taken on Aug. 6, 1981

| Sieve size | Feed coal | Screen overflow | Screen underflow |
|---|---|---|---|
| | Cumulative percent retained on sieve | | |
| 1.5 in. | 5.5 | 9.0 | |
| 0.5 in. | 37.4 | 67.1 | 19.8 |
| 9 mesh | 77.9 | 87.8 | 57.4 |
| 28 mesh | 88.9 | 96.1 | 79.5 |
| PAN | 100.0 | 100.0 | 100.0 |

## Internal Distribution

1. R. A. Bradley
2-6. V. K. Brantley
7. D. W. Burton
8. K. Carr
9. H. D. Cochran
10. C. S. Daw
11. D. M. Eissenberg
12. E. C. Fox
13. D. S. Griffith
14. J. E. Jones Jr.
15. R. P. Krishnan
16. M. P. Lambo
17. R. E. MacPherson
18. L. E. McNeese
19. J. C. Moyers
20. M. W. Rosenthal
21. S. P. Singh
22. H. E. Trammell
23. D. B. Trauger
24. Patent Office
25. Central Research Library
26. Document Reference Section
27-28. Laboratory Records
29. Laboratory Records (RC)

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31. Pete Blackwell, Midwestern Industries, P.O. Box 810, Massillon, OH 44648
32. Allen Boswell, Webster County Coal Company, Rural Route 3, Clay, KY 42404
33. Bill Derrick, Sr., Derrick Manufacturing Company, P.O. Box 221, Buffalo, NY 14225
34. Clarence Garrett, Webster County Coal Company, Rural Route 3, Clay, KY 42404
35. E. C. Hise, 106 East Irving Lane, Oak Ridge, TN 37830
36. Allen Holman, Mechanical Data, Inc., P.O. Box 23378, Knoxville, TN 37933
37. F. V. Karlson, Electric Power Research Institute, P.O. Box 10412, 3412 Hillview Avenue, Palo Alto, CA 94303
38. Jeff Knight, Rochester and Pittsburgh Coal Company, 655 Church Street, Indiana, PA 15701
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