DOE/PETC/TR-85/1
(DE85002885)

EFFECT OF OPERATING PARAMETERS AND REAGENT ADDITION ON FINE COAL DEWATERING IN A SCREEN BOWL CENTRIFUGE

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November 1984

MASTER

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Distribution Category UC-90b

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By

Kenneth J. Miller[1] and Wu-Wey Wen[2]

ABSTRACT

A six-inch continuous screen bowl centrifuge was employed in a pilot plant study designed to evaluate the effect of reagent addition, coal particle size distribution, slurry feed rate, and slurry feed solids concentration on the dewatering of finely ground Pittsburgh bed coal. The test results showed that 30%-solids slurry of minus-35-mesh coal could be dewatered to as low as 16% surface moisture with the addition of surfactant to the feed slurry. Without surfactant addition, the dewatered coal moisture level was about 20%. Similar tests with minus-200-mesh coal resulted in final product moisture levels of 21% to 23% with surfactant addition, and 25% to 27% without surfactant.

With synthetic organic flocculant addition, on the other hand, the dewatered coal moisture content was always higher than without reagent. The increased moisture content appeared to be directly related to the molecular weight of the flocculant.

Preparatory to the tests with reagents, several series of tests were run to evaluate the capacity of the centrifuge. These tests showed that feed rates greater than about 3 gal/min of 30%-solids slurry resulted in excessive coal losses in the effluent discharge. And feed slurry solids concentrations greater than about 30% at the 3 gal/min feed rate resulted in high product moisture content and excessive coal losses to the screen discharge.

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INTRODUCTION

Dewatering of the fine coal fraction (usually minus 28 mesh) represents one of the most difficult and costly operations in typical coal preparation plant circuits. The proportion of these fine particles in modern preparation plants has been increasing steadily over the years and can be as high as 20% of the product in some plants. Rotary vacuum filters, probably the most common devices used for fine coal dewatering, ordinarily yield products containing over 20% moisture. Because of the limited dewatering capability of vacuum filtration, thermal drying facilities are often needed to ensure a salable product. But because removing water mechanically is less expensive, less complicated, and more acceptable than thermal drying from an environmental standpoint, studies are being conducted in an effort to evaluate and improve various available processes (in this case, screen bowl centrifugation).

It has been known for some time that the dewatering of fine coal by vacuum filtration can be improved by adding surface active reagents (1,2,3, and 4).[3] Also, it has been demonstrated that synthetic organic polymers or flocculants can improve the dewatering process by increasing the filtration rate and eliminating the stratification of coarse and fine particles during cake formation (5 and 6).

Because certain chemical additives have been shown to improve dewatering by vacuum filtration, it is presumable that these same reagents might also improve dewatering by screen bowl centrifugation. For this reason, and to generally evaluate the screen bowl centrifuge for fine coal dewatering, this study was carried out.

EXPERIMENTAL PROCEDURE AND RESULTS

Screen Bowl Centrifuge

The screen bowl centrifuge (Figures 1 and 2) is a continuous-discharge, two-stage unit that combines a solid bowl clarifier with a centrifugal-filtration section. The feed slurry is introduced through a stationary feed pipe and is brought up to full rotational speed in an acceleration chamber. The slurry is distributed through feed ports to the inner diameter of the solid bowl wall, while the liquid migrates toward the axis of rotation.

Once this initial separation has taken place, a helical screw conveyor, operating at a slightly lower speed (~0.7% to 0.5% slower depending on the particular gear ratio used), moves the partially dewatered solids forward into the screen section of the machine where centrifugal filtration occurs. The "clarified" liquid discharges at the effluent end of the machine, and the dewatered product discharges at the feed end. Typically, the screen discharge material contains some coal and in industrial applications might

[3] Underlined numbers in parentheses refer to items in the list of references at the end of this report.

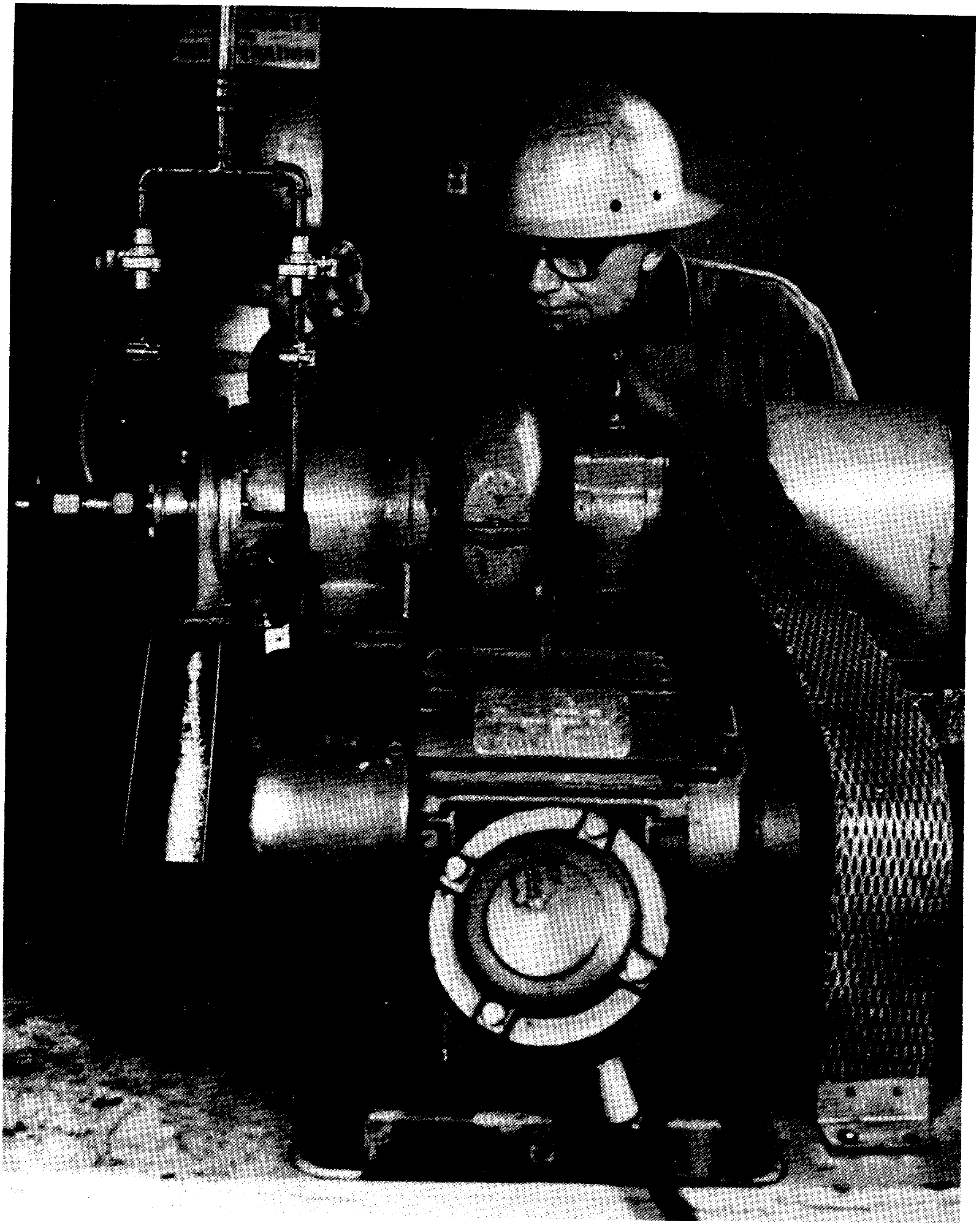

FIGURE 1 - SCREEN BOWL CENTRIFUGE.

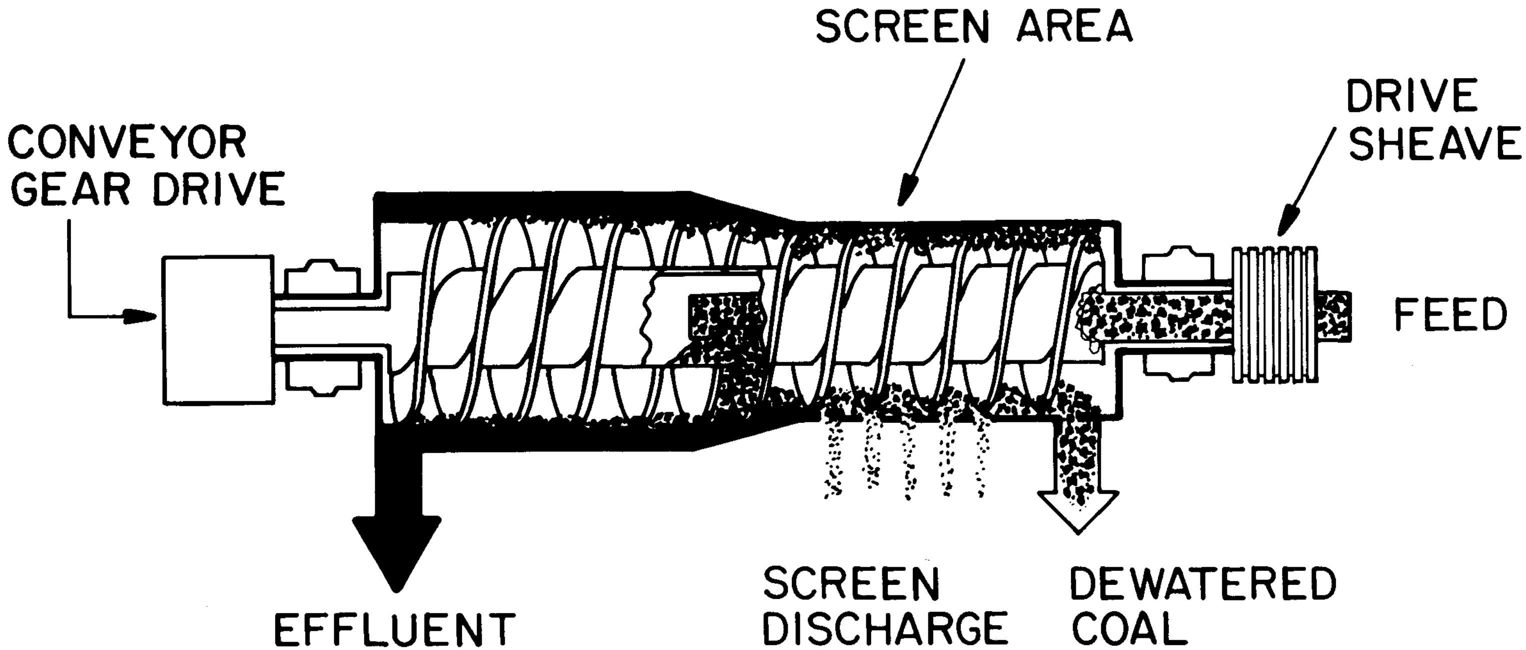

Figure 2 - Cutaway view of screen bowl centrifuge.

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be recycled into the feed system to be re-treated, or it might be dewatered separately in some other way. A more detailed description of the screen bowl centrifuge and its application in the dewatering of coal fines can be found in several other publications (7,8,9, and 10).

Coal Sample

The Pittsburgh bed coal sample used in the screen bowl centrifuge dewatering tests was obtained from the Bureau of Mines experimental mine at the Pittsburgh Energy Technology Center. The lump coal sample, as obtained from the mine, contained only about 5% ash. For the dewatering work, the coal was ground to nominal minus 35 mesh (in a few cases, to minus 200 mesh) through a high-speed hammer mill and a micropulverizer. Wet-sieve size analyses of the pulverized coal are given in Table 1.

Reagents

Flocculants

These are long-chain, water-soluble polymers usually based on polyacrylamide. Flocculants are available in nonionic, cationic, and anionic forms. The basic function of the long-chain polymers is to adsorb at the solid/liquid interface and bridge between individual particles, thus forming multiparticle aggregates. The aggregation or flocculation of fines produces a more porous filter cake or centrifuge product through which water can pass via a less tortuous and restricted route.

Surfactants

These consist typically of molecules composed of a water-avid and a water-repellent grouping, often based on sulfosuccinate. It is widely believed that surfactants enhance dewatering by concentrating at the liquid/air interface, causing a reduction in filtrate interfacial tension, thus allowing the product cake capillaries or pores to drain more freely. It is also believed that the surfactant adsorbs to some degree on the particles, making them more hydrophobic and thus more apt to reject surface moisture.

Test Procedure

Normally, a 30%-solids slurry composed of 100 lb of finely ground coal and 27 gal of water was prepared in the mixing tank. The 30%-solids concentration was chosen as a standard to approximate a typical feed to a preparation plant dewatering circuit -- froth flotation concentrate, for example. The slurry was stirred and simultaneously pumped through a closed-loop piping system to ensure thorough wetting of the coal particles before dewatering tests were begun. For tests requiring greater than 30% solids, the most concentrated pulp was prepared for initial tests and subsequently diluted with makeup water to each successively lower solids concentration.

Each batch of coal slurry prepared was used for a series of three or four tests, usually with incrementally greater reagent concentration. The reagents were mixed with the slurry in the feed tank prior to centrifugation.

TABLE 1. Wet Screen Size Analysis of the Pittsburgh Bed Coal Used in the Screen Bowl Centrifuge Dewatering Tests

	Direct Data, Percent		Cumulative Data, Percent	
Size, Mesh	Weight	Ash	Weight	Ash
	Nominal Minus 35 Mesh			
+ 35	5.0	5.6	5.0	5.6
35 x 48	10.7	6.1	15.7	5.9
48 x 100	24.8	3.4	40.5	4.4
100 x 200	23.4	3.8	63.9	4.2
200 x 325	11.3	4.5	75.2	4.2
- 325	24.8	4.9	100.0	4.4
	Nominal Minus 200 Mesh			
+ 200	1.6	3.8	1.6	3.8
200 x 325	11.3	3.4	12.9	3.4
325 x 400	4.6	3.6	17.5	3.5
- 400	82.5	4.7	100.0	4.5

A simplified flow diagram of the screen bowl centrifuge circuit is shown in Figure 3.

Test Results

The first series of tests was done to obtain operating experience and to test the general capacity of the six-inch screen bowl centrifuge with 30% solids slurry of minus-35-mesh coal. Three flow rates were selected for these tests -- 3, 5, and 7 gal/min. As Table 2 and Figure 4 show, the dewatered coal product recovery fell from about 90% to 50%, and the solids lost in the effluent increased from about 2% to over 46% when the feed rate was increased from 3 gal/min to 7 gal/min.

In addition to the tests with 30%-solids slurry at different flow rates, a series of tests was done using a constant flow rate of 3 gal/min with slurry of 30%, 40%, and 50% solids, again to test the capacity of the machine. These results (Table 3 and Figure 5) show that as the solids content increased, the yield (dewatered coal) decreased while the screen discharge product increased until the machine began to overload at somewhere between 40% and 50% solids. This can be seen by the greatly increased moisture content of the dewatered coal.

Flocculant Addition

Tables 4 and 5 show test results with a high molecular weight anionic polyacrylamide type flocculant and a relatively low molecular weight polyacrylonitrile flocculant. Clearly, the high molecular weight polymer (Accoal-Floc 204)[4] has the more deleterious effect on final dewatered coal moisture content. The increased moisture content with flocculant addition is believed to be due to the entrapment of water within the loose aggregates or floccules of coal. Figure 6 is provided to illustrate the differences between the effects of the two polymers.

Surfactant Addition

Table 6 shows test results with the addition of a nonionic surface active agent, Triton X-114. The results show that the dewatered-coal moisture content decreased with increased addition of the surfactant. That is, with no surfactant addition, the moisture content was 20.1%; and with 4.0 lb/ton, it was 16.0%. Similar results occurred with minus-200-mesh coal, as shown in Table 7. Here, moisture content dropped from a normal 28.0% to as low as 21.4%.

Figure 7 illustrates the data given in Tables 6 and 7, and shows the gradually decreasing surface tension of the slurry water with increased addition of surfactant. Surface tension was measured with a Fisher Surface Tensiometer that employs the du Nouy ring method.

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[4] Reference to trade names does not imply endorsement by DOE.

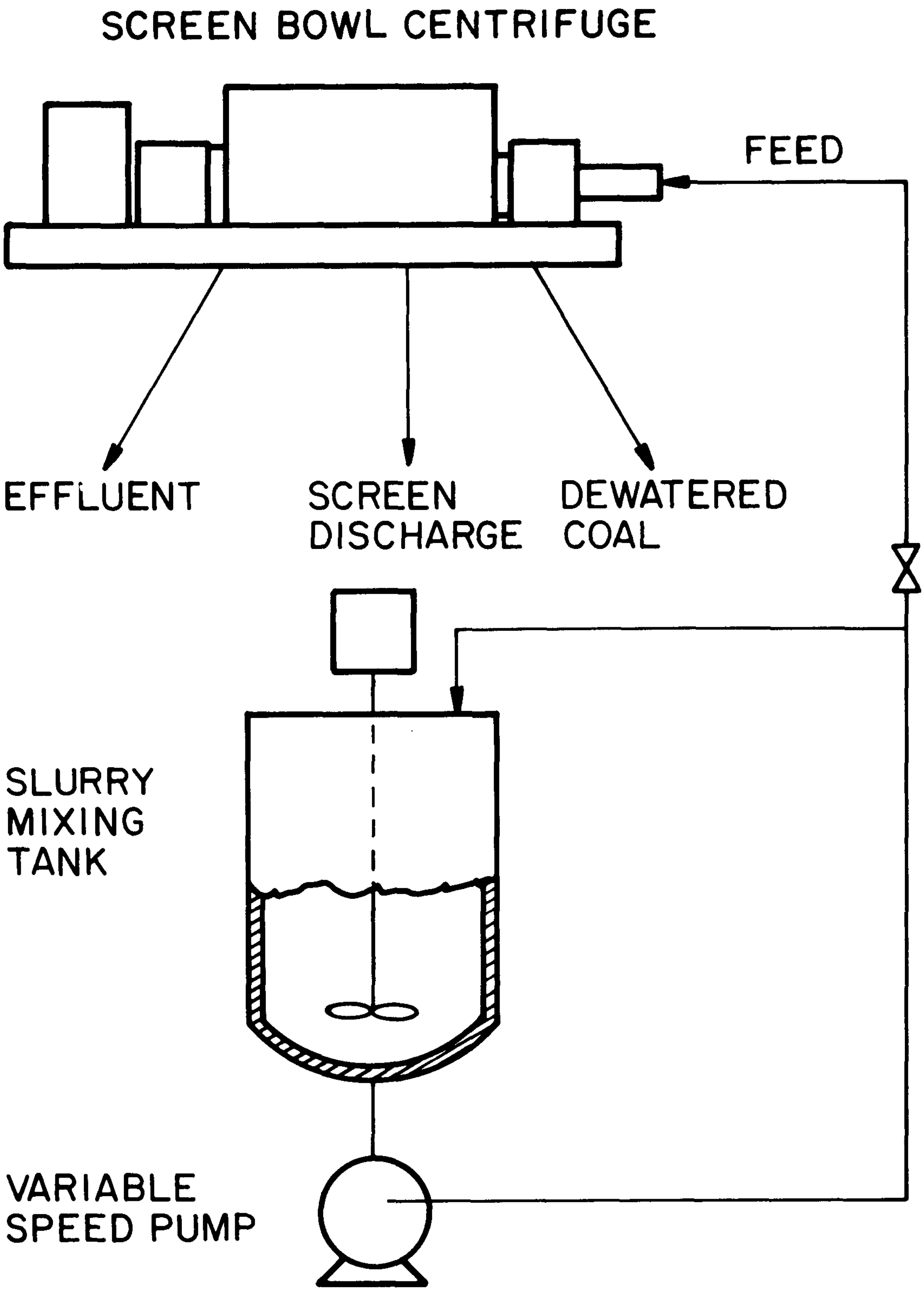

Figure 3 - Flow diagram of screen bowl centrifuge circuit.

TABLE 2. Tests with Minus-35-Mesh Feed at 30% Solids and Various Slurry Feed Rates

Product	Weight Percent (Dry)	Moisture, Percent
	3 gal/min Slurry Feed Rate	
Dewatered Coal	89.4	19.6
Screen Discharge	8.4	78.5
Effluent	2.2	98.9
Feed	100.0	70.4
	5 gal/min Slurry Feed Rate	
Dewatered Coal	72.9	18.2
Screen Discharge	6.5	83.5
Effluent	20.6	90.2
Feed	100.0	70.3
	7 gal/min Slurry Feed Rate	
Dewatered Coal	49.9	17.7
Screen Discharge	3.8	86.0
Effluent	46.3	81.7
Feed	100.0	70.3

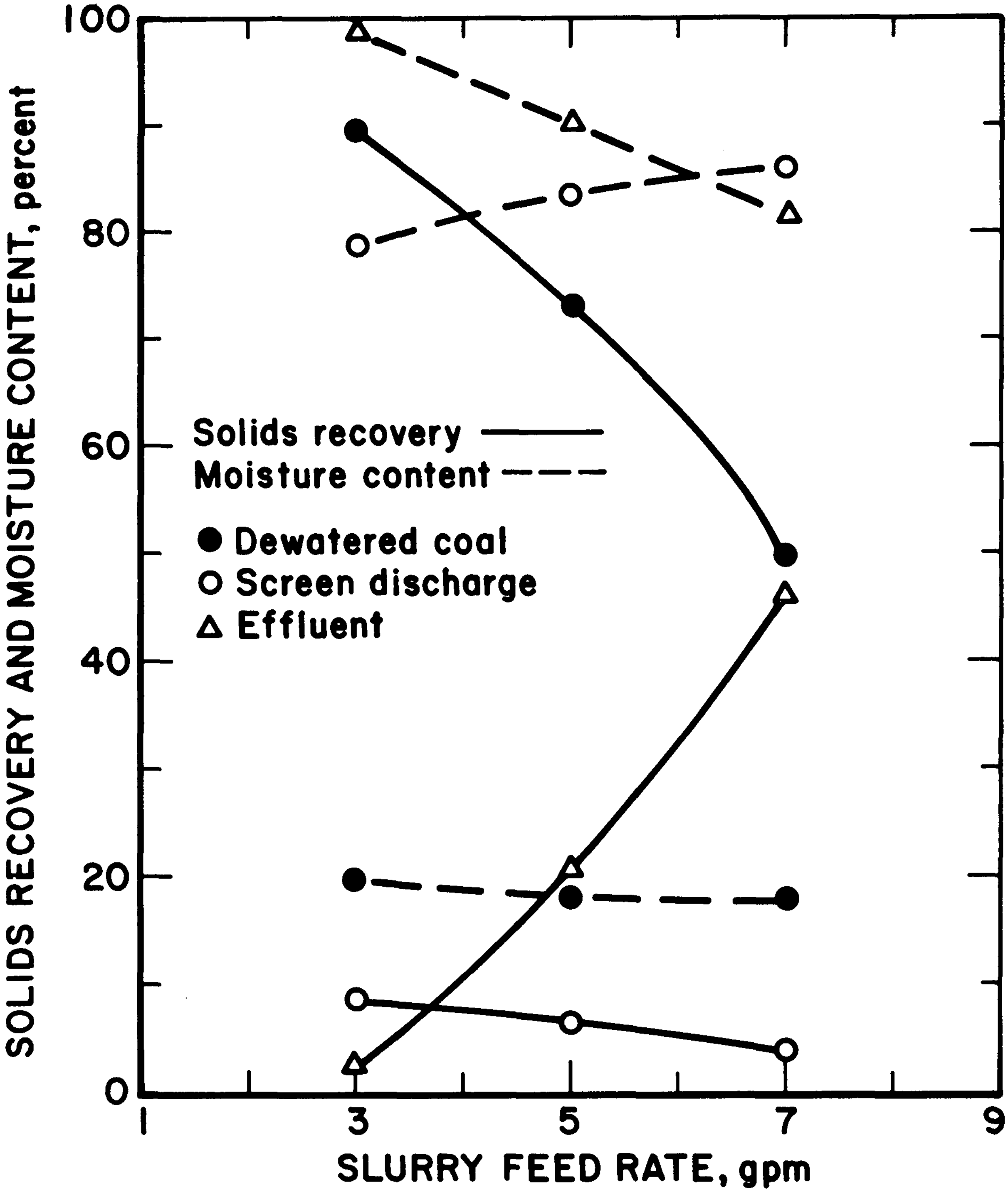

Figure 4 - Solids recovery and percent moisture in products from screen bowl centrifuge as a function of slurry feed rate.

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TABLE 3. Tests with Minus-35-Mesh Feed using Different Feed Slurry Solids Concentrations at a Constant Slurry Feed Rate of 3 gal/min

Product	Weight Percent (Dry)	Moisture, Percent
	30% Solids Feed	
Dewatered Coal	89.4	19.6
Screen Discharge	8.4	78.5
Effluent	2.2	98.9
Feed	100.0	70.4
	40% Solids Feed	
Dewatered Coal	79.8	18.4
Screen Discharge	17.9	71.9
Effluent	2.3	97.9
Feed	100.0	62.4
	50% Solids Feed	
Dewatered Coal	83.4	27.5
Screen Discharge	16.6	84.5
Effluent	---*	100.0
Feed	100.0	52.9

*Insufficient material for analysis

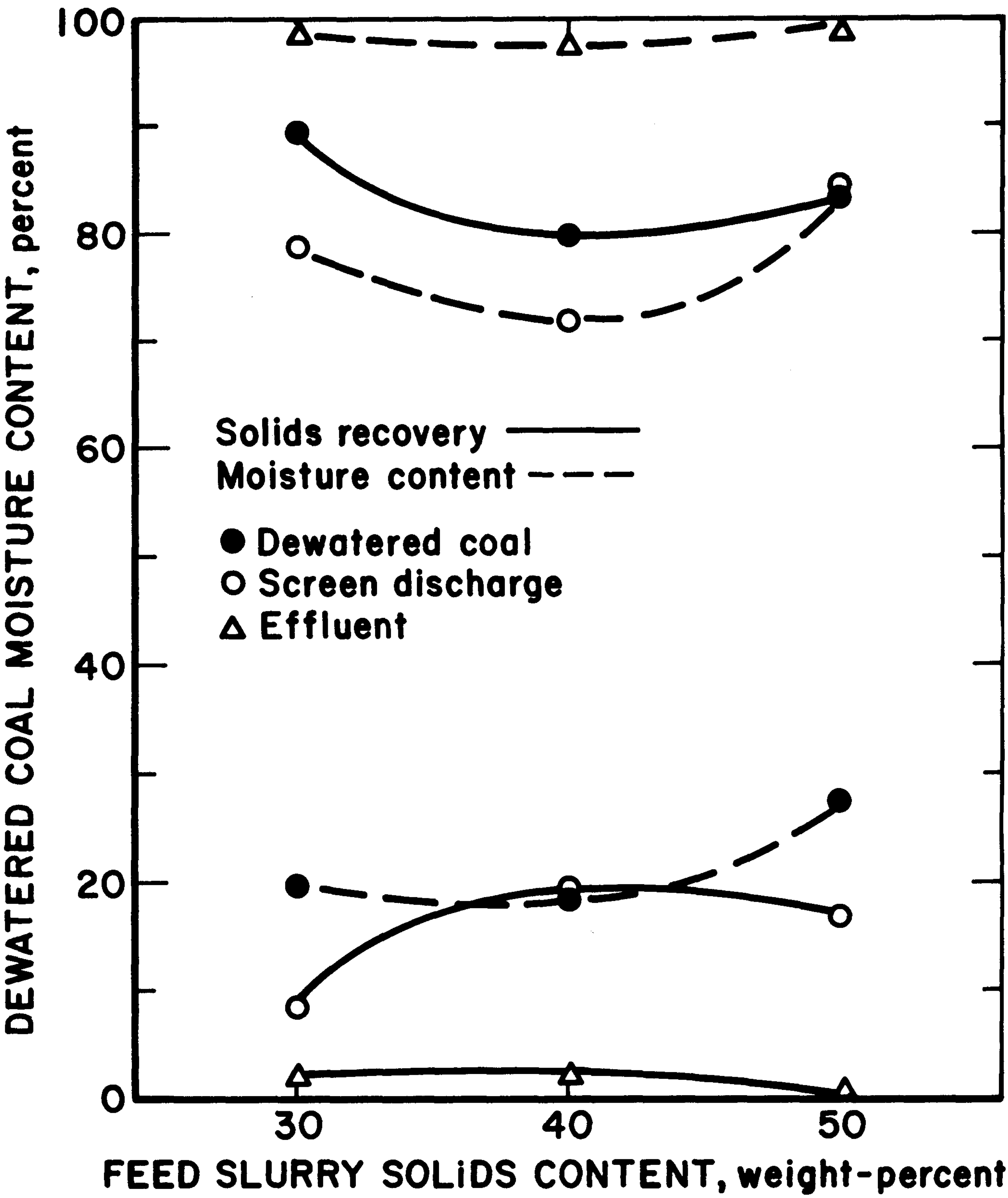

Figure 5 - Solids recovery and percent moisture in products from screen bowl centrifuge as a function of slurry feed solids concentration.

TABLE 4. Tests with Minus-35-Mesh Feed at 30% Solids and a Feed Rate of 3 gal/min in the Presence of Accoal-Floc 204 Flocculant

Product	Weight Percent (Dry)	Moisture, Percent
	No Reagent	
Dewatered Coal	90.6	20.0
Screen Discharge	7.7	80.9
Effluent	1.7	99.1
Feed	100.0	70.9
	Accoal-Floc 204 - 0.1 lb/ton	
Dewatered Coal	91.4	21.1
Screen Discharge	8.3	84.3
Effluent	0.3	99.8
Feed	100.0	71.4
	Accoal-Floc 204 - 0.2 lb/ton	
Dewatered Coal	91.0	21.4
Screen Discharge	8.7	83.3
Effluent	0.3	99.8
Feed	100.0	71.9
	Accoal-Floc 204 - 0.4 lb/ton	
Dewatered Coal	91.8	21.9
Screen Discharge	6.8	84.3
Effluent	1.4	99.3
Feed	100.0	72.7
	Accoal-Floc 204 - 0.8 lb/ton	
Dewatered Coal	90.1	24.0
Screen Discharge	7.8	81.4
Effluent	2.1	99.2
Feed	100.0	75.0

TABLE 5. Tests with Minus-35-Mesh Feed at 30% Solids and a Feed Rate of 3 gal/min in the Presence of Accoal-Floc 550 Flocculant

Product	Weight Percent (Dry)	Moisture, Percent
	No Reagent	
Dewatered Coal	90.3	20.1
Screen Discharge	7.1	80.4
Effluent	2.6	98.7
Feed	100.0	70.9
	Accoal-Floc 550 - 0.1 lb/ton	
Dewatered Coal	90.0	20.8
Screen Discharge	7.7	81.9
Effluent	2.3	98.8
Feed	100.0	71.7
	Accoal-Floc 550 - 0.2 lb/ton	
Dewatered Coal	90.6	21.2
Screen Discharge	7.5	82.0
Effluent	1.9	99.0
Feed	100.0	71.7
	Accoal-Floc 550 - 0.4 lb/ton	
Dewatered Coal	90.7	21.2
Screen Discharge	7.2	82.5
Effluent	2.1	99.0
Feed	100.0	72.6
	Accoal-Floc 550 - 0.8 lb/ton	
Dewatered Coal	91.0	21.3
Screen Discharge	6.7	81.2
Effluent	2.2	98.9
Feed	100.0	74.6

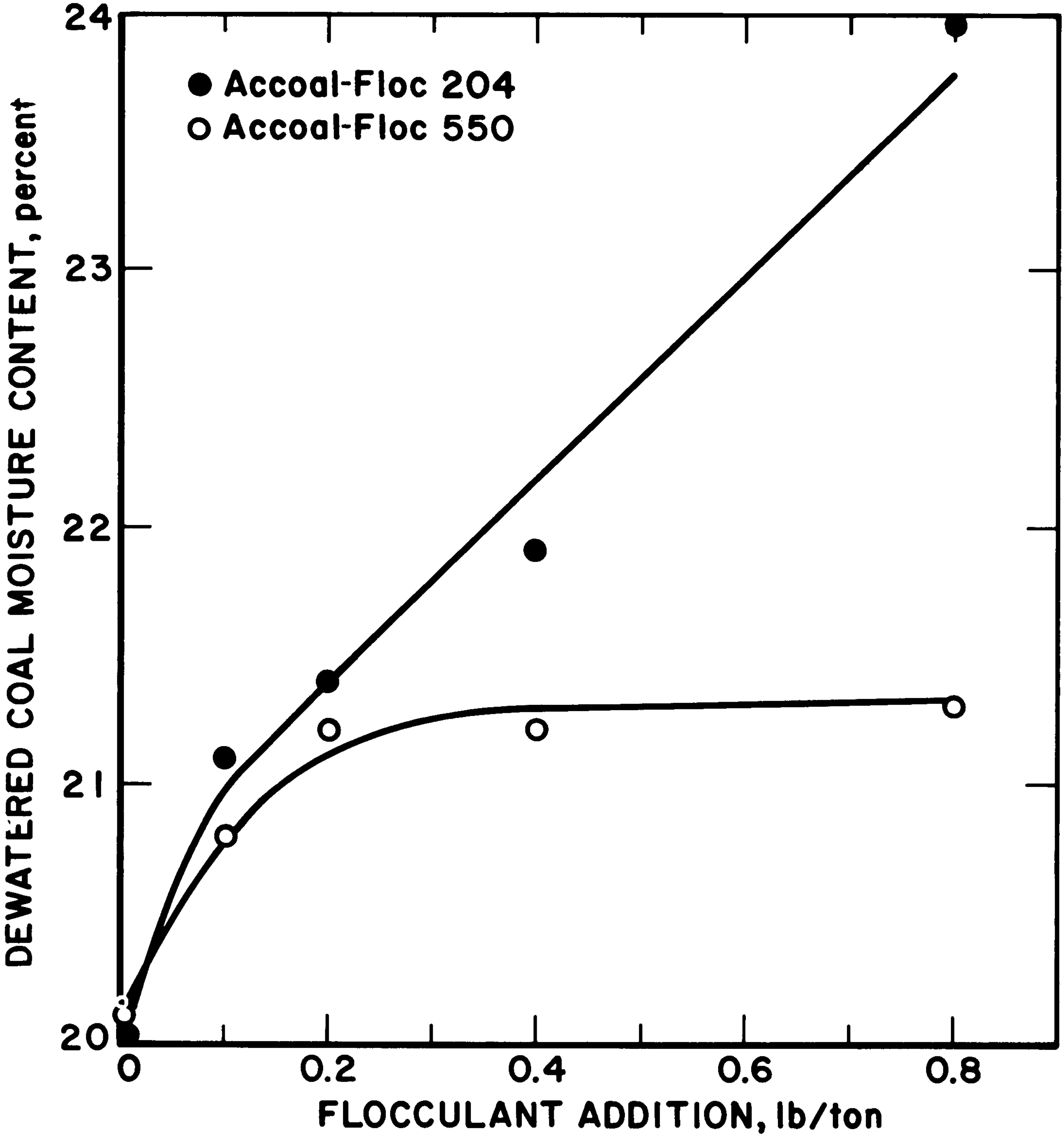

Figure 6 - Effect of flocculant addition on dewatered coal moisture content.

TABLE 6. Tests with Minus-35-Mesh Feed at 30% Solids and a Feed Rate of 3 gal/min in the Presence of Triton X-114 Surfactant

Product	Weight Percent (Dry)	Moisture, Percent
	No Reagent	
Dewatered Coal	87.6	20.1
Screen Discharge	9.4	73.3
Effluent	3.0	98.5
Feed	100.0	70.8
	Triton X-114 - 0.5 lb/ton	
Dewatered Coal	91.3	20.4
Screen Discharge	6.3	84.1
Effluent	2.4	98.7
Feed	100.0	71.0
	Triton X-114 - 1.0 lb/ton	
Dewatered Coal	87.9	18.7
Screen Discharge	9.4	74.6
Effluent	2.7	98.7
Feed	100.0	71.1
	Triton X-114 - 2.0 lb/ton	
Dewatered Coal	88.5	17.9
Screen Discharge	9.5	71.4
Effluent	2.0	99.0
Feed	100.0	71.3
	Triton X-114 - 4.0 lb/ton	
Dewatered Coal	86.7	16.0
Screen Discharge	10.8	68.4
Effluent	0.5	98.8
Feed	100.0	72.1

TABLE 7. Tests with Minus-200-Mesh Feed at 30% Solids and a Feed Rate of 3 gal/min in the Presence of Triton X-114 Surfactant

Product	Weight Percent (Dry)	Moisture, Percent
	No Reagent	
Dewatered Coal	81.9	28.0
Screen Discharge	14.5	69.2
Effluent	3.6	98.2
Feed	100.0	71.6
	Triton X-114 - 0.5 lb/ton	
Dewatered Coal	80.6	26.2
Screen Discharge	17.1	65.5
Effluent	2.3	98.8
Feed	100.0	71.5
	Triton X-114 - 1.0 lb/ton	
Dewatered Coal	80.6	25.8
Screen Discharge	17.5	65.5
Effluent	1.9	99.0
Feed	100.0	71.7
	Triton X-114 - 2.0 lb/ton	
Dewatered Coal	81.3	26.3
Screen Discharge	17.5	66.7
Effluent	1.2	99.4
Feed	100.0	72.3
	Triton X-114 - 4.0 lb/ton	
Dewatered Coal	81.7	21.4
Screen Discharge	14.8	68.0
Effluent	3.5	98.2
Feed	100.0	72.6

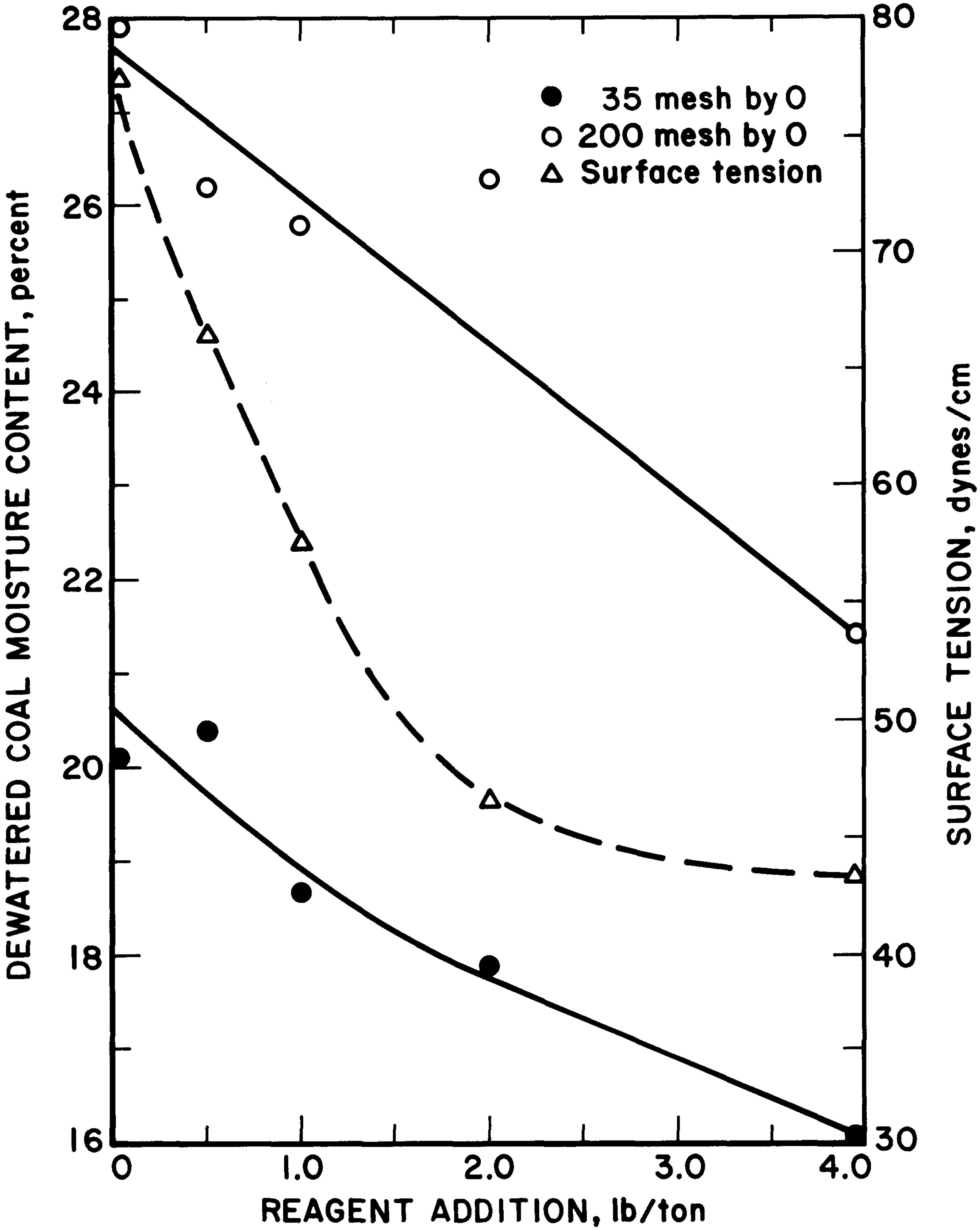

Figure 7 - Effect of surfactant addition on dewatered coal moisture content

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DISCUSSION AND CONCLUSIONS

The screen bowl centrifuge is an effective device for dewatering fine coal slurry, but its effectiveness cannot be compared directly with that of the vacuum filter because of the centrifuge's inherent desliming or screening action. The slimes removed during centrifugation must be taken into account, not only for their advantageous effect on dewatering but also because these refractory slimes must be dewatered separately in some other way. It is not enough to suggest that the slimes be recycled to the centrifuge to be treated again, for this could ultimately lead to a circuit replete with fines.

The addition of a surfactant to coal slurry prior to dewatering in the screen bowl centrifuge results in a drier coal product than would be obtained without surfactant addition. The degree of improvement in dewatering is approximately equal to that obtained in vacuum filtration pilot plant work with surfactants (1).

Despite the fact that these reagents help to reduce surface moisture in fine coal dewatering, their full-scale use in coal preparation plants has not been accepted because of cost and the possible secondary effects on other unit operations such as flotation and refuse thickening. Work needs to be done to demonstrate the use of surfactants on an industrial scale so that accurate economic analyses can be done, and so that the effect of surfactant accumulation in a closed water circuit can be determined.

The addition of synthetic organic flocculants results in a wetter cake than would be obtained without flocculant addition. The amount of additional water retained in the coal product is directly related to the molecular weight of the flocculant.

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