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The effect of particle-size distribution on the flotation of two South African coals

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SYNOPSIS

The flotation characteristics of two South African coals were investigated: one from the Durnacol Colliery in Natal, and the other from Landau Colliery in the Witbank Coal Field. Samples of fine coal (smaller than 1 mm) were studied, the Durnacol coal showing significantly better ash-liberation characteristics than the Landau coal.

Neither coal was found to produce satisfactory flotation concentrates, except at very fine sizes. The poor flotation performance can be ascribed to the non-selective flotation of unliberated particles that may contain considerable quantities of ash. Flotation recoveries were greatest for particles between 100 and 200 μm, and fell off rapidly as the size increased above 200 μm. Very fine particles were found to float adequately, and acceptable concentrates can be made at comparatively high yields from materials smaller than 75 μm.

The flotation of ultrafine coal was demonstrated successfully in a continuous pilot plant. This result opens the way to a potentially viable industrial process for the beneficiation of ultrafines from the Witbank No. 2 seam, which for decades has been regarded as non-floatable.

SAMEVATTING

Die flottasiekenmerke van twee soorte Suid-Afrikaanse steenkool is ondersoek: een afkomstig van die Durnacolsteenkoolmyn in Natal en die ander van die Landau-steenkoolmyn in die Witbank-steenkoolveld. Monsters fyn steenkool (kleiner as 1 mm) is bestudeer en die Durnacolsteenkool het beduidend beter asbevrydingskenmerke as die Landau-steenkool getoon.

Behalwe vir baie fyn groottes het nie een van die steenkoolsoorte bevredigende flottasiekonsentrate gelewer nie. Die swak flottasievertoning kan toegeskryf word aan die nie-selektiewe flottasie van onbevryde partikels wat aansienlike hoeveelhede as kan bevat. Die herwinnings deur flottasie was die grootste vir partikels tussen 100 en 200 μm en het vinnig afgeneem namate die grootte toegeneem het tot meer as 200 μm. Daar is gevind dat baie fyn partikels doeltreffend geflotteer kan word, en aanvaarbare konsentrate kan met betreklik hoë opbrengste van materiaal kleiner as 75 μm verkry word.

Die flottasie van ultrafynsteenkool is suksesvol gedemonstreer in 'n deurlopende proefaanleg. Hierdie resultaat baan die weg vir 'n potensieel lewensvatbare industriële proses vir die veredeling van ultrafyn steenkool van die Witbank-laag nr. 2 wat dekades lank as nie-flotteerbaar beskou is.

Introduction

Coal smaller than 0,5 mm does not lend itself very readily to beneficiation. Consequently, much of the fine coal produced in collieries during mining, comminution, and other processing operations is lost as discards. This represents a significant loss of useful coal since the composition of the fine coal fraction makes it potentially suitable for beneficiation to saleable products. Flotation would be an obvious process for the beneficiation of fine coal, but it has been found that not many South African coals can be satisfactorily beneficiated by that process. The study reported here was undertaken specifically on the flotation characteristics of fine South African coals in an attempt to establish the conditions under which flotation could be profitably used to produce low-ash saleable products. This project was undertaken together with a sister project in which the dense-medium cyclone was investigated as a beneficiation device. The results[1-3] from these studies give a clear indication that the dense-medium cyclone should be used only for the beneficiation of coal larger than 75 μm, and the results reported in this paper show that the finer coal can be effectively beneficiated by flotation. Thus, a combination of the two processes can be recommended for use in South African collieries, which will significantly reduce the amount of fine coal that is lost at present by dumping.

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Materials Used

Bulk samples of fine coal arising from operations at Durnacol and Landau collieries were obtained. The particle-size distribution of the materials is shown in Tables I and II. The Durnacol coal assayed 27,2 per cent ash and the Landau coal 19,8 per cent ash. The ash content as a function of particle size is also shown in Tables I and II. The increase in ash at fine sizes could be ascribed to more efficient desliming of low-density solid material at the finer sizes on the plants, but could also be indicative of preferential liberation of the ash-forming components.

The washability properties of the coals at three particle sizes are shown in Figs. 1 and 2, which give histograms of the percentage yield to flotation in narrow density ranges. The difference between the Durnacol and Landau coals is very striking, and the significantly better liberation of coal from ash in the former coal is clearly evident. It is clear that liberation is not significant, even in coals as fine as 125 μm in the Landau coal, and the

TABLE I
PARTICLE-SIZE DISTRIBUTION OF RAW FINE COAL FROM DURNACOL

Size fraction µm	Mass %	Ash %	Cumulative mass %	Cumulative ash %
+ 850	15,16	27,91	15,16	27,91
− 850 + 600	16,41	25,13	31,57	26,46
− 600 + 425	16,48	23,57	48,05	25,47
− 425 + 300	12,30	23,30	60,35	25,03
− 300 + 212	9,75	23,22	70,10	24,78
− 212 + 150	9,46	26,46	79,56	24,98
− 150 + 106	6,00	29,44	85,56	25,29
− 106 + 75	4,29	36,22	89,85	25,81
− 75	10,15	39,84	100,00	27,24
Total	100,00	27,24	−	−

TABLE II
PARTICLE-SIZE DISTRIBUTION OF RAW FINE COAL FROM LANDAU

Size fraction µm	Mass %	Ash %	Cumulative mass %	Cumulative ash %
+ 1180	3,13	16,79	3,13	16,79
− 1180 + 850	4,59	16,85	7,71	16,83
− 850 + 600	11,07	17,40	18,78	17,16
− 600 + 500	7,69	17,41	25,48	17,24
− 500 + 425	10,84	17,20	37,32	17,23
− 425 + 300	16,12	18,34	53,44	17,56
− 300 + 250	7,69	18,61	61,13	17,69
− 250 + 212	4,74	19,61	65,87	17,83
− 212 + 150	11,84	19,86	77,72	18,14
− 150 + 125	4,15	21,90	81,87	18,33
− 125 + 106	3,60	22,78	85,47	18,52
− 106 + 90	1,84	23,84	87,31	18,63
− 90 + 75	2,05	25,81	89,36	18,80
− 75	10,64	28,05	100,00	19,78
Total	100,00	19,78	−	−

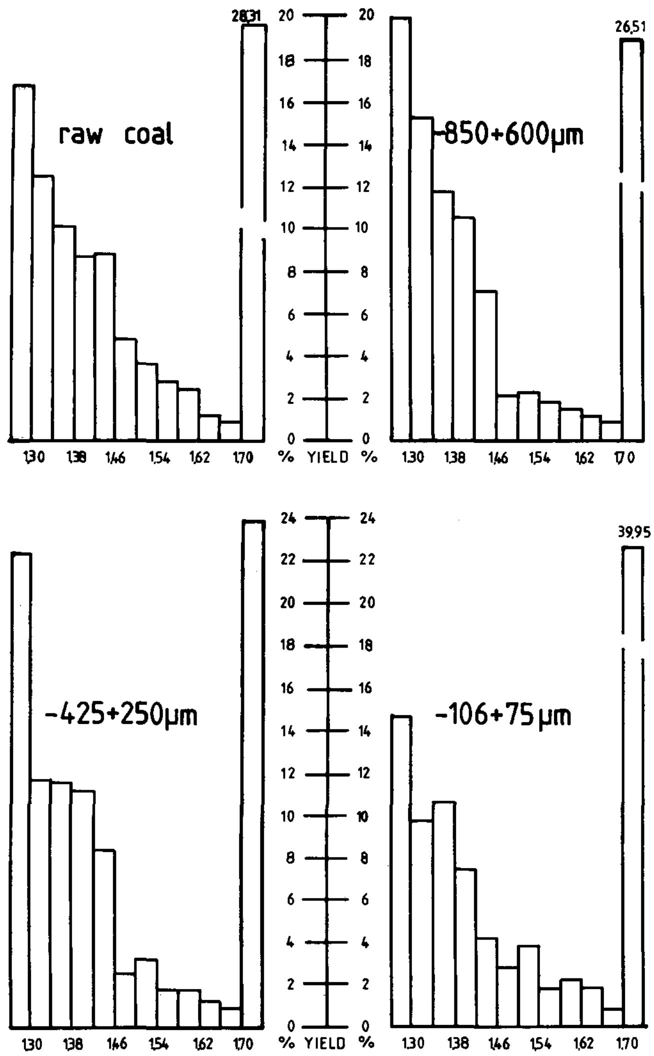

Fig. 1—Distribution of density fractions as a function of particle size for Durnacol coal

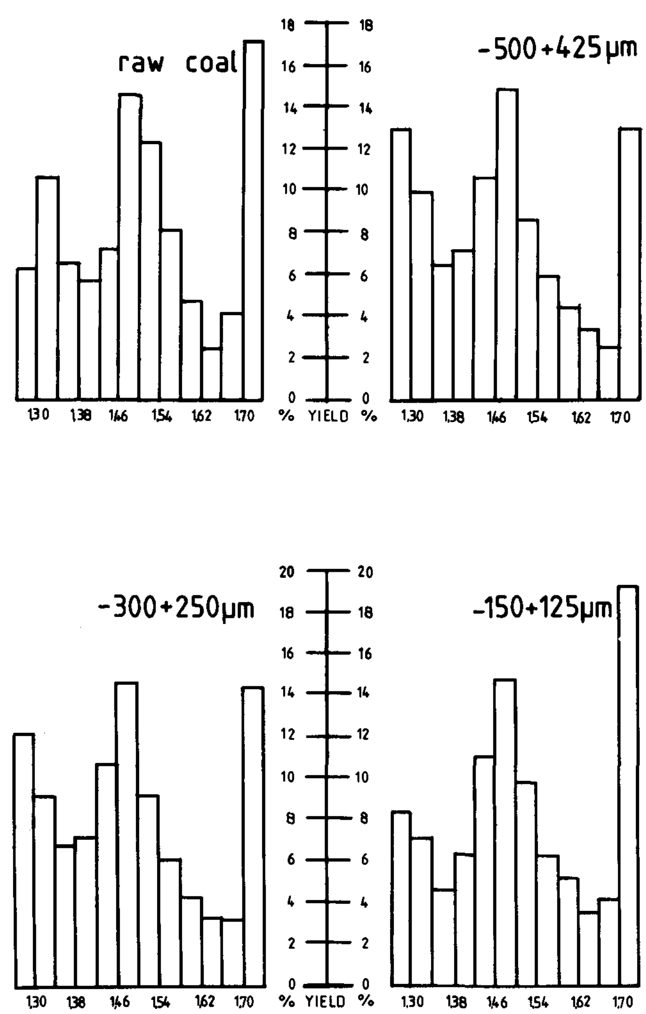

Fig. 2—Distribution of density fractions as a function of particle size for Landau coal

liberation size must be significantly smaller. The presence of considerable quantities of intermediate-density material in the Landau coal is the chief reason for the difficulty in beneficiating this material.

Exploratory Tests

A series of exploratory tests was conducted on Durnacol coal to establish the best combination of percentage solids, aeration rate, collector concentration, and froth concentration. The results of these tests are shown in Table III, and in Fig. 3, where the grade–recovery combinations measured are compared against the theoretical limit for a perfect separating device. It is clear from Fig. 3 that experiments 9, 10, 11, and 12, which were run at low percentage solids in the floatation cell and a low aeration rate, show slightly improved performance in comparison with the others. Table III shows that single-stage rougher flotation is not likely to produce an acceptable product, even for the comparatively easily floatable Durnacol coal. The very strong positive correlation between dosage of frother and total recovery is also clearly evident from Table III.

Two-stage continuous operations were simulated by two-stage additions of reagent during a single batch test, and the results are shown in Tables IV and V. Table V gives a clear indication that the larger particles are recovered more effectively during the second stage. The two-stage grade–recovery relationship is shown in Fig. 3, from which it is clear that the performance was significantly better than that in a single stage.

The predicted performance of a dense-medium hydrocyclone is also shown in Fig. 3 for comparison. It is clear that the single-stage dense-medium hydrocyclone easily out-performs single- and two-stage flotation, ex-

TABLE III
EXPLORATORY FLOTATION TESTS

Conditions

Cell	2,7 litre
Reagent addition	1 stage
Impeller speed	1200 r/min
Flotation time	3 min

Run	Solids	Aeration rate	Collector	Frother	Yield, %	Ash, %
1	H	L	H	H	40,7	14,5
2	H	L	H	L	31,5	11,1
3	H	L	L	H	37,4	13,8
4	H	L	L	L	20,1	10,1
5	H	H	H	H	38,1	15,3
6	H	H	H	L	29,9	12,4
7	H	H	L	H	45,4	14,5
8	H	H	L	L	26,1	11,7
9	L	L	H	H	31,5	10,6
10	L	L	H	L	9,1	8,4
11	L	L	L	H	26,2	10,6
12	L	L	L	L	9,5	8,8
13	L	H	H	H	32,6	12,3
14	L	H	H	L	17,5	10,5
15	L	H	L	H	33,5	12,0
16	L	H	L	L	13,8	10,9

Solids
H 10% solids
L 5% solids

Aeration rate
H 4 l/min per litre of cell
L 1 l/min per litre of cell

Collector
H 140 g/t (Diesel oil)
L 70 g/t

Frother
H 160 g/t (80% Dowfroth 200, 20% froth conditioner M210)
L 80 g/t

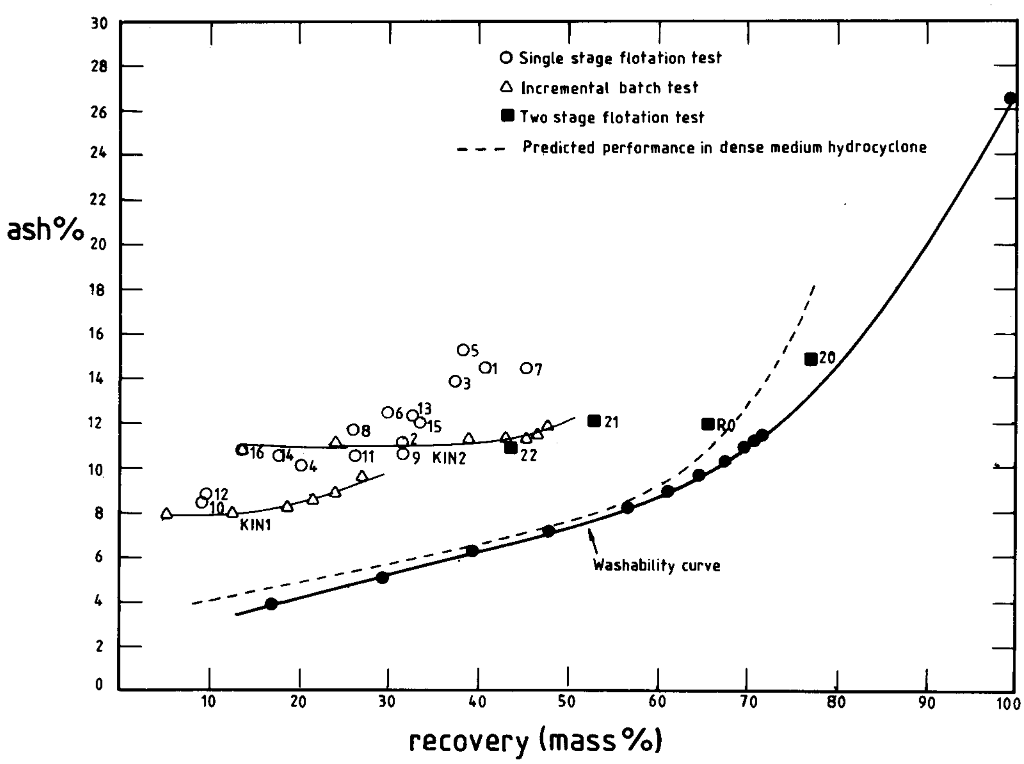

Fig. 3—Grade-recovery relationship for the batch flotation of Durnacol fines (the experiment numbers refer to Tables I to III)

TABLE IV
THE EFFECT OF THE TWO-STAGE ADDITION OF REAGENT ON FLOTATION PERFORMANCE

Conditions
Collector Sasol C11
Frother Sasol cresylic acid

	1st concentrate, %		2nd concentrate, %		Reagents	
Test	Yield	Ash	Yield	Ash	Collector kg/t	Frother g/t
20	60,1	12,8	17,1	22,1	1,0/1,0	100/100
21			52,9	12,1	0,5/0,0	50/50
22	8,4	9,3	35,4	11,2	0,25/0,25	50/50
R0	30,0	9,2	35,6	14,3	0,5/0,5	50/50
R1	6,5	10,2	56,3	14,7	0,5/0,5	150/150
R2	17,3	11,2	46,8	15,3	1,0/0,5	150/150
R3	42,5	13,2	35,7	16,4	2,0/0,3	150/100
R4	9,2	10,4	38,6	13,3	1,5/0,5	100/100

Tests 20–22 and R0 used Durnacol coal. Tests R1–R4 used Landau coal.
For test 21, the first- and second-stage results are combined.

TABLE V
YIELD OF SIZE FRACTION FOR TEST R0 ON DURNACOL COAL

Size fraction μm	1st stage	2nd stage	Total
+ 600	21,1	43,6	64,7
− 600 + 250	27,4	39,3	66,7
− 250 + 75	35,0	31,4	66,4
− 75	38,1	25,7	63,8

cept where an ash content of 14 per cent in the clean coal is the target.

The results from two incremental batch tests on Durnacol coal are also shown in Fig. 3. The grade–recovery trajectories of these tests are unusually flat and indicate non-selective flotation—coal and ash are apparently displaying very similar kinetic behaviour. The results marked KIN1 were obtained with diesel oil (0,13 kg/t) and Dowfroth 200 (70 g/t) as collector and frother, respectively, and at 8,8 per cent solids in the pulp. The data marked KIN2 were obtained with Sasol C11 (1,0 kg/t) and Sasol cresylic acid (100 g/t) at 8,2 per cent solids.

The grade–recovery relationships as determined for Landau fines are shown in Fig. 4. Data points 0 to 7 show the effect of collector and frother types and dosage rates, the conditions being defined in Table VI. All the tests were conducted at 8 per cent solids. It is clear from the results that the depression of ash is not an effective technique for the preparation of low-ash coal.

Kinetics of Flotation

The kinetics of the flotation of various types of particles was determined so that the reason for the poor performance of these fine coals during flotation could be identified. An incremental batch test was conducted on fines from Landau Colliery. The recoveries as functions of particle size are shown in Fig. 5, and the recovery as a function of particle density is shown for three different sizes of particles in Fig. 6. Fig. 5 exhibits the characteristic maximum in the relationship between flotation recovery and particle size, the peak occurring between 100 and 200 μm. The fall-off in flotation recovery is very marked above 200 μm and decreases to almost zero at a particle size of 1 mm. Fig. 6 is especially informative. It indicates that only in the larger sizes does recovery vary significantly with particle density, and at the smaller sizes it is only the very high-density particles that are effectively depressed. The relationship between recovery and particle density measured for the same coal in a dense-medium

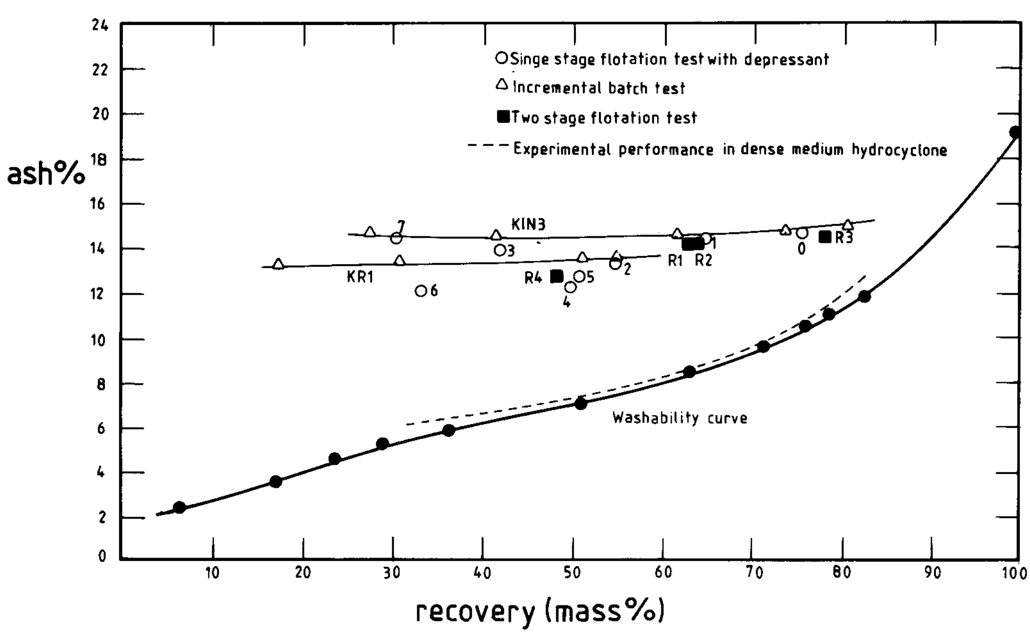

Fig. 4—Grade-recovery relationship for the batch flotation of Landau fines (the experimental conditions are defined in Tables II and IV)

TABLE VI
GRADE-RECOVERY RELATIONSHIPS FOR LANDAU COAL

Expt	Collector kg/t		Frother g/t		Depressant* g/t	Recovery %	Ash %
0	Sasol C11	2,4	Sasol cresylic acid Sasol heavy alcohol	200 100	None	75.4	14,7
1	Sasol C11	2,4	Sasol cresylic acid Sasol heavy alcohol	200 100	100	64,7	14,3
2	Sasol C11	2,4	Sasol cresylic acid Sasol heavy alcohol	200 100	200	54,8	13,3
3	Sasol C11	2,4	Sasol cresylic acid Sasol heavy alcohol	200 100	300	41,4	13,9
4	Dow M210	0,25	Sasol cresylic acid	300	100	48,8	12,3
5	Dow M210	0,25	Sasol cresylic acid	300	175	50,5	12,7
6	Dow M210	0,25	Sasol cresylic acid	300	250	32,9	12,1
7	Dow M210	0,25	Sasol cresylic acid	300	500	29,9	14,3

*Cynamid Aero 610

cyclone[1-3] is also shown in Fig. 6. The very much sharper selectivity of the latter device is very clearly evident. The stark difference in performance between the gravity-specific dense-medium process and the surface-specific flotation process is highlighted dramatically in Fig. 6. Obviously, flotation is not competitive as a beneficiation process at these particle sizes, and the importance of adequate liberation to improve flotation cannot be over-emphasized.

As an assessment of the true kinetic behaviour of the various types of particles, the relationships of recovery versus time were determined for particles in narrow size and density ranges. The results showed that each type of particle can be characterized by a floatable and non-floatable component. The specific flotation rate constant for the floatable component is shown in Fig. 7. The results are surprising in that there is a significant increase in the flotation rate constant as the density increases, particularly in the larger sizes. This is contrary to expectations, and is a good indication that selective flotation is not possible on the basis of the ash content of the floated particles. The fraction of floatable material as a function of relative density for three particle sizes is shown in Fig. 8. The parameter is surprisingly constant over a

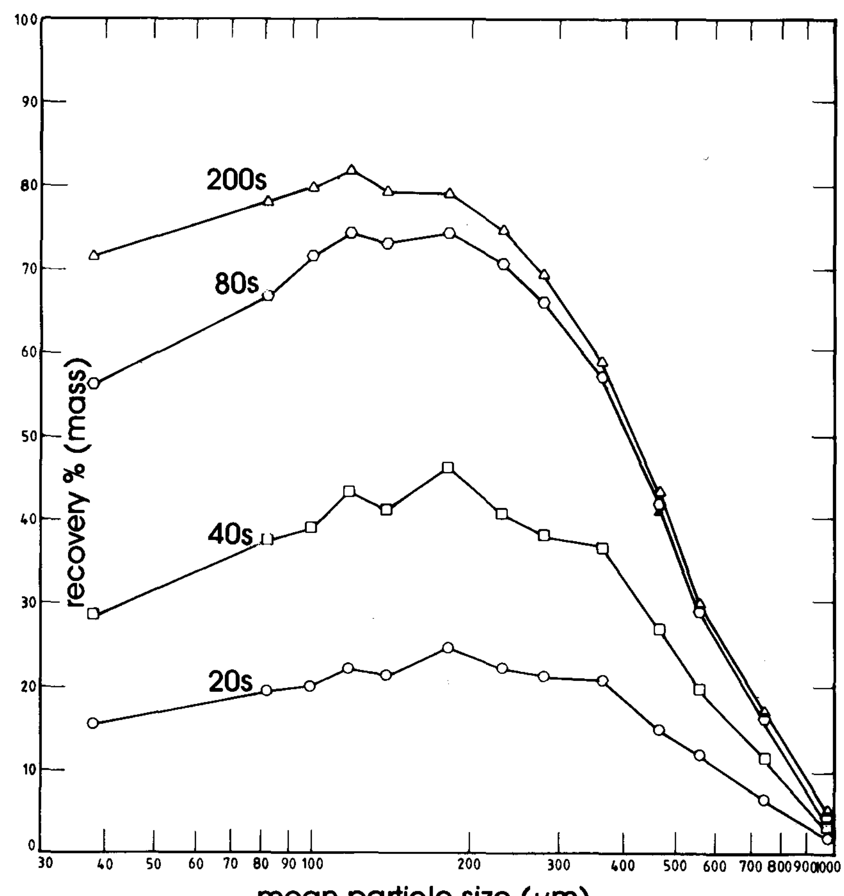

Fig. 5—Recovery as a function of particle size at 4 times in an incremental batch flotation test

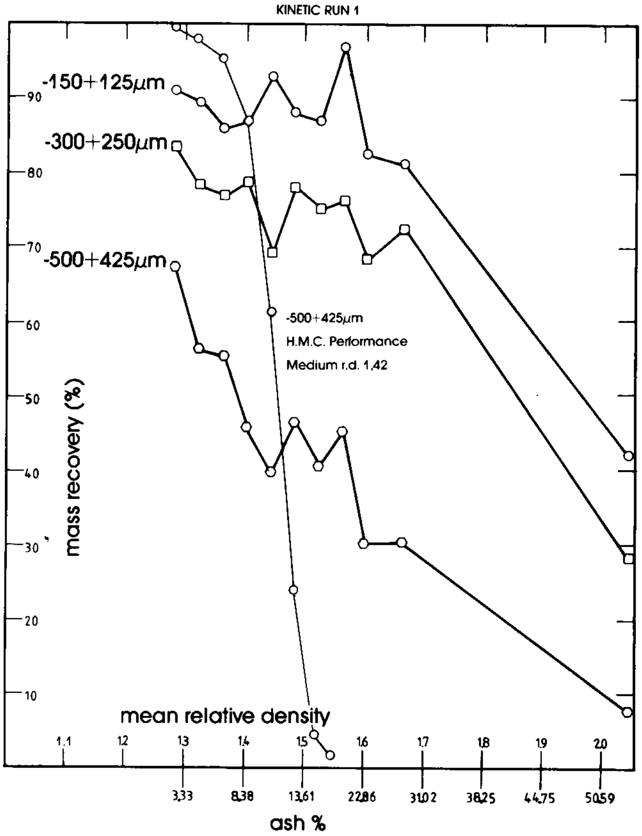

Fig. 6—Recovery as a function of particle density for 3 particle sizes in a batch flotation test on Landau coal. The measured recoveries for the − 500 + 425 μm fraction of the same coal in a dense-medium cyclone are also shown[1,2]

wide range of densities and falls significantly only for particles that have a very high ash content. The two incremental batch tests are not strictly comparable, and the details are given in Tables VII and VIII.

These kinetic results demonstrate very clearly and unambiguously that very little selectivity on a particle basis was achieved during flotation, and consequently high degrees of upgrading cannot be obtained by flotation at the particle sizes that were studied in these tests.

Flotation of Ultrafine Coal

The results presented above give a very clear indication that flotation is likely to be a successful technique only if a significant degree of liberation of ash can be achieved. With this in view, a study of the flotation characteristics of ultra-fine particles (smaller than 75 μm) was undertaken. Ultrafine coal for the tests was obtained from two sources: the Landau fines already tested were ground for various periods in a laboratory batch mill, and a sample of the slimes produced at Landau Colliery was obtained. One-, two-, or three-stage addition batch tests were performed. The properties of the feed are given in Table IX. One incremental batch test was conducted to establish the kinetic constants for the flotation process.

The results are shown in Fig. 9. The improvement in the flotation performance for the material from Landau after it had been ground for 4 hours is very obvious, particularly when compared with the results shown in Figs. 3 and 4. The ash–yield curves are again very flat, but very

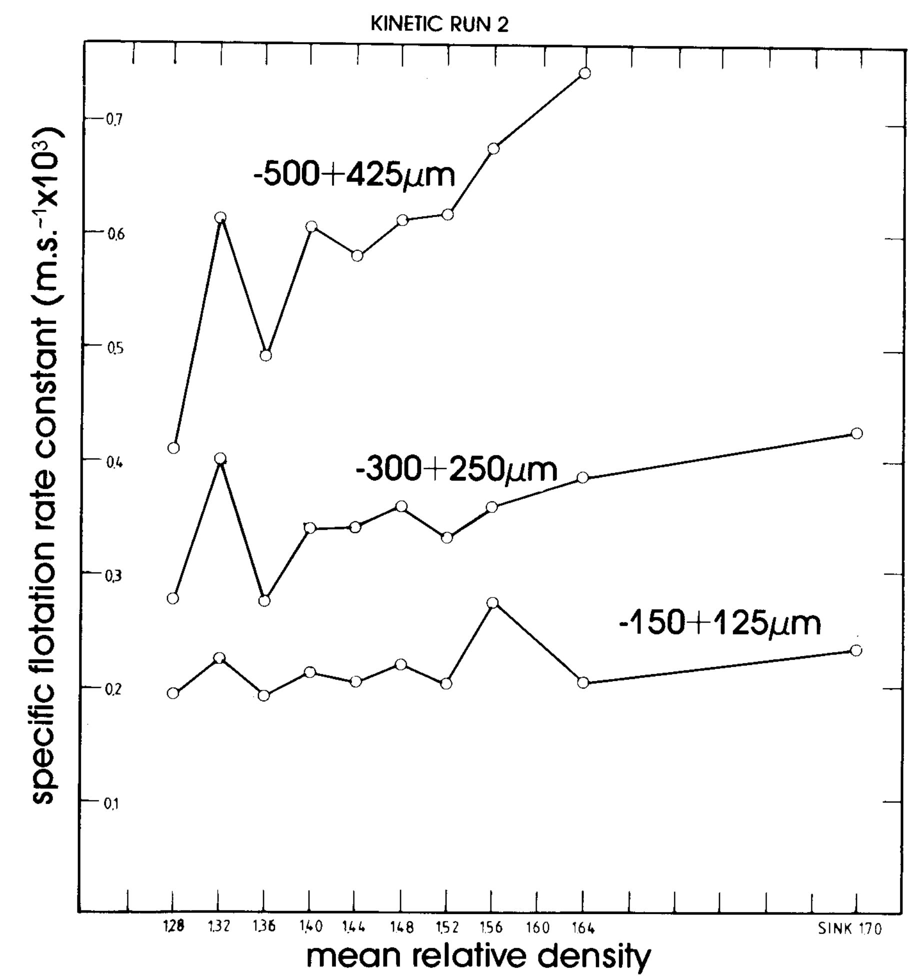

Fig. 7—Specific flotation rate constant for the floatable component as a function of particle density for 3 sizes

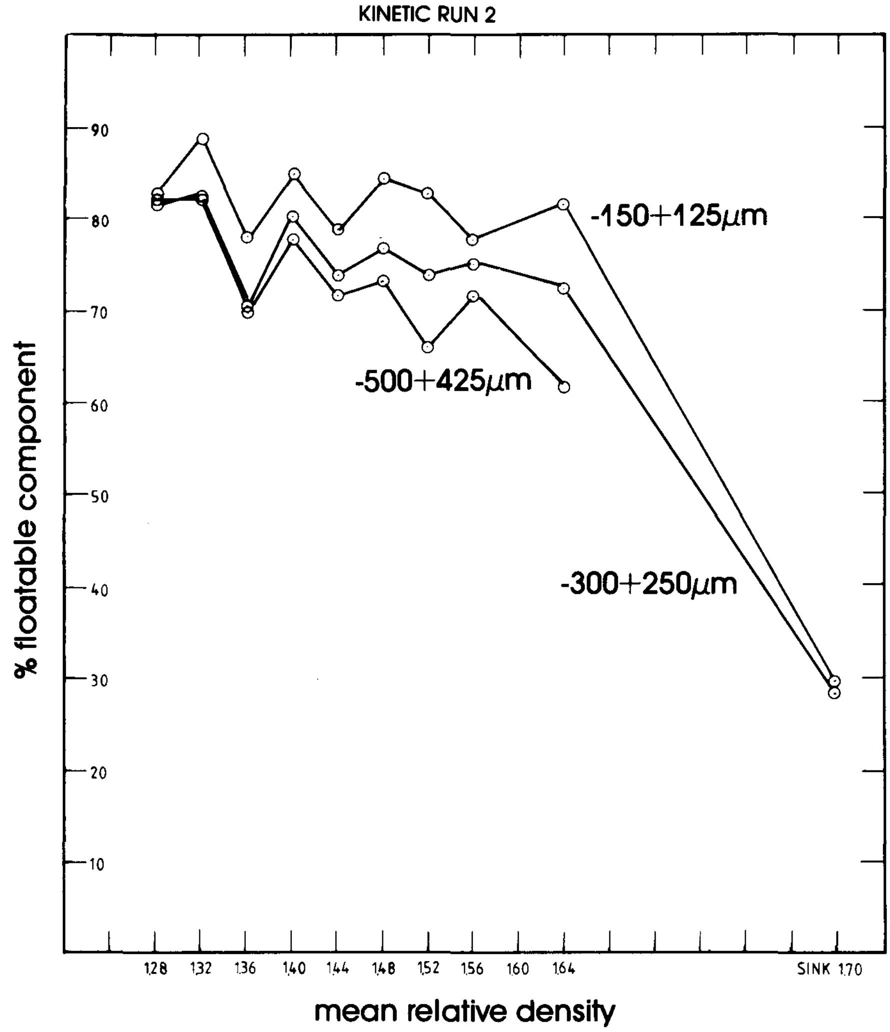

Fig. 8—Percentage of the particles that are floatable as a function of particle density

TABLE VII

DETAILS OF INCREMENTAL BATCH TESTS: KINETIC RUN 1

Conditions
Cell 10 litre
Collector 3 kg/t of Sasol C11
Frother 150 g/t of Sasol cresylic acid
Aeration rate 1 l/min per litre of cell
Impeller speed 1200 r.p.m. during conditioning time
1000 r/min during flotation time
Solids 8,9%

Product	Time, s	Mass, %	Ash, %
Concentrate 1	20	16,9	13,4
2	20	13,6	13,7
3	40	20,2	13,9
4	120	4,1	13,9
Total concentrate	200	54,8	13,7
Tailings	–	45,2	27,2
Total	–	100,0	19,8

TABLE VIII

DETAILS OF INCREMENTAL BATCH TEST: KINETIC RUN 2

Conditions
Cell 10 litre
Collector 2 kg/t Sasol C11
Frother 150 g/t Sasol cresylic acid
100 g/t Sasol heavy alcohol
Impeller speed 1200 r/min conditioning
1000 r/min flotation
Aeration rate 0,5 l/min per litre of cell
Solids 9,7%

Product	Time, s	Mass, %
Concentrate 1	20	35,5
2	20	12,9
3	40	14,8
4	120	3,9
Total concentrate	200	67,1
Tailings	–	32,9
Total	–	100,0

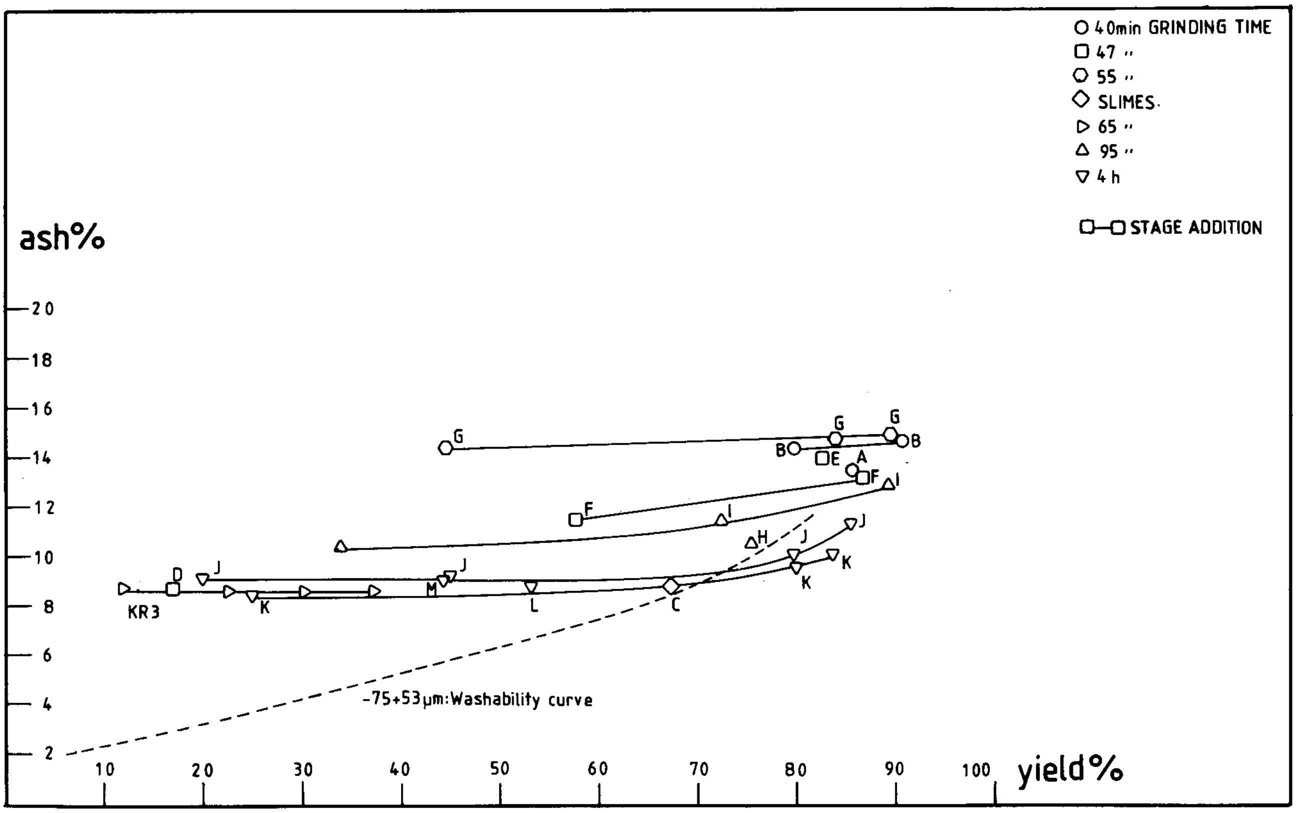

Fig. 9—Grade-recovery relationships in the flotation of reground Landau fines in batch flotation tests

TABLE IX
PROPERTIES OF THE LANDAU SLIMES

Washability of +38 μm fraction		
Relative density		Mass, %
Float 1,50		78,5
1,50 to 1,70		11,7
1,70 to 2,00		2,7
Sink 2,00		1,2
Ash Content		
Relative density	Mass, %	Ash, %
+38 μm fraction	34	9,1
−38 μm fraction	66	23,1
Total feed		18,3

good yields (of more than 80 per cent) at better than 10 per cent ash can be achieved with a very finely ground coal. The slimes from the plant produced a result that coincided with the curve for percentage ash versus yield for the finest coal produced by grinding.

Woodburn *et al.*[4] recently demonstrated very similar performance when floating a low-rank coal from the Northern Hemisphere (NCB 902) using kerosene as a collector. They reported steadily decreasing ash contents in the concentrate as the particle size decreased from 45 μm to less than 20 μm. They also demonstrated very high yields for the ultrafine coal (93 per cent yield at 7,5 per cent ash from feed with an ash content of 14,4 per cent).

Flotation of Ultrafine Coal in a Continuous Pilot Plant

The results obtained in the batch flotation of ultrafine coal were very encouraging in the sense that they offered the possibility of a dual process in which the dense-medium cyclone is used for the coarser fines and flotation is practised for the ultrafines. Accordingly, the flotation of ultrafine Landau slimes was investigated in a continuous pilot plant. A simple open-circuit configuration as shown in Fig. 10 was used for the testwork. The properties of the feed material are summarized in Table IX.

The slurry was made up in a batch in the sump and circulated to a constant-head tank, from which it fed the sump of a variable-speed positive-displacement monopump. The feed rate to the flotation cells was controlled by the pump speed. Collector was added to the sump of the feed pump, and frother to the inlet weir of the first cell. A second stage of frother and collector addition was made at the overflow weir from the fourth rougher cell. Aeration at positive pressure was supplied from the compressed-air main. The total air supply was monitored through a rotameter and controlled manually. A fixed impeller speed of 900 r/min was used in all the cells. Timed samples of concentrate were collected from each cell, as well as composite concentrates from the rougher and scavenger banks. The total flowrates of pulp and solids were determined, as were the ash content, particle-size distribution, and relative-density distribution for each concentrate.

The results of two tests are given in Tables X to XIV, and more extensive detailed results are available elsewhere[5].

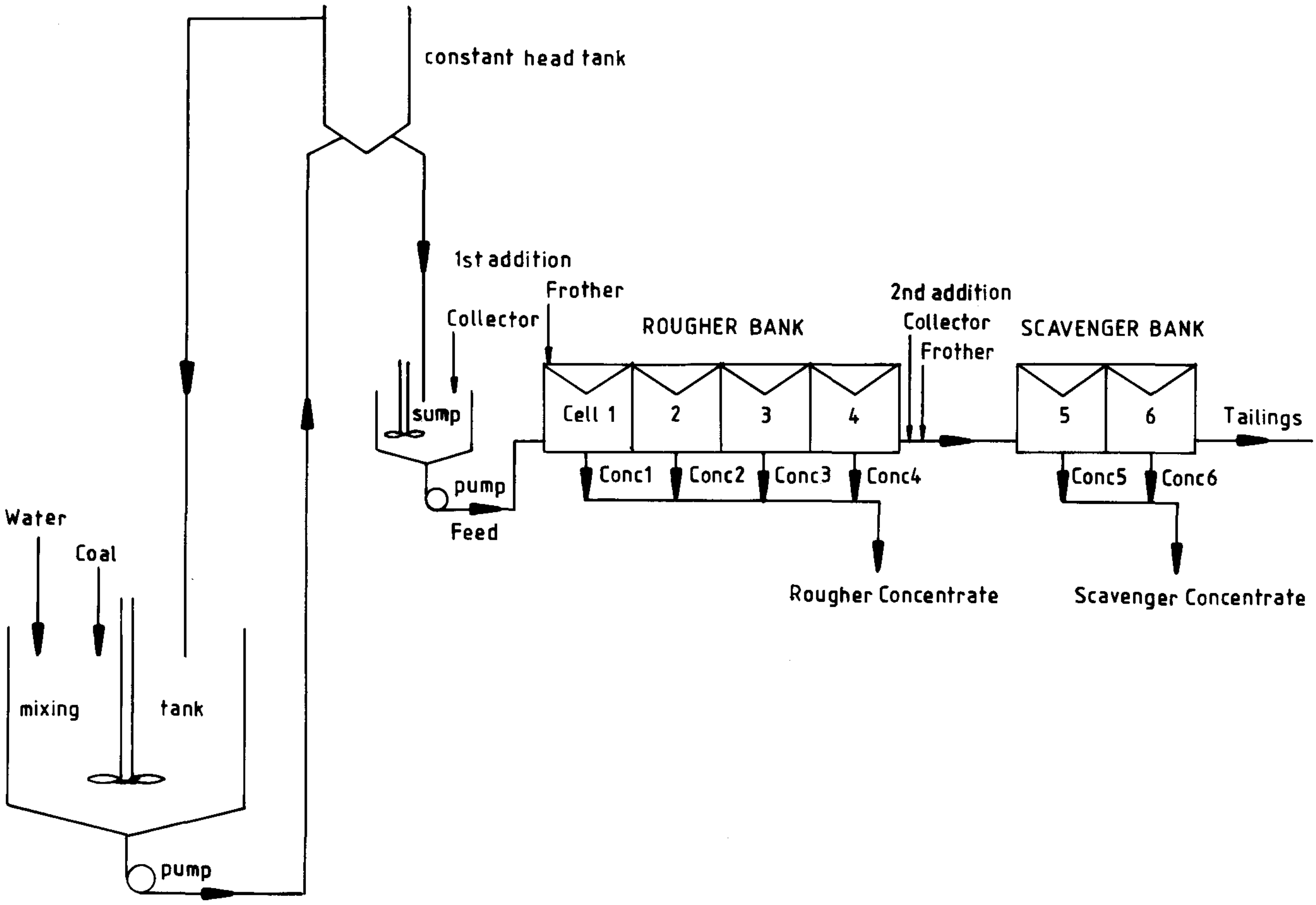

Fig. 10—Layout of the continuous pilot plant for the flotation of ultrafine coal

TABLE X
RESULTS FROM TEST 5

Conditions
Pulp density 4,6% solids
Collector Shellsol A, 3 kg/t
Frother MIBC, 0,115 kg/t
Aeration rate 17,5 l/min per cell

Sample	Flowrate of pulp kg/min	Flowrate of coal kg/min	Yield %	Ash content %
Combined conct. 1	1,60	0,26	70,3	8,7
Tailing 1	7,70	0,11	29,7	36,6
Reconstituted feed	9,32	0,37	100,0	17,0
Combined conct. 2	1,14	0,15	42,0	7,6
Tailing 2	8,08	0,20	58,0	24,2
Reconstituted feed	9,22	0,35	100,0	17,3
Cell 1	0,79	0,110	37,1	7,7
Cell 2	0,30	0,047	15,8	8,6
Cell 3	0,16	0,020	6,8	8,6
Cell 4	0,05	0,007	2,3	9,2
Total concentrate	1,30	0,184	62,0	8,1
Tailing	6,88	0,113	38,0	33,8
Reconstituted feed	8,18	0,297	100,0	17,9

TABLE XI

PARTICLE-SIZE DISTRIBUTION OF CONCENTRATES FROM TEST 5

Particle size µm	Combined concentrate 1		Tailing 1	
	Distribution, %	Yield, %	Distribution, %	Yield, %
+ 53	24,5	57,4	43,1	42,6
− 53 + 38	7,7	84,7	3,3	15,3
− 38 + 25	8,6	83,3	4,1	16,7
− 25	59,2	73,9	49,5	26,1
Total	100,0	70,3	100,0	29,7

TABLE XII

RESULTS FROM TEST 6

Conditions

Pulp density 4,6%
Collector Shellsol A 2,6 kg/t (rougher), plus 1,77 kg/t (scavenger)
Frother MIBC 0,128 kg/t
Aeration rate 10,7 l/min per cell

Sample	Flowrate of pulp kg/min	Flowrate of coal kg/min	Yield %	Ash content %
Cell 1	0,72	0,119	30,6	7,8
Cell 2	0,17	0,018	4,5	9,0
Cell 3	0,15	0,017	4,3	7,7
Cell 4	0,06	0,006	1,6	7,2
Total (1 to 4)	1,10	0,160	41,1	7,9
Cell 5	0,88	0,135	34,8	10,5
Cell 6	0,29	0,034	8,8	13,4
Total (5 to 6)	1,17	0,169	43,6	11,1
Total (1 to 6)	2,27	0,329	84,7	9,5
Tailing	7,94	0,059	15,3	67,2
Reconstituted feed	10,20	0,388	100,0	18,3

Combined concentrates

Collector Shellsol A 2,25 kg/t (rougher) plus 1,52 kg/t (scavenger)
Frother MIBC 0,11 kg/t

Sample	Flowrate of pulp kg/min	Flowrate of coal kg/min	Yield %	Ash content %
Rougher conct.	1,13	0,159	35,2	7,6
Scavenger conct.	0,96	0,233	51,8	11,3
Total	2,09	0,392	87,0	9,8
Tailing	6,74	0,058	13,0	64,0
Reconstituted feed	8,83	0,450	100,0	16,8

TABLE XIII
DISTRIBUTION OF DENSITY FRACTIONS IN TEST 6

Condition
Size fraction + 38 μm

Sample	Density fraction				Total
	Float 1,50	1,50 to 1,70	1,70 to 2,00	Sink 2,00	
Cell 1	83,96	14,58	1,31	0,16	100,00
Cell 2	60,91	31,48	7,20	0,41	100,00
Cell 3	81,87	14,35	1,39	2,39	100,00
Cell 4	82,09	16,47	1,13	0,31	100,00
Cell 5	78,80	17,99	2,77	0,43	100,00
Cell 6	74,46	21,12	3,80	0,62	100,00
Tailing	47,10	22,01	6,24	24,65	100,00
Total	78,48	17,70	2,66	1,16	100,00

TABLE XIV
PERCENTAGE RECOVERY OF DENSITY FRACTIONS IN TEST 6

Condition
Size fraction + 38 μm

Sample	Density fraction			
	Float 1,50	1,50 to 1,70	1,70 to 2,00	Sink 2,00
Cells 1 to 4	27,1	21,8	14,3	5,3
Cells 5 to 6	71,1	74,3	78,4	28,1
Total	98,2	96,1	92,6	33,4
Tailing	1,87	3,89	7,36	66,5

The result of primary interest is the relationship between ash content and yield, and this is shown in Fig. 11. The characteristic flat shape of this curve mirrors that found in the batch tests, and it was possible to achieve the high yields already found for ultrafine coal in the batch flotation cell. A yield of 88 per cent at an ash content of 10 per cent was obtained. The maximum rate of flotation was found in the -53 μm $+$ 38 μm size fraction in test 5, which is somewhat smaller than the fastest-floating size found for fines in the batch cell (Fig. 5). The recovery of individual density fractions is shown in Table XIV, and the gradual decrease in flotation rate with relative density is again evident. These results can be compared with those shown in Fig. 6 for the flotation of coarser material in the batch cell. The greater degree of liberation of ash in the ultrafines allows higher yields at 10 per cent ash than in the coarser material, in spite of the persistent lack of selectivity in flotation rate.

The high yield at 10 per cent ash would represent acceptable performance for industrial coal-washing operations, where the production of a middlings product is viable.

After the results[5] of the flotation of ultrafines from this study had been published early in 1985, Anglo American Corporation installed a small 3-cell pilot plant at Landau Colliery to assess the applicability of the results in an industrial environment. A feed was taken from the desliming hydrocyclone overflow and, after conditioning, was subjected to continuous flotation. The results of that investigation were reported recently[6], and they are summarized in Fig. 11. The results are seen to confirm the results of the present study and even to improve on them, using a continuous feed of ultrafine coal from the plant. It is interesting that the unusually flat response of percentage ash versus yield was reproduced in the industrial plant. Further pilot-plant work by Anglo American Corporation is now in progress, using both microbubble column and conventional flotation cells. There are indications that ultrafine flotation will prove to be viable in many South African collieries.

Conclusions

The poor flotation performance of fine coal from Landau Colliery on the Witbank Coalfield is due primarily to the low selectivity exhibited by particles that contain ash. The difference in flotation rate is very small for particles ranging in relative density from 1,3 to 1,7 (and ash content from 2 to 31 per cent). Good flotation performance can be expected only if the coal is very fine and fine enough to liberate a substantial fraction of the ash. The rate of flotation does not fall off particularly rapidly as the size decreases, and this allows high yields to be obtained even for ultrafine coal. The favourable relationship between ash content and yield found during the batch flotation of ultrafine coal was reproduced in a continuous pilot plant, confirming that the flotation of ultrafine coal can form the basis of a viable industrial process for the beneficiation of fine coal, of which considerable quantities are currently being dumped in South Africa.

Acknowledgements

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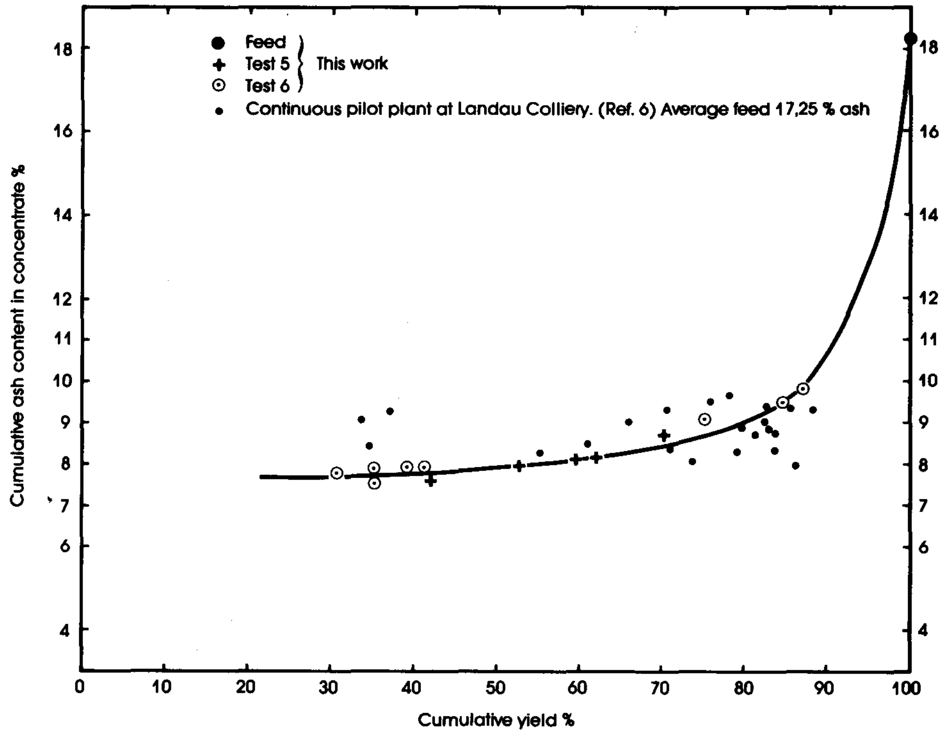

Fig. 11—Grade-recovery relationships in the flotation of ultrafines in the continuous pilot plant. Data obtained on a continuous pilot plant at Landau Colliery are also shown, confirming that the present results are achievable under industrial conditions

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Donation to university

In February, Mr Robin Plumbridge, Chairman and Chief Executive of Gold Fields of South Africa Limited, presented Professor Mike De Vries, Rector and Vice Chancellor of the University of Stellenbosch, with a cheque for one million rands on behalf of The Gold Fields Foundation.

This is the largest single donation that the University of Stellenbosch has ever received, and will enable the University to provide residential facilities for about a hundred students to the northern end of the campus. 'In style and appearance this accommodation will be somewhat different from what our students have been used to', said Professor De Vries. 'Instead of the traditional style, preference will be given to the concept of modular housing'.

Eight modules are to be built with The Gold Fields Foundation's donation. The individual modules will be named after the gold mines in the Gold Fields Group, which are Kloof, Doornfontein, Venterspost, Libanon, Deelkraal, East Driefontein, West Driefontein, and Leeudorn. A module will comprise two units built on two levels, each with its own sitting-room, kitchen, and toilet facilities. Each will house six students, i.e. twelve students per module. The modules will be sited to form a square, and every design precaution has been taken to ensure that the buildings do not detract from the environment. The completion date has been set for early in December 1986, which means students will move in at the beginning of the 1987 academic year.

Professor De Vries said that Coloured, Black, and Asian students would, for the time being, enjoy preference in the allocation of accommodation in the new Gold Fields complex. He added: 'This new complex will also afford the University greater scope for broadening its education spectrum and extending equal opportunities for study and participation in university activities to all students irrespective of race, colour, or creed.'