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BENEFICIATION OF FINE COAL IN THE REPUBLIC OF SOUTH AFRICA

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Synopsis

The beneficiation of minus 0,5 mm coal in the Republic of South Africa is reviewed in terms of the availability of fines, the formidability of its cleaning, and cleaning processes. As regards the latter, specific reference is made to froth flotation, autogenous cyclones, tables, and dense medium cyclones.

1. Introduction

The need to utilize coal resources judiciously is of global concern. This not only implies optimisation of the production sequence (eg. mining, beneficiation, transport) but also the need to apply the product to the greatest advantage.

As regards the utilization of -0,5 mm coal, South Africa stands guilty. Because of the difficulty of cleaning these fines, present practice is either to dump it or add it to steam coal, the latter option adding to the problems of the end user. If it is borne in mind that these fines constitute a potential source of low ash content coal (7% ash) then both options constitute a wastage of a prime product.

Assuming the fines can be upgraded economically, then its use as a blend coking coal constitutes an immediate outlet. Application as a feedstock for the chemical industry is a further potential outlet and the exciting prospect of producing an ashless intermediate, via solvent refining or extraction routes, comes to mind.

2. Availability of Raw Fines

The quantity of fines available, and hence of an upgraded product, can be estimated given the coal trade and size distribution data.

The latest figures available to the Fuel Research Institute of South Africa, on annual coal sales and its distribution are condensed in Table 1.

1)

Table 1

Annual Coal Sales and Distribution During 1975

Consumer	Tons x 10^6	%
Export*	2,29	3,3
Inland:		
1. Power (P F)	41,33 (29,33)	59,9 (42,5)
1. Power (Other)	(12,00)	(17,4)
2. Other**	25,39	36,8
	69,01	100,0

*Projected figure for 1977: In excess of 10 million tons

**Includes: rail transport, mining, industry carbonization and household.

According to Table I, 42,5% of the coal traded during 1975 was combusted in the pulverized state. Low ash product retrieval from this coal is not deemed likely in the near future. The generation of available fines is therefore largely due to the 37,39 (25,39 + 12,00) million tons of coal traded on the inland market.

It is difficult to be precise about the size grading for the industry as a whole, since the grading varies from mine to mine.

Raab [2)3)] has shown that the content of -0,5 mm material in run-of-mine coal varies between 2 and 9 per cent, depending on the degree of mechanization. Crushing of the run-of-mine coal will shift the average towards the higher limit, and an 8% fines content for the industry as a whole is considered not unrealistic.

On this basis it is estimated that some 2,99 million tons of -0,5 mm coal was generated during 1975. The figure projected for 1977 is 3,4 million tons, assuming the average growth rate recorded during the period 1973 to 1975 to be maintained.

3. Potential Quantity of Upgraded Product

Data on the washability of -0,5 mm fines is not yet as well established as that of the +0,5 mm coal. It is well known only for those coals from which a low ash content product is currently being prepared for export to the Japanese Steel Industry.

Typical data for Witbank coal are illustrated in Table II.

[4)]

Table II

Washability of No. 2 Seam Coal, Witbank Area

0,5 x 0,075 mm Size Fraction

Relative density	Fractional		Cumulative	
	Yield %	Ash %	Yield %	Ash %
F 1,30	14,8	2,9	14,8	2,9
1,30 - 1,40	14,7	5,5	29,5	4,2
1,40 - 1,50	25,4	8,7	54,9	6,3
1,50 - 1,60	24,7	17,0	79,6	9,6
1,60 - 1,70	5,9	29,0	85,5	10,9
1,70 - 1,80	3,1	37,3	88,6	11,9
S 1,80	11,4	63,5	-	-
	100,0		100,0	17,8

Table II indicates a theoretical yield of 61% at an ash content of 7%. Assuming a conservative yield of 40% (i.e. an organic efficiency of only 66,6%) for the industry as a whole some 1,3 million tons of 7% ash coal is potentially available per annum.

Clearly not all of this is economically exploitable. Factors such as the available market, the output and existing cleaning facilities at individual collieries, etc, will play an important role. Nevertheless, the potential is there and attempts at exploiting it should be made.

4. Formidability of Cleaning

Reference has already been made to the difficulty of cleaning -0,5 mm coal. This is due to the high proportion of near-density material*, which for South African coal averages at about 50%, but can range from 25 to 75%. (The coal listed in Table II, for example, contains 49% near-density material at 1,51 relative density, the cut-point required to produce a 7% ash content product).

Bird[5] has related the degree of separating difficulty to the near-density content of the coal, stating that if this exceeds 25% the separation becomes formidable. Just how formidable is shown in Figure I, in which the solid lines relate to a 7% ash content product.

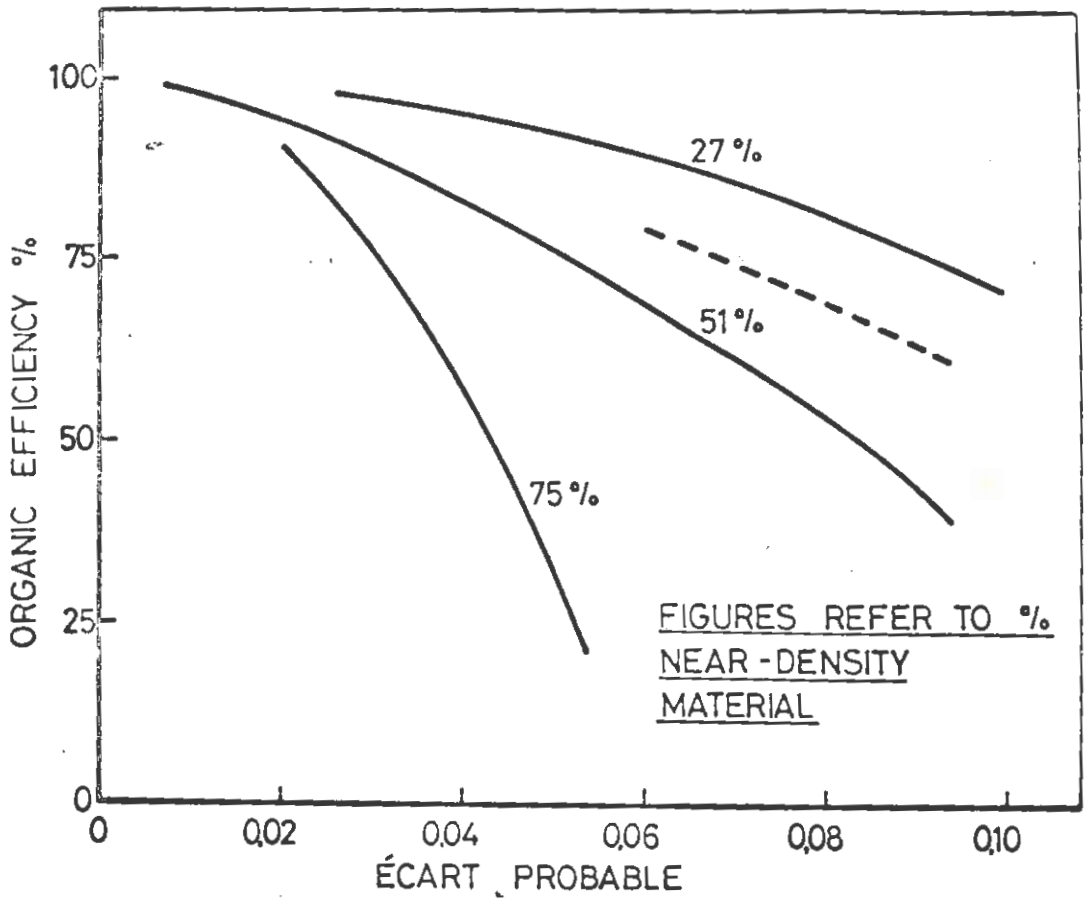

FIGURE 1

The curves reproduced in the figure were obtained by computer simulation of the washing process. Use was made of statistical data[6] on the performance of the Institute's cyclone washer operating on +0,5 mm coal. It was assumed that the characteristic shape of the partition curve is not too seriously altered by a reduction in the coal size.

Figure I relates the organic efficiency to the écart probable at three different levels of near-density content. The salient point is the low écart probable values required to effect efficient separation. Consider for

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* Material with a relative density lying between the limits 0,1 on either side of the cut-point.

example the extreme case, i.e. a 75% near-density content. The required écart probable is of the order of 0,03 to achieve a 75% organic efficiency.

The écart probable requirements are less stringent for products having ash contents greater than 7%. This is illustrated by the broken line in the figure, which relates to an 8% ash content product derived from a 51% near-density content coal.

The curves must not be interpreted as hard-and-fast but rather as indicative. Nevertheless, from the South African point of view, the écart probable forms a convenient means of judging whether a unit will find likely application.

In order to effect acceptable organic efficiencies, we have selected écart probable values of 0,06 or better as the ideal for units to be employed in the local production of a 7% ash content product.

Similar results and conclusions obtained by Horsfall*, a member of the Institute's Research Advisory Committee, were presented to the Fuel Research Board in support of the need to establish a dense medium cyclone plant for the cleaning of -0,5 mm fines (See section 6.2)

5. Cleaning Methods

The commissioning of the Institute's coal preparation pilot plant in 1957 marks the true birth of the technology in South Africa. The initial objective of the pilot plants was performance evaluation of a variety of units under local conditions. Since then, considerable experience has accumulated on the cleaning of large coal (+12 mm) and small coal (12 x 0,5 mm).

Flotation cells were originally included to clean the shale medium for the Barvoys washer, now no longer in existence. It was not until 1960 that these were used in the cleaning of -0,5 mm coal. Attention has since also focused on other possible routes for upgrading -0,5 mm coal, viz., autogenous cyclones, tables, and dense medium cyclones. Of these, dense medium cyclones are considered the more promising and currently absorb the greater part of the research effort.

A brief review of the results obtained on the various units is given below.

5.1 Froth Flotation

Froth flotation is probably the best established method of cleaning -0,5 mm fines and is in extensive use abroad. In South Africa, however, flotation is at present confined to the upgrading of coking coals from the Natal coalfield and four units are currently in operation in that area.

Even for coking coals, which by South African standards are classified as amenable to flotation, the process is not altogether straightforward. This is revealed by an in-depth study[7] on the batch-wise flotation of a coking coal using paraffin and MIBC** reagents.

The results obtained indicate that (i) there is no definite relation between product recovery and the ash content of the product; (ii) the method of

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* Consulting metallurgist, Anglo American Corporation of South Africa Limited.

** Methyl-isobutyl-carbinol.

The concept of graphically relating the organic efficiency to the écart probable was first introduced by Horsfall in 1974, September 18th at a Metallurgical Colloqium under the auspices of S.A. Institute of Mining and Metallurgy.

The écart probable was found to be of the order of 0,25 and the cut-point in the region of 1,7 relative density. The improvement of the ash content was found to be some 2 to 3 per cent; the corresponding organic efficiency was disappointingly low, being of the order of 80 per cent.

Classification causes the cut-point of the various size fractions to be distributed over a relatively wide range, with the overall cut-point increasing as the proportion of fines within the feed increases.

The work on autogenous cyclones was extended to include compound water cyclones (tri-cones). Orientating tests were initially conducted using a 100 mm diameter unit; investigations were subsequently extended to include a 200 mm diameter unit capable of treating -3 mm coal at a rate of 5 tons per hour.

A series of tests were conducted to optimize the vortex finder diameter and clearance, the apex diameter, and the inlet pressure. Once established, tests proper were conducted using a relatively easy-to-clean coal, i.e. near-density material being 23 per cent.

Typical performance results recorded by Saler [14] are condensed in Table IV.

Table IV

Performance of a 200 mm Compound Water Cyclone

Near-Density Material: 23%

Solids in Feed: 10%

Size µm	% of feed	Yield %	Écart probable	Product ash %
+ 500	28,0	50,2	0,088	6,2
+ 250	67,9	58,6	0,20	6,8
+ 150	86,4	62,1	0,25	7,1
+ 75	100,0	65,0	0,31	7,4

Two points emerge from Table IV. Firstly, it will be noted that the écart probable rapidly deteriorates with successive inclusion of the finer fractions of the feed. The high écart probale for the +0,075 mm material indicates unsuitability as regards cleaning of coal high in near-density content.

Secondly, the relative sensitivity of the yield to successive inclusion of the finer fractions implies an increase in cut-point for the smaller size fractions. (The ash data bear this out). This is more clearly illustrated in Table V.

Table V

Cut-Point Versus Size Grading

200 mm Compund Water Cyclone

Size µm	Yield %	Cut-Point
+ 500	50,2	1,415
500 x 250	64,5	1,590
250 x 150	74,9	> 2,0
150 x 75	83,7	> 2,0

Saler argues that classification overrides cleaning for the smaller size fractions.

5.3 Tabling

Tabling is a popular means of upgrading small and fine coal in the USA, but has not found commercial application in South Africa. The Institute nevertheless acquired a quarter-size Deister table during 1972 in order to evaluate its performance on -0,5 mm coal.

The following is typical of the results recorded. A raw coal, having an ash content of 15,3% could be upgraded to 8,1% ash at a yield of 51,4%. Desliming at 0,075 mm changed the ash content and yield to 6,9% and 46,5%, respectively [15], representing an organic efficiency of 71,6%.

The écart probables recorded were of the order of 0,08 and although this looks reasonable serious "tails", increasing the ash content of the product, were revealed by the partition data.

A major draw-back is the low capacity of the units. Indications are that if a 7% ash content product is to be derived from 1 x 0 mm coal the load on the quarter-size table should be about 0,5 ton/hour.

5.4 Combinations

Various combinations of flotation, water only cyclones and tables were investigated [10]. A low ash content product of about 7% ash could only be obtained if the table were used as the 2nd stage unit. The disadvantage of low capacity still applies to this configuration.

6. Dense Medium Cyclones

6.1 Introduction

Traditionally, dense medium cyclones were used to clean raw coal deslimed at 0,5 mm. Stamicarbon and Evence-Coppee [16] extended the field of application to include undeslimed raw coals. As a result two full-scale plants were erected in Belgium viz., Tetre and Winterslag.

The results [16] obtained on one of the full-scale plants were reported as:

Table VI

Size grading (mm)	Separation r.d.	Écart probable
9,53 x 0,84	1,57	0,035
0,84 x 0,30	1,63	0,05
0,30 x 0,15	1,83	0,10

Pilot plant investigations [17] conducted at the US Bureau of Mines revealed somewhat higher écart probable values, e.g. 0,158 for a 0,3 x 0,15 mm size range. They considered the cyclone an attractive tool for coals high in near-density content and for low separating relative densities.

From the South African point of view these results were encouraging, in that the reported écart probable values are close to that considered necessary for effective cleaning of local coals high in near-density content. In fact, the results played a significant role in the decision to proceed with the erection of a dense medium cyclone pilot plant for coal fines.

6.2 The Pilot Plant

Erection of the plant commenced in 1976 and commissioning during the first quarter of 1977.

A simplified solids and medium flow sheet is reproduced in Figure II.

The nominal 0,5 x 0 mm raw coal is deslimed in a cyclone and dewatered on an AEG screen. The 0,5 x 0,075 mm cut is mixed with correct dense medium and pumped to the separating cyclone. Magnetite recovery from the cleaned coal is effected in a bank of magnetic separators, the cleaned coal being thickened in a cyclone and finally dewatered on an AEG screen. The discard from the separating cyclone is treated likewise.

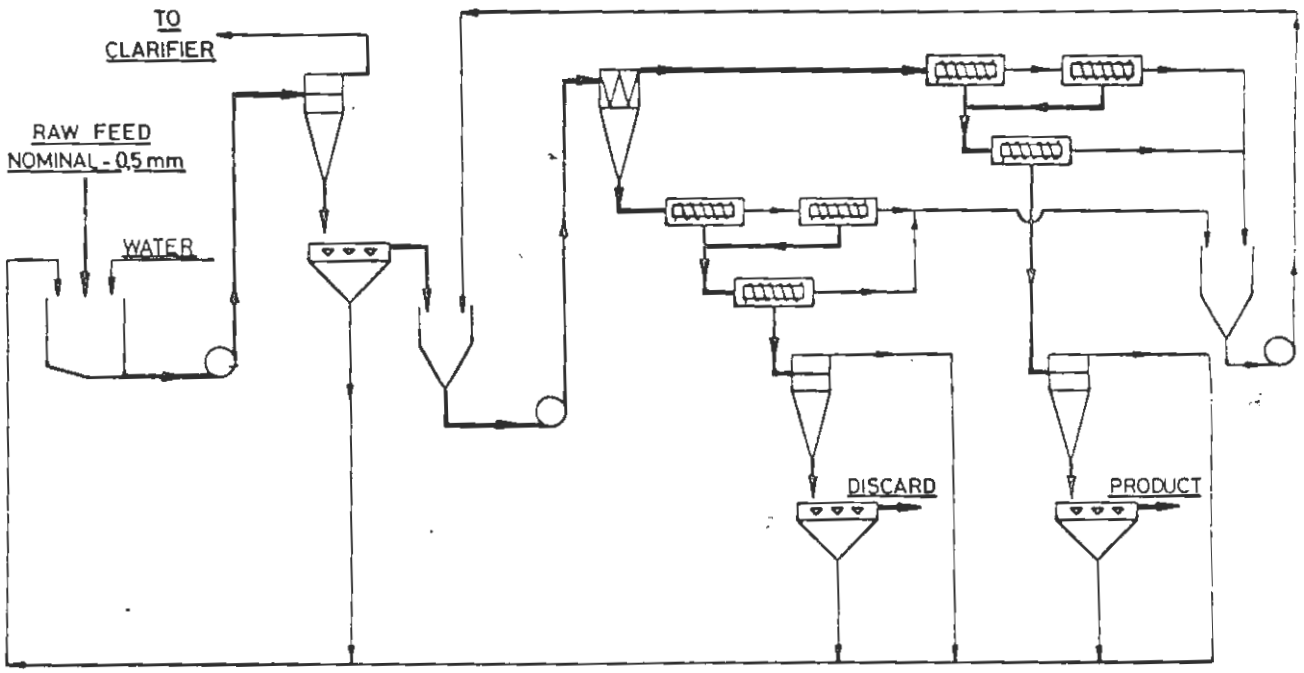

FIGURE 2

SOLIDS AND MEDIUM RECOVERY FLOW-SHEET

Each bank of magnetic separators comprises a rougher unit feeding to a cleaner unit, and the under-flows from both report to a scavenger unit.

Some of the characteristics of the separating cyclone are:

1) Maximum coal feed rate : 5 000 kg/h
2) Pulp feed rate : 35 000 l/h
3) Operating pressure range : 125 - 140 kPa
4) Diameter : 150 mm

6.3 Results

The research program proper comprises two main objectives, viz., a) the optimisation of the parameters of the separating cyclone, and b) the establishment of an effective magnetic recovery circuit.

As a first step a number of orientating tests were conducted on the plant as designed. Only the results of these were available at the time of writing.

The screen analyses of the circulating medium are given in Table VII.

Table VII

Screen Analyses of Medium

Size	Percentage oversize	
µm	Initial	After 7 tests
250	0,9	1,3
90	1,8	3,9
50	5,5	7,3
32	33,8	36,5
20	90,4	95,4

The variation in the size consist is attributed to two factors, viz., (i) magnetite losses occuring in the plant, and (ii) magentite contamination of the raw feed. (Contamination occured at the supplying collieries)

The raw feeds utilized for preliminary performance evaluation had the following size distribution:

Table VIII

Screen analyses of Feed Coal

Size	Percentage oversize		
mm	Test A	Test B	Test C
1	5,6	4,0	0,2
0,5	28,0	20,0	18,0
0,25	60,0	46,0	51,7

Corresponding plant performance data are condensed in Table IX.

Table IX

Plant Performance Data

Test No.	Near-density material	Cut-point	Organic efficiency	Écart probable	
-	%	-	%	75/25	90/10
A	51	1,46	89,3	0,035	0,072
B	25	1,57	85,3	0,063	0,103
C	49	1,44	80,1	0,073	0,193

The reported écart probable values refer to the overall size range. It is doubtful whether the superior écart probable value recorded for test A is solely due to the "coarseness" of the feed coal. More detailed information is required to clarify this point.

A drawback of the écart probable is that it takes no cognizance of the asymmetry of the partition curve. The degree of asymmetry is best illustrated by the ratio $(d_{50}-d_{75})/(d_{25}-d_{50})$, wherein d_{25}, d_{50}, and d_{75} are the relative densities corresponding to partition coefficients of 25, 50 and 75, respectively.

Table X

The Asymmetry of the Partition Curve

Test No.	Cut-point	$\frac{d_{50}-d_{75}}{d_{25}-d_{50}}$
A	1,46	1,35
B	1,57	0,98
C	1,44	1,21

Indications are that the ratio increases with decreasing cut-point. A similar trend [6] was observed from the results using the Institute's cyclone washer for treating small coal.

Initial indications are that the magnetite losses are somewhat high, being in the range of 2 to 3 kg/t of feed coal.

7. Conclusions

A number of processes have been developed to treat -0,5 mm coal. Though the best established are apparently not suitable from the South African point of view, further investigations may result in improved efficiency.

The results recorded to date indicate the dense medium cyclone to be the most promising unit as regards difficult feeds.

8. Acknowledgement

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