Journal Paper

Optimal coal processing route for the 3 x 0.5 mm size fraction?

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Synopsis

Traditionally the feed to dense-medium cyclones was deslimed at 0.5 mm and the minus 0.5 mm size fraction was then processed in spirals. With the increase in the diameter of dense-medium cyclones, the particle size at which the cyclone feed coal is de-slimed has also increased to approximately 3 mm. Processing the minus 3 mm coal in water-only processes such as spirals and teetered bed separators does not provide the most viable beneficiation route since dense-medium cyclones, even the large diameter units, can more effectively process this coal. The paper reviews the different processing routes available for the minus 3 mm size fraction and provides data from actual test work conducted.

Introduction

Traditionally the feed to coal preparation plants was deslimed at 0.5 mm. The +0.5 mm size fraction was processed via dense-medium cyclones and the -0.5 mm size fraction was beneficiated with froth flotation, water-only cyclones or spirals.

With the introduction of large diameter cyclones, the aperture sizes of desliming screens have progressively increased to about 3 mm in the belief that the larger cyclones are not able to effectively beneficiate coal that has a particle size below the 'breakaway' size. The efficiency of separation in the large dense-medium cyclones is improved by presenting a coarser feed to the units. At the same time, the capacity of the desliming screens is increased due to the larger screen apertures and in effect, the throughput capacity of the dense-medium section is increased.

The 3 x 0.5 mm size fraction, which was previously processed in the dense-medium cyclones, is now added to the fine coal size fraction and processed by water-only methods such as teetered bed separators (TBS) and spirals. Whether this practice is the most economical way to process the 3 x 0.5 mm size fraction requires further thought since the best processing route for the 3 x 0.5 mm size fraction will depend on a number of factors, among which are:

- The washability of the coal and the amount of near-density material
- Processing efficiency
- Specification of the required product
- The price paid by the customer for the product
- The cost of processing the coal.

Breakaway size

The 'breakaway' size is defined as the particle size below which the Epm of the smaller particles starts to decrease significantly. Bosman[1] provides an approximate breakaway size versus cyclone diameter (Figure 1). It should be kept in mind though that the Epm of the small particles is a function not only of the cyclone diameter but also of feed pressure, medium density, medium viscosity, particle shape and density, top size of particles in the feed, etc.

Figure 2 shows the partition curve obtained for the 3 x 0.5 mm size fraction from an 800 mm dense-medium cyclone processing minus 50 mm coal.

The performance data for the separation shown in Figure 2 are summarized in Table I.

The partition curve shown in Figure 3 depicts the recovery efficiency for the 2 x 0.5 mm size fraction, measured in a 660 mm dense-medium cyclone processing minus 50 mm coal.

The performance efficiency is summarized in Table II.

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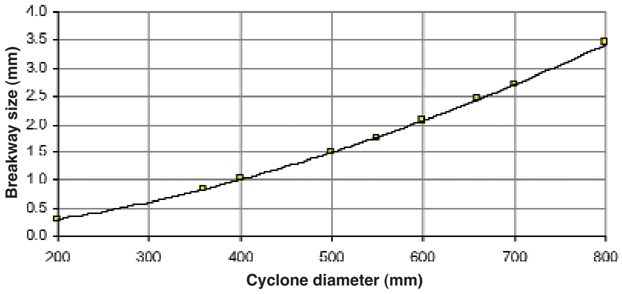

Figure 1—Breakaway size versus cyclone diameter[1]

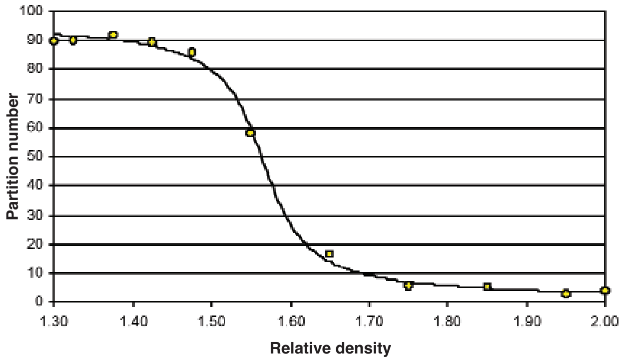

Figure 2—Partition curve for 800 mm DM Cyclone: -3 +0.5 mm size fraction

One can see from the data that the separation efficiency achieved on the fine size fractions is somewhat impaired, compared to the efficiency of separation of the coarser size ranges. The recovery efficiency is, however, still superior to some water-only processes.

Alternative processing options

When desliming the feed to the dense-medium cyclones at 3 mm, the coal in the desliming screen underflow reports to the fines stream. This coal is usually further deslimed with hydrocyclones to yield a nominal plus 100-micron size fraction, which is sent to the fine coal beneficiation circuit. In South Africa, spirals are still the fine coal processing method of choice. There is, however, a move towards accepting the TBS as an alternative to spirals.

Dense-medium beneficiation of fine coal has been successfully employed in the past and there is now a renewed investigation into employing this technique for the beneficiation of fine coal in South Africa. In general, smaller cyclones and higher feed pressures are employed when beneficiating fine coal in dense-medium cyclones.

Extensive test work was conducted at Homer City in the USA[2]. The results obtained from the 3 x 1 mm and 1 x 0.6 mm fractions, which were treated in different circuits using non-industry standard 500 mm cyclones, are shown in Table III.

Test work conducted by the United States Bureau of Mines[3] on 200 mm cyclones produced the results shown in Table IV. It is important to note that the near gravity (+/- 0.1 RD) was 94% for these tests.

When processing the 3 x 0.5 mm size fraction in dedicated dense medium cyclones, relatively sharp separations can be obtained. The partition curve shown in

Table I

Performance data for 800 mm cyclone

Feed % ash	24.1
Product % ash	13.1
Discard % ash	40.0
Product yield %	59.1
SG_{50}	1.563
Epm	0.0430
Organic efficiency %	86.5
Sink in float %	4.8
Float in sink %	9.7
Total misplaced	14.5

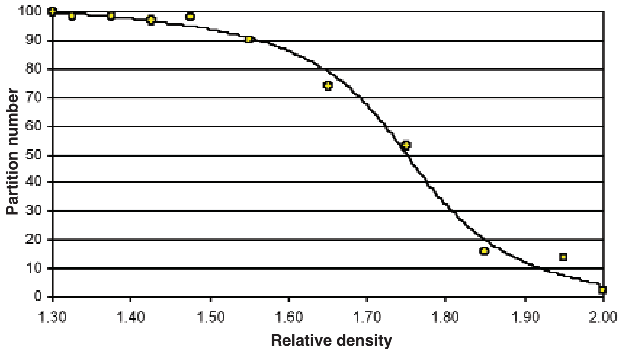

Figure 3—Partition curve for 660 mm DM Cyclone: -2 +0.5 mm size fraction

Table II

Performance data for 660 mm cyclone

Feed % ash	24.6
Product % ash	15.6
Discard % ash	60.8
Product yield %	80.1
SG_{50}	1.750
Epm	0.0791
Organic efficiency %	97.9
Sink in float %	1.5
Float in sink %	5.1
Total misplaced	6.6

Table III

Homer City 3 x 1 mm and 1 x 0.6 mm results

	3 x 1	1 x 0.6
Feed % ash	-	
Product % ash	4.15	4.57
Discard % ash	-	-
Product yield %	45.3	62.2
SG_{50}	1.312	1.38
Epm	0.021	0.031
Organic efficiency %	91.5	90.1
Sink in float %	-	-
Float in sink %	-	-
Total misplaced	-	-

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Figure 4 and the data shown in Table V relate to the separation obtained when processing fine coal (nominal 1 x 0,1 mm) in a two-stage fine coal dense-medium plant.

Spirals can effectively beneficiate fine coal in the minus 1 mm size range. Spirals typically have Epm values of about 0.15 and cut-point densities around 1.80. It is possible to feed the minus 3 mm coal to spirals but the tendency that spirals have towards 'beaching' may be aggravated by the bigger particles in the feed stream.

Upward-current washers, including TBS units, the Reflux Classifier and the Cross-Flow Classifier, have efficiencies very similar to that of spirals. A TBS unit is capable of fairly large capacity per unit area and offers the advantage over spirals that a single unit can process the same tonnage as a multitude of spirals. It is further possible to control the amount of material comprising the teetered bed in the unit, which in turn either lowers or raises the effective cut-point density achieved.

The performance of a Reflux Classifier for a number of closely sized fractions is summarized in Figure 5[4].

In practice a wider range of particle sizes will be processed through the unit. The predicted partition curve for the Reflux Classifier when processing a 3 x 0.5 mm size fraction is shown in Figure 6. The Epm for the overall partition curve is 0.101.

The results obtained from a test conducted on a TBS unit processing 3 x 0.5 mm coal is shown in Table VI. The resulting partition curve is shown in Figure 7.

Table IV

United States Bureau of Mines 200 mm cyclone test work

	3.35 x 0.212
Feed % ash	4.3
Product % ash	1.6
Discard % ash	23.3
Product yield %	87.3
SG_{50}	1.35
Epm	0.026
Organic efficiency %	96.7
Sink in float %	0.9
Float in sink %	3.7
Total misplaced	4.6

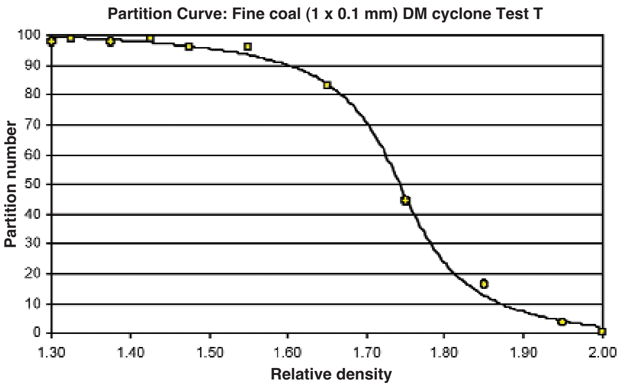

Figure 4—Partition curve for fine coal dense-medium cyclones

Table V

Performance of fine coal dense-medium plant

Feed % ash	26.8
Product % ash	13.8
Discard % ash	64.8
Product yield %	74.5
SG_{50}	1.7427
Epm	0.0537
Organic efficiency %	98.4
Sink in float %	1.2
Float in sink %	2.4
Total misplaced	3.6

Comparison of different options

While it is not always easy to compare the efficiencies obtained in various units at different cut densities, one way to obtain a comparison is to 'normalize' or 'reduce' the measured Epm value. Dividing the Epm by the cut density does this. The result is a normalized or reduced parameter, which can then be used as the basis of a comparison. The normalized Epm values for the various options discussed are shown in Table VII.

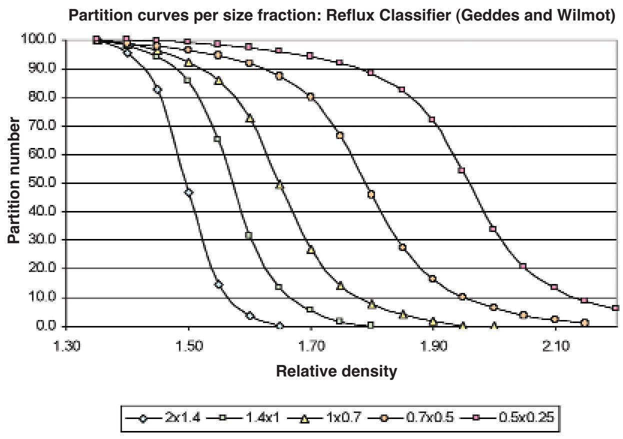

Figure 5—Partition curves for Reflux Classifier: narrow size fractions

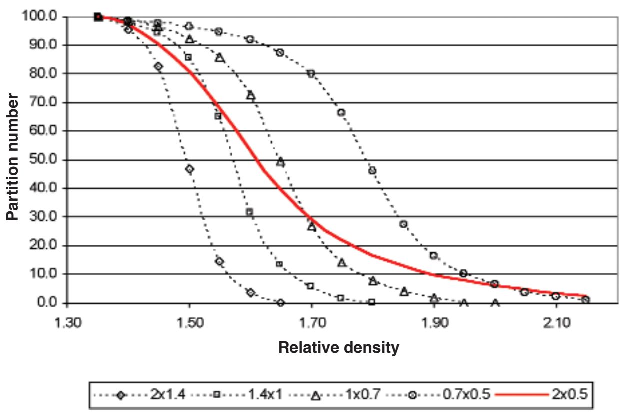

Figure 6—Partition curve for Reflux Classifier: 3 x 0.5 mm size fraction

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Table VI

Performance of TBS unit: 3 x 0.5 mm size fraction

Feed % ash	23.2
Product % ash	12.3
Discard % ash	48.6
Product yield %	69.9
SG_{50}	1.672
Epm	0.1043
Organic efficiency %	93.6
Sink in float %	3.4
Float in sink %	8.3
Total misplaced	11.7

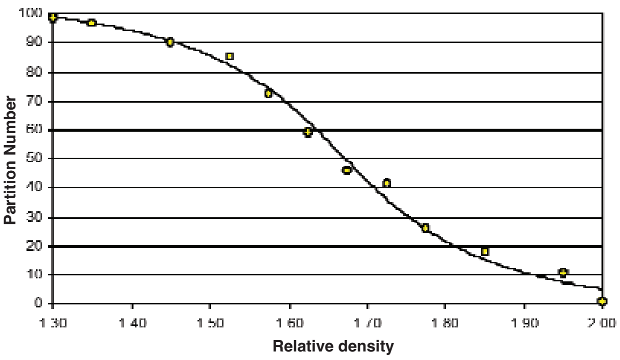

Figure 7—Partition curve for TBS processing - 3 +0.5 mm size fraction

The following important facts can be derived from the results:

- For medium based separation, a higher efficiency is achieved by treating the fine fraction separately from the coarser fraction
- Medium based separation, both combined and separate and for small and large cyclone diameters results in a better efficiency compared to treating the same fraction in a water based process.

Choosing the best option

The best processing route for the 3 x 0.5 mm size fraction will largely be decided by economic considerations. The option resulting in the best financial return will be the preferred option. It is, however, necessary to identify all the contributing variables before a decision can be made. Amongst other things, the following factors will need to be considered:

- If a high value product can be produced from the 3 x 0.5 mm size fraction, the most efficient process should be considered to maximize the yield of saleable coal
- Difficult-to-wash raw coals with high near-density material may be effectively beneficiated with only an efficient process
- Dense-medium processing is usually more expensive than water-only processes since magnetite is consumed. Often, the cost of magnetite is more than compensated for by the improved recovery efficiency of dense-medium processes.
- If existing dense-medium cyclone plant capacity is a consideration, an increase in desliming screen aperture could be a possible means of improving capacity. An increase in fine coal processing plant would, however, be necessary.
- When processing (low-price) coal for the local thermal coal market, it would normally be more cost-effective to employ the cheaper water-only processes to beneficiate the 3 x 0.5 mm size fraction.

Conclusion

Each plant is unique in terms of the coal processed, the products produced, and the customers provided with such products. It is therefore necessary to assess the optimal processing route for each size fraction in every case. The best size at which to deslime the feed to the dense-medium cyclones and the subsequent processing route for the de-sliming screen underflow material will have to be considered individually. Knowing the processing efficiency of the different processes available greatly assists in making such decisions.

References

1. Bosman, J. Dense Medium Cyclones – Sizing and Selection. Paper presented at the *9th Technical Dense Medium Symposium*. 1994.
2. Gonan, T. and Chedgy, D. Processing Various Coal Sizes at Ultra-Low Separations in the Homer City Coal Preparation Facility.
3. Deurbrock, A. Washing Fine Size Coal in a Dense Medium Cyclone, Bureau of Mines Report of Investigation, 1974
4. Geddes, A. and Wilmot, S. The Development and Commercialization of the Ludowici MPE Reflux Classifier. Ludowici Mineral Processing Equipment, Pty. Ltd. ◆

Table VII

Comparison of different options using normalized Epm as a parameter

	Medium based						Water based		
	Cyclone 800 mm	Cyclone 660 mm	Cyclone 500 mm	Cyclone 500 mm	Cyclone 200 mm	Cyclone two stage	Spirals two stage	Reflux	TBS
Size	3 x 0.5	2 x 0.5	3 x 1	1 x 6	3.35 x 0.212	1 x 0.1	1 x 0.1	3 x 0.5	3 x 0.5
Epm	0.043	0.079	0.021	0.031	0.026	0.054	0.150	0.101	0.104
SG_{50}	1.563	1.750	1.312	1.380	1.350	1.743	1.800	1.630	1.672
Epm/SG_{50}	0.028	0.045	0.016	0.022	0.019	0.031	0.083	0.062	0.062