Fine Coal Processing with Dense-Medium Cyclones

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Paper to be read at the Fine Coal Symposium "*Challenges in Fine Coal Processing, Dewatering and Disposal"* to be held by the Coal Preparation Society of America, Pittsburgh Section Society for Mining, Metallurgy and Exploration, Inc., and Pittsburgh Coal Mining Institute of America in Pittsburgh, USA from 23 – 25 October 2012.

CSIR/CMI/NMM/EXP/2012/0013/A

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Abstract
Dense-medium cyclones have been used for many years in a number of countries around the world to beneficiate fine coal. The use of cyclones in this application is, however, not widespread and at present, the process is employed only in South Africa and China. The paper provides a brief overview of the past and current application of dense-medium cyclones in the processing of fine coal and reviews some of the important considerations for successful application of the technique.

INTRODUCTION

The dense-medium cyclone has, since its development by the Dutch State Mines almost 70 years ago, become the main processing unit in the coal industry. It is capable of efficient separations even on coals containing high amounts of near-density material and accurate control of product quality is possible. Although cyclones have been proven capable of processing coal down to fine sizes, it is generally applied only to coal coarser in size than 0.5 mm.

Beneficiation of fine coal, nominally below 0.5 mm, with dense-medium cyclones was implemented as long ago as 1957 and cyclones are still being used to process fine coal today but the history shows that the application of cyclones in fine coal processing has not been nearly as successful as in the processing of coarser coal.

There is a perception in the coal processing industry that dense-medium cyclone processing of fine coal is expensive, that it consumes much magnetite and that the separation efficiency is not good. There are, however, some who realize that cyclones are still the most effective means to process fine coals containing elevated amounts of near-density material at low cut-point densities and as such, the technology is presently in limited use in South Africa and widely employed in China.

A BRIEF OVERVIEW OF DENSE-MEDIUM FINE COAL PROCESSING

South Africa
Some of the earliest work on the beneficiation of fine coal with a dense-medium cyclone was carried out in South Africa by the Fuel Research Institute (FRI) of South Africa under the guidance of Dr. PJ van der Walt in 1949. Using a 240 mm diameter cyclone and barites as the dense medium, the results shown in Table 1 were obtained when processing minus 1 mm by 0.25 mm coal. The results showed that fine coal could be processed at a low relative density and with very good separation efficiency.

Table 1. FRI results on fine coal

Test No.	31 A	31 B	31 C	31 D	31 F
RD[1] of separation	1.35	1.37	1.37	1.37	1.32
EPM[2]	0.0387	0.0275	0.0283	0.0345	0.0336
Feed pressure (psi)	25	17.5	10	7.5	4
Feed pressure (kPa)	172	120	70	52	27.6

[1] Relative Density

[2] Ecart Probable Moyen or Probable Error

Belgium
In 1957, a flowsheet was developed by DSM/Stamicarbon and Evence Coppée for a new dense-medium cyclone plant at Tertre in Belgium to process 10 x 0 mm raw coal. The plant was unique in that the feed to the plant was not de-slimed before processing. The raw coal was mixed with magnetite and gravity-fed to two 500 mm diameter (D) cyclones at a feed pressure of 9D. The minus 0.75 mm coal in the feed drained through the product and discard screens into the circulating medium tank. A part of the circulating medium was pumped, using a separate pump, to two 350 mm diameter cyclones at a feed pressure of approximately 30D to affect a separation on the minus 0.75 mm coal. The overflow and underflow medium from the 350 mm diameter cyclones were directed to separate product and discard magnetic separators to recover a fine coal product and discard in the underflows of the magnetic separators. The product and discard were dewatered using conventional dewatering equipment. A simplified flow diagram of the circuit employed at Tertre is shown in Figure 1.

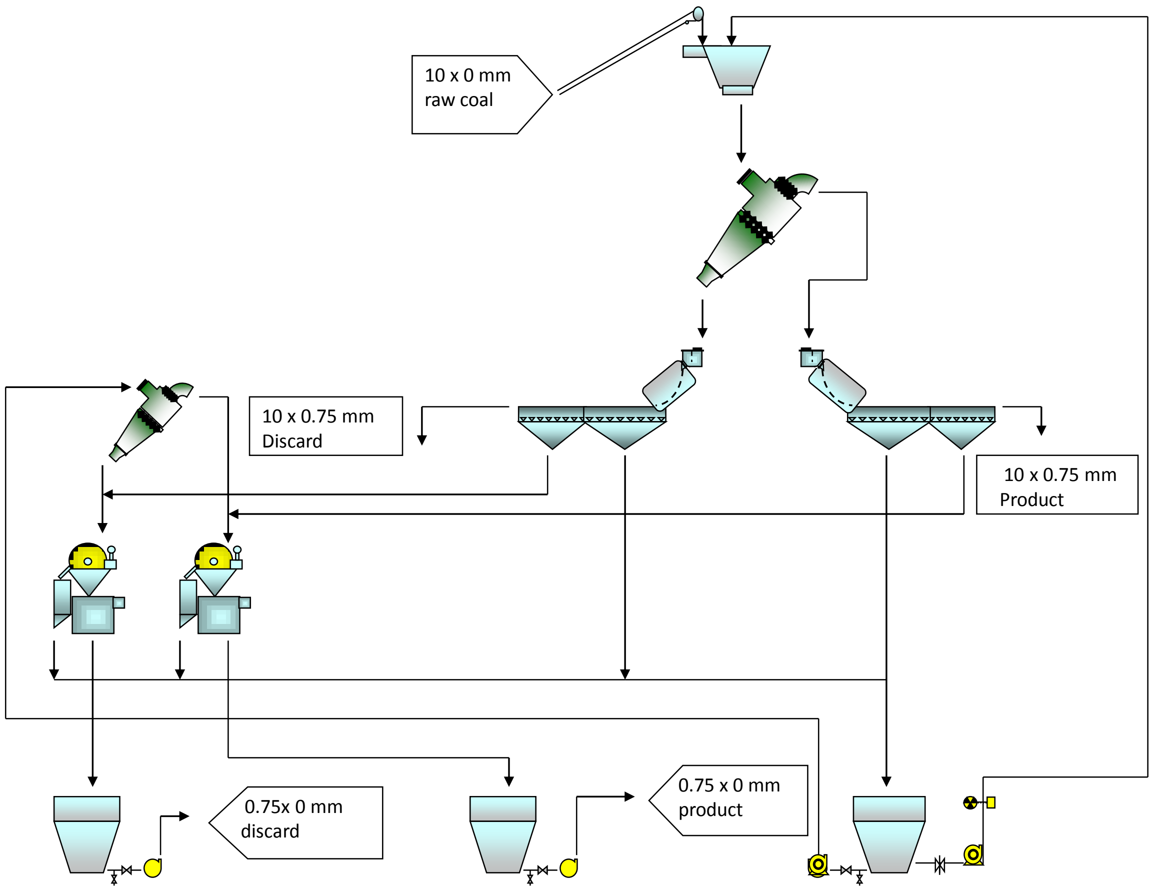

Figure 1. Simplified flow diagram of circuit used at Tertre

The separation efficiency of the plant at Tertre was good and the results were reported by Mengelers and Absil (1976) (see Table 2). The magnetite consumption for the operation at Tertre was approximately 1 kg per feed ton. In 1965, a similar plant was constructed at Winterslag in Belgium. This plant remained in operation for some 17 years and was also reported to perform satisfactorily (Lathioor and Osborne 1984).

Table 2. Results obtained in Tertre plant

Coal size fraction (mm)	RD of separation	EPM
10 x 0.75	1.57	0.035
0.75 x 0.3	1.63	0.050
0.3 x 0.15	1.83	0.010

United States of America

During the 1970's, a number of 'wash-to-zero' plants, based on the Tertre flowsheet, were built in the US by Stamicarbon's licensee Roberts & Schaefer. In these plants, efficient separation of the minus 0.5 mm size fraction was not specifically targeted and therefore, the fine coal was processed, together with the coarser coal, in a large diameter cyclone. Recovery of the fine coal from the drained medium was carried out in a similar manner as in the Belgian plants. A simplified flowsheet for a typical wash-to-zero plant is shown in Figure 2.

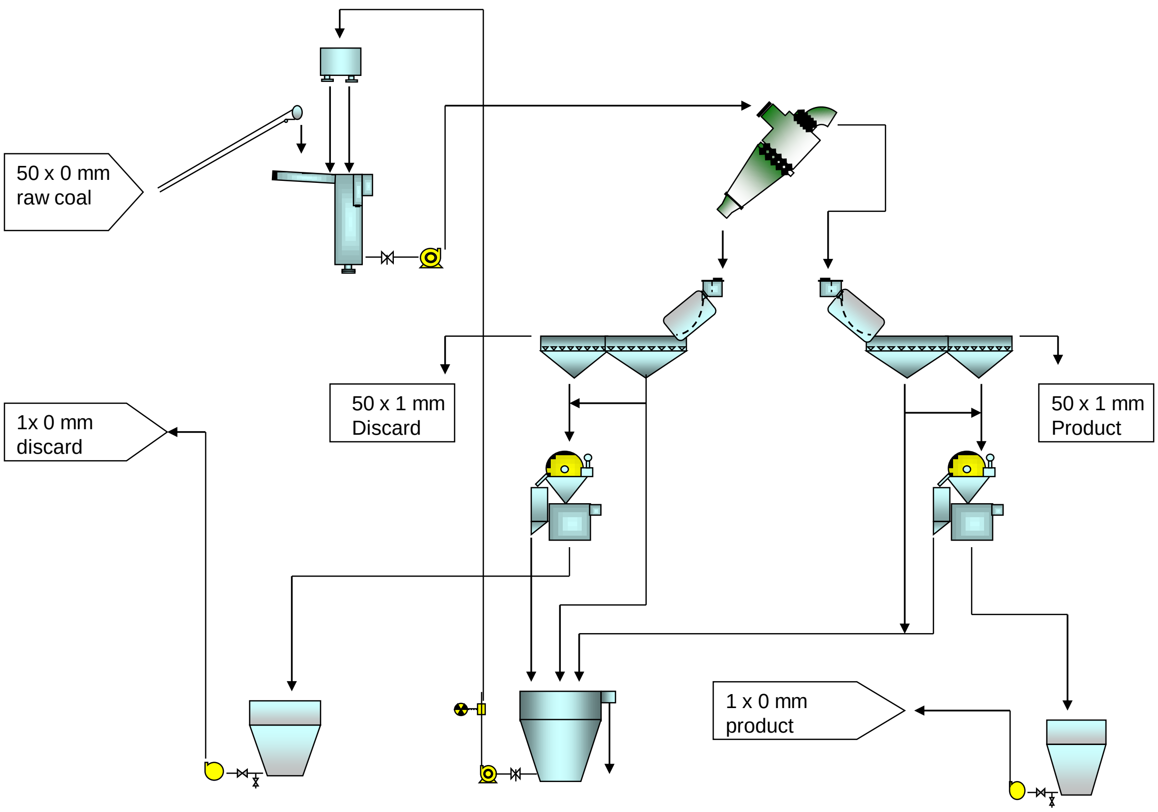

Figure 2. Wash-to-zero flow diagram

The results obtained from a wash-to-zero plant in West Kentucky, as reported by Taylor and Chen (1980), are shown in Table 3. As can be seen, the separation efficiency obtained on the fine coal was worse than that obtained in the Belgian plants. The finer coal was also separated at a much higher relative density than the coarser coal. Magnetite consumption for the plant was reported to be around 0.5 kg/feed ton.

Table 3. Results obtained in wash-to-zero plant

Cyclone module	Coal size fraction (mm)	RD of separation	EPM
Module 1: 28" cyclone operating at 9D	25 x 0.6	1.54	0.027
	0.6 x 0.15	1.95	0.149
Module 2: 24" cyclone operating at 20D	32 x 0.6	1.65	0.035
	0.6 x 0.15	2.03	0.159

Similar results were reported by the Island Creek Company, which constructed a number of wash-to-zero plants during the late 1970's and early 1980's. Table 4 summarizes the results obtained at the Providence Plant (Burch 1985). Table 5 shows the names and commissioning dates for some of the wash-to-zero plants built by the Island Creek Company.

Table 4. Results obtained in Providence wash-to-zero plant

Test No.	Coal size fraction	RD of separation	EPM
1	32 mm x 600 μm	1.455	0.020
	600 x 150 μm	1.61	0.168
2	32 mm x 600 μm	1.48	0.032
	600 x 150 μm	1.71	0.205

Table 5. Wash-to-zero plants built by the Island Creek Company

Plant	Contractor	No. of cyclones	Feed size (inches)	Year commissioned
Pond Fork	Childress	1	3/8 x 0	1976
Coal Mountain # 12	Childress	1	3/8 x 0	1977
Providence	J.O. Lively	4	1-1/4 x 0	1979
Fies # 9	J.O. Lively	4	1-1/4 x 0	1979
Hamilton # 1	J.O. Lively	6	1-1/4 x 0	1979
Hamilton # 2	J.O. Lively	4	1 x 0	1979
Holden # 22	J.O. Lively	4	1 x 0	1980
No. 25 Mine	F.M.C.	3	1 x 0	1981
North Branch	Envirotech	2	1-1/4 x 0	1981
North Branch	Island Creek	2	1-1/4 x 0	1983

The main advantage offered by the wash-to-zero concept is simple plant layout, which translates to low capital cost. The de-sliming screens and the fine coal beneficiation section can be eliminated while still providing an efficient separation on the coarse coal. The separation obtained on the fine coal, without any additional equipment, is still better than that which can be had with most water-based fine coal processing equipment.

South Africa

In the early 1970's, South African coal companies concluded a contract with the Japanese steel industry for the supply of a low ash blend coking coal. This coal was to have an ash value of 7% and would be produced by processing the raw coal from the Witbank No. 2 Seam. The coal had to be processed at low relative density in the presence of very high amounts of near-density material and dense-medium separation was found to be only process capable of affecting the required separation. At the time, the fine coal could not be washed to 7% ash and was therefore added raw to the lower-value middling coal.

Extensive research conducted in South Africa led to the conclusion that dense-medium cyclones would be the only process capable of beneficiating the fine coal to 7% ash (Horsfall 1976) and a 5 t/h pilot plant was subsequently built at the FRI test facility in Pretoria in 1976. The plant was equipped with a single 150 mm diameter dense-medium cyclone supported by all the additional equipment needed to feed the cyclone and recover magnetite. The cyclone was fed at feed pressures ranging typically between 80 and 150 kPa (40 to 70D). The plant was employed to test the beneficiation of fine coal from several collieries in the country and proved that the production of low ash coal from the fine fraction was possible. A simplified flow diagram of the FRI fine coal dense-medium plant is shown in Figure 3.

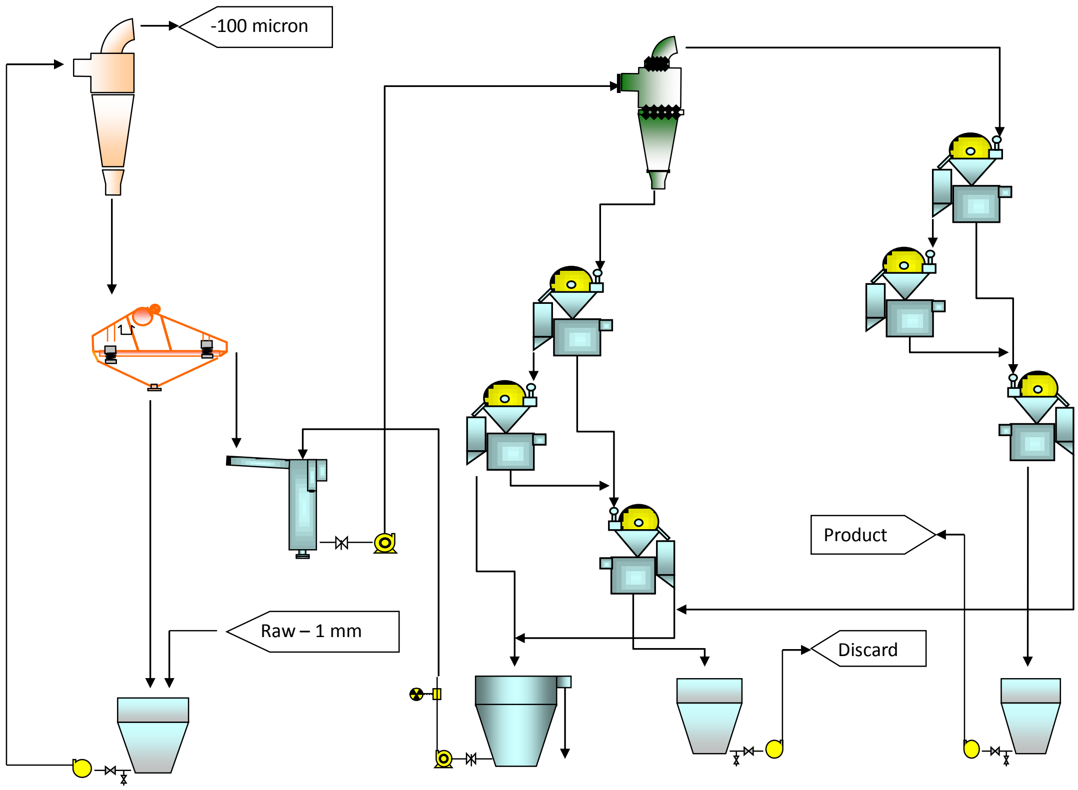

Figure 3. Simplified flow diagram of FRI pilot fine coal dense-medium plant

The results obtained during a 10-day continuous period of operation of the pilot plant are shown in Table 6 (Fourie et al. 1980). Based on the success of the pilot-plant work, a full-scale fine coal dense-medium plant was built at Greenside Colliery and was commissioned in 1980. This plant produced low ash coal from the fines fraction and remained in operation for some 18 years. Three further plants, based on the FRI design, were constructed in South Africa at Newcastle-Platberg Colliery, at High Carbon Products in Natal and at Rooiberg Tin Mine.

The 150 mm diameter dense-medium cyclone used in the FRI pilot plant is shown in Figure 4 (CSIR 1980)

Table 6. Results obtained from FRI pilot fine coal dense-medium plant

Test no.	1	2	3	4
Product ash%	6.5	7.7	7.4	5.9
Product yield %	53.1	64.2	58.8	43.3
RD of separation	1.46	1.50	1.48	1.43
EPM	0.022	0.031	0.025	0.020
Total magnetite losses (kg/t)	0.81	1.11	1.32	0.9

Figure 4. 150 mm cyclone in FRI dense-medium fine coal pilot plant

United States of America

Two plants designed to process 1 x 0.1 mm coal were built in the USA during the late 1970's. The plants were at Marrowbone in West Virginia and at Homer City in Pennsylvania. The coal preparation plant at Homer City was built to prepare 'deep cleaned' coal for burning in the power station. The main purpose of the plant was to reduce the ash level and the sulfur content of the coal fed to the power station as an alternative to flue gas desulfurization.

The washability of the coal at Homer City is such that a very low cut-point density of around 1.30 had to be employed to achieve coal of the required quality. Since the minus 1 mm size fraction is beneficiated at a relatively higher cut-point density than the coarser coal in a wash-to-zero operation and further due to the fact that this density cannot be controlled, it was necessary at Homer City to employ a separate fine coal circuit to beneficiate the fine coal. The fine coal plant was commissioned in July 1978. The performance of the plant during the first year is reported to have been poor.

In February 1979, the utility owners initiated an in-depth investigation to trace the problem areas in the circuit and to rectify such problems. The following major ‘flaws’ were identified as a result of the investigation (Sehgal et al.1982):

- The circulating medium was contaminated with fine coal. This was a result of entrapment of fine coal by the magnetic separators. The entrapment of coal by the magnetic separators in turn was caused by too high a percentage of solids in the magnetic separator feed.
- The high percentage of fines in the circulating medium increased the viscosity of the medium, which in turn led to reduced efficiency of separation in the 14 inch (350 mm) dense-medium cyclones.
- The high percentage of fine coal in the medium made it very difficult to control the density of the medium.
- The magnetite in the circuit degraded as a result of high losses of particularly the ultra-fine fraction.

A number of modifications were made to the circuit following this investigation. The most significant of these was to modify the size split of coal fed to the fine coal beneficiation plant. Where a minus 3 mm feed was previously fed to the circuit, the screening arrangement was modified so that the 3 mm x 0.5 mm raw coal was removed and fed to a separate, conventional, dense-medium cyclone circuit employing conventional drain-and-rinse screens. Only the minus 0.5 mm coal was sent to the fine coal dense-medium circuit which resulted in a significant reduction in feed tonnage. With the smaller top size and reduced tonnage being fed to the circuit, it was possible to change the dense-medium cyclones from 350 mm to more efficient 200 mm cyclones.

Additional Derrick screens were installed for de-sliming the feed. Rapped sieve bends were installed to drain medium from the product and discard following the separating cyclones. This allowed a substantial part of the medium to be re-circulated directly back to the medium tank. The sieve bend overflow material was diluted with sufficient water before being fed to the magnetic separators to minimize entrapment of fine coal in the recovered medium. The medium density control was improved by utilizing a nuclear density gauge in conjunction with a Ramsey coil. This allowed the contamination of the medium to be “calculated” and the actual density of the medium in the circuit could thus be controlled (Esposito and Higgens 1982). The plant was understood to have operated satisfactorily after these modifications.

Australia

A fine coal dense-medium plant was constructed at ARCO's Curragh Mine in Central Queensland, Australia in the early 1990's. As in South Africa, the motivation for the plant at Curragh was to produce a product containing 7 % ash from the minus 0.5 mm size fraction.

Much of what had previously been learned about dense-medium cleaning of fine coal was incorporated into the design of the Curragh plant, which was carried out in co-operation with CLI Corporation of Pittsburgh, USA. The lessons learned from the Homer City plant in particular were taken into account (Kempnich et al. 1993).

The plant was equipped with two 500 mm diameter dense-medium cyclones. Much attention was devoted to the design of the magnetite-recovery circuits, as well as to the de-sliming of the feed coal. Vibrating sieve bends were used to assist in both the de-sliming of the feed and the recovery of medium. The plant started up 'smoothly' during commissioning. Magnetite consumption seemed low and there was no noticeable impact on the magnetite consumption of the overall Curragh operation. Problems were however encountered with the efficiency of the cyclones, and it was not possible to produce the required 7 % ash level in the product. Test work carried out on site led to the conclusion that the initial cyclone feed pressure of 9D or approximately 45 kPa was too low. The feed pressure was therefore increased to 120 kPa after which a 7 % ash product was consistently achieved. (Kempnich et al. 1993).

The fine coal plant at Curragh closed down towards the end of 1996. The exact reason for this is not known.

South Africa

In 2001 a 25 t/h pilot fine coal dense-medium plant was built in South Africa by the Coaltech Research program. The objective of the plant was to demonstrate that coal from the Witbank number 4 seam, which is difficult to process, can be upgraded to export quality, something that could not be done using spirals. The plant employed two dense-medium cyclones in series to improve separation efficiency and was run on standard 'medium' grade magnetite – one of the objectives of the research. A simplified flow diagram of the Coaltech circuit is shown in Figure 5.

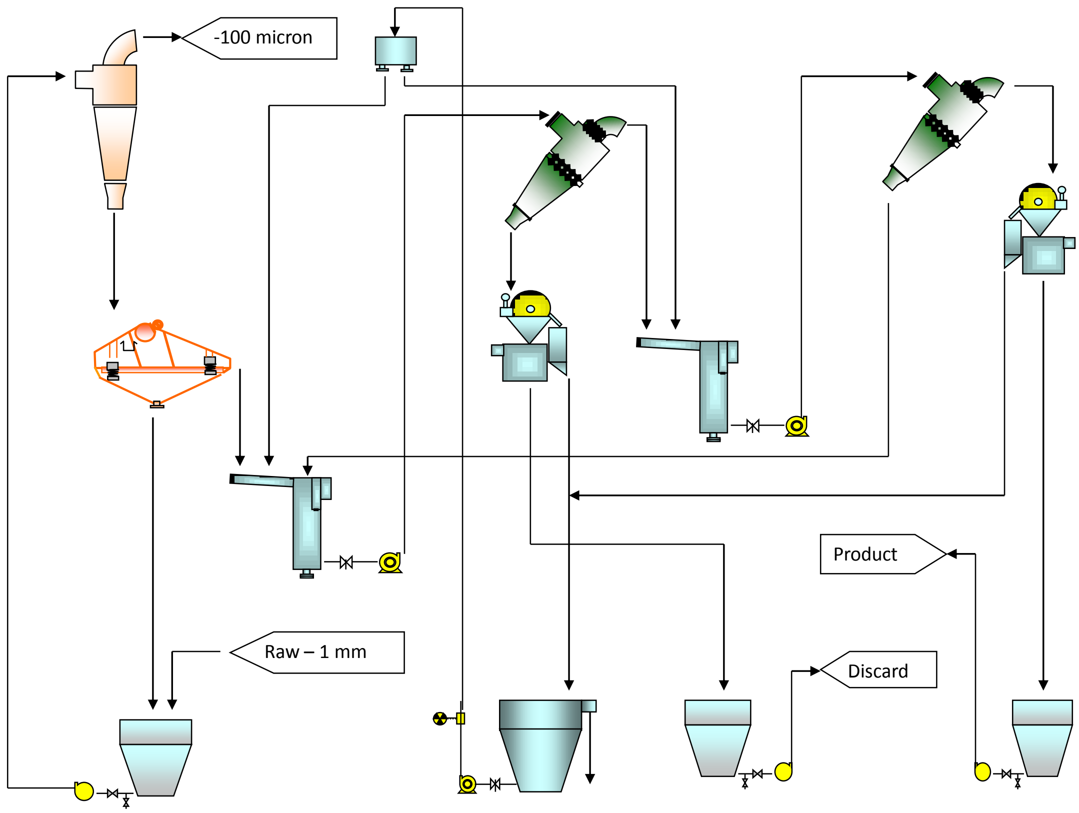

Figure 5. Flow diagram of Coaltech pilot plant

Extensive test work was conducted on the raw fine coal from several collieries over a period of 5 years and much valuable information was gained from the plant. As a result of the work done, the spiral plant at Leeuwpan Colliery was replaced with a dense-medium cyclone plant. This plant is presently in operation at Leeuwpan. The dense-medium cyclones in the Leeuwpan plant are shown in Figure 6, a photograph taken during the construction of the plant.

Figure 6. Dense-medium cyclones in Leeuwpan fine coal plant

China

In recent years a large number of plants were built in China using the wash-to-zero approach to beneficiate coarse and fine coal simultaneously without the use of additional fine coal processing equipment.

In the new Chinese plants, un-deslimed raw coal is fed to large diameter (up to 1500 mm) three-product dense-medium cyclones and the plus 0.25 mm product (coking coal), middling and discard is recovered using conventional drain-and-rinse screens. Part of the medium draining through the product (coking coal) screen, is diverted and pumped to small (350 mm) conventional dense-medium cyclones where the minus 0.25 mm fine coal in the medium is beneficiated to yield a coking- and a middling coal. The coal is recovered from the small cyclone overflow and underflow with magnetic separators. The circuit employed is similar to the one implemented at Tertre in Belgium some 55 years ago but by using the overflow medium from the three-product cyclones, fine magnetite is automatically ensured. The separation of the fine coal is reported to be effective (Zhao and Yu 2010), and some typical results are shown in Table 7.

Table 7. Separation efficiency obtained on fine coal

Coal size range (mm)	RD of separation	EPM	Comment
0.5 x 0.25	1.65	0.099	Processed in 1500 mm diameter 3-product cyclone
0.25 x 0.15	1.52	0.080	Processed in 350 mm diameter fine coal cyclone

LESSONS LEARNED FROM THE PAST

From the preceding overview on the subject of dense-medium processing of fine coal, one can gather that the use of dense medium to clean fine coal has not always been easy or completely successful. Mixed results were obtained but some useful learning does emerge. Some of the more pertinent aspects of the process are briefly discussed.

Cyclone Diameter and Cyclone Geometry

There appears to be general consensus that smaller diameter cyclones result in better separation efficiency. This is principally due to the higher centrifugal forces generated in smaller cyclones, which aids in the separation between fine coal and fine shale particles. Very small cyclones are, however, prone to blockages should oversized particles be present in the feed and a compromise is therefore necessary in practice between separation efficiency and practical operation. It appears that the optimum cyclone diameter for fine coal beneficiation is thus between 250 and 350 mm.

Cyclones with longer body sections and lower cone angles appear to be better suited for fine coal processing. Van der Walt (1949) found that a 25° cone angle cyclone gave better results than a 38° cyclone.

Magnetite Sizing

Magnetite size consist is perhaps the most confusing aspect of fine coal processing. It is well known that finer magnetite improves the separation efficiency in cyclones for the plus 0.5 mm size fractions (DSM 1970; de Korte 2007). In general, it is assumed that for finer sized coal, even finer magnetite is required and the FRI (Fourie et al. 1980) insisted that magnetite which is 50% finer than 10 μm is necessary for efficient separation in the 150 mm diameter cyclone. Sokaski and Geer (1963) found that the best separation could be obtained using grade "B" magnetite. They further found that using finer magnetite improved the cyclone performance for coal particles coarser than 350 μm but no improvement was noted for the finer sizes.

Tests conducted in a 250 mm diameter cyclone, operating at a feed pressure of 117 kPa and using saturated brine as a medium (Mengelers 1982) indicated that results which were very similar to those obtained using magnetite were obtained. Table 8 shows a summary of the results obtained by Mengelers.

Table 8. Separation results obtained with brine medium at RD 1.20

Test	Conditions	RD of separation	EPM
1	Coal 320 g/l	1.41	0.0790
2	Coal 185 g/l de-slimed	1.32	0.0543
3	Coal 235 g/l de-slimed	1.33	0.0457

It is interesting to note that there is a differential of between 0.12 to 0.21 between the medium relative density of 1.20 and the actual RD of separation. The EPM values obtained are similar to those obtained elsewhere with magnetite. Figure 7 shows the normalized partition data for the brine tests compared to the normalized results obtained at Homer City on a 200 mm diameter cyclone operating at a feed pressure of 70 kPa and using Grade B magnetite (Esposito and Higgens 1982). One can see that the results compare well.

The results obtained by Deurbrouck (1974) when processing fine coal sized between 350 and 150 μm, using zinc chloride as the medium, also indicated EPM values in the range of 0.04 to 0.065. These values compare well to the results obtained when processing fine coal using magnetite as a medium.

It is difficult to conclude from these results what grade of magnetite would be best in practice but it would most probably be safe to assume that the finest magnetite available should be used. Cyclone overflow medium from coarse coal cyclones can be effectively used to provide fine magnetite to a fine coal processing circuit. This is the practice at Leeuwpan Mine and also in the Chinese plants.

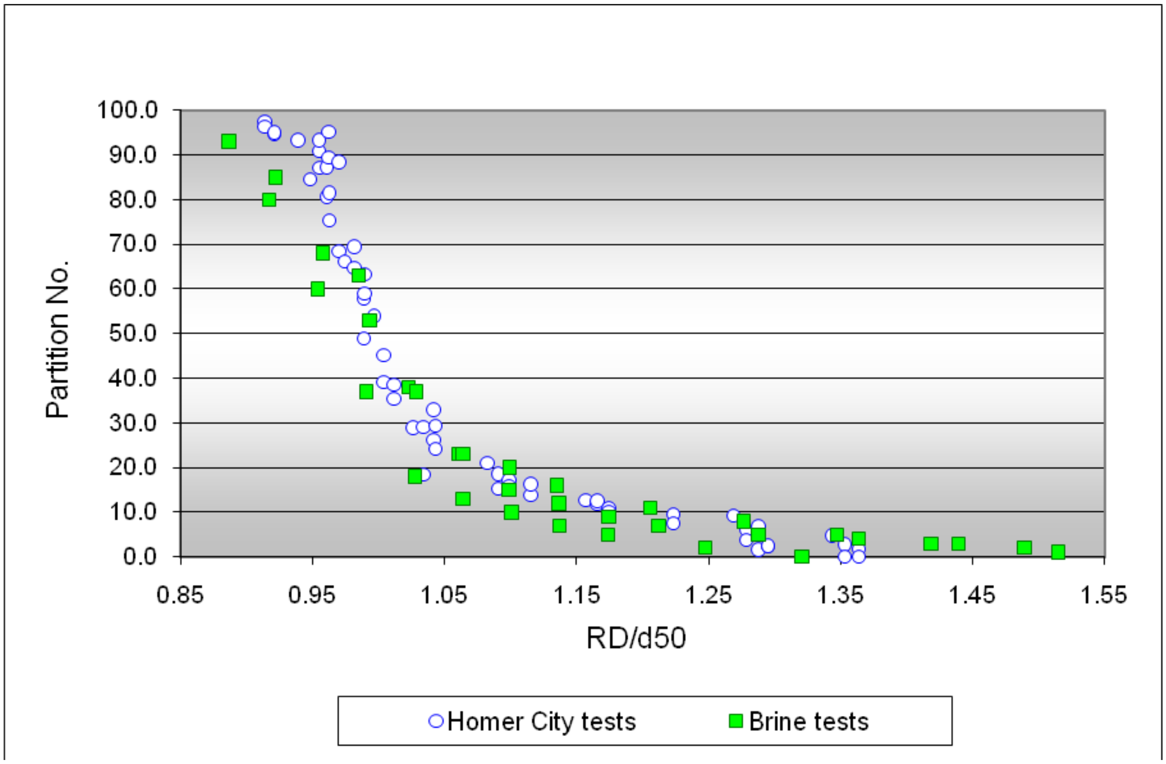

Figure 7. Comparison of normalized partition data (d50 = relative density of separation)

Cyclone Feed Pressure

In general it has been found that an increase in cyclone feed pressure results in an improved separation. The most convincing proof is the experience at Curragh in Australia. The plant at Curragh was initially designed to operate at a cyclone feed pressure of 45 kPa. When the plant started operation, it was found that the required 7% ash product could not be produced. When the cyclone feed pressure was increased, initially to 65 kPa and then to 120 kPa, the required low ash product could be obtained (Kempnich et al. 1993). The influence of the cyclone feed pressure on the performance of the cyclones at Curragh is summarized in Table 9.

Tests carried out in the Coaltech pilot plant in South Africa indicated that the normalized EPM value obtained when processing 1 x 0.1 mm coal could be improved from 0.066 at 18D to 0.028 at 24D (McGonigal and de Korte 2005). Tests conducted at Homer City, however, found that better separation efficiency was obtained at low cyclone feed pressures when processing fine coal at very low relative density (Chedgy et al. 1986). It therefore seems that specific conditions can dictate the required cyclone feed pressure.

Table 9. Effect of feed pressure on cyclone performance at Curragh

Parameter	Cyclone feed pressure			Cyclone feed pressure		
	45 kPa	65 kPa	120 kPa	45 kPa	65 kPa	120 kPa
	+ 0.25 mm size fraction			-0.25 mm + 0.125 mm size fraction		
RD of separation	1.596	1.752	1.480	1.841	2.078	1.663
EPM	0.1513	0.0704	0.0367	0.2663	0.1369	0.1492
Imperfection[1]	0.0948	0.0402	0.0248	0.1446	0.0659	0.0897

[1] EPM/RD of Separation

Magnetite Consumption

The magnetite consumption reported from the majority of dense-medium fine coal plants, both stand-alone and wash-to-zero plants, mostly fall within normal limits. In general, these plants have magnetite consumption of between 1.0 and 1.5 kg/feed ton which compares favorably with that of conventional dense-medium plants processing de-slimed feed. In the modern Chinese wash to zero plants, magnetite consumption of around 0.55 kg/t is reported (Zhao and Yu 2010).

In recent years, the performance of magnetic separators has improved dramatically through the use of more sophisticated magnetic materials. The counter-rotation magnetic separators, installed in the Coaltech pilot plant in South Africa are shown in Figure 8 and the performance of these units, measured over a period, is summarized in Table 10. The separators were manufactured by two different companies and were found to be equally effective.

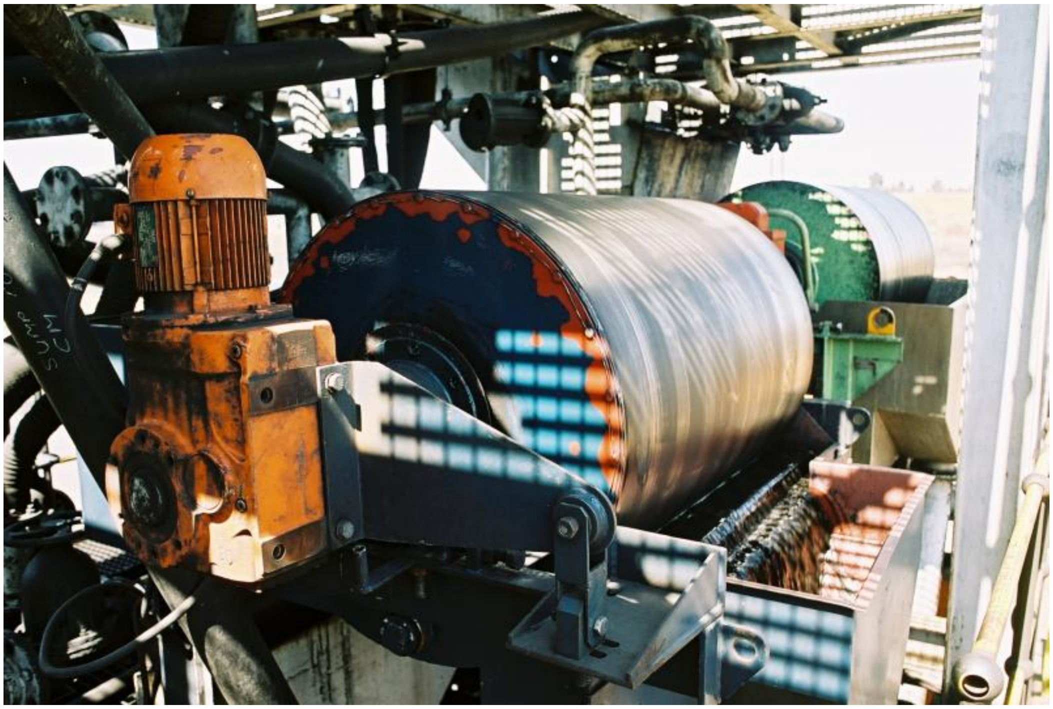

Figure 8. Magnetic separators in Coaltech pilot plant

Table 10. Performance of magnetic separators

	Date of determination					
Product	01-Nov-01	31-May-02	15-May-06	08-Jun-06	15-Jun-06	Average
Feed g/l magnetite	252.90	54.49	172.04	218.56	170.20	173.64
Concentrate g/l magnetite	1022.31	1138.93	513.35	743.59	602.22	804.08
Tailing g/l magnetite	0.16	0.19	0.18	0.51	0.19	0.24
Efficiency %	99.954	99.675	99.929	99.836	99.921	99.86
Discard						
Feed g/l magnetite	113.17	122.17	527.84	519.90	508.48	358.31
Concentrate g/l magnetite	1862.47	1542.24	1316.04	1061.40	1657.65	1487.96
Tailing g/l magnetite	0.003	0.22	0.13	0.15	0.04	0.11
Efficiency %	99.998	99.837	99.986	99.985	99.994	99.96

Older dense-medium fine coal plants used rapped sieve bends and multiple stages of magnetic separation to recover magnetite. With the new generation of magnetic separators, very good magnetite recovery is possible with magnetic separators only – this can simplify plant configuration significantly. For optimum recovery of magnetite with these magnetic separators, it is required to dilute the feed to the separators to ensure that the amount of magnetite as well as non-magnetic material in the feed falls within the design loading for the units. This also results in minimum entrapment of coal in the over-dense medium recovered by the magnetic separator.

Even with the modern, efficient magnetic separators, magnetite lost in the magnetic separator underflow is the finer size fraction. Tests conducted on the magnetic separators in the Coaltech pilot plant confirmed that the magnetite lost in the magnetic separators effluent is mostly below 10 μm in size (de Korte 2002). The size distribution of the magnetite lost via the product and discard magnetic separators is shown in Figures 9 and 10. A photograph of the magnetite in the magnetic separator tailing is shown in Figure 11.

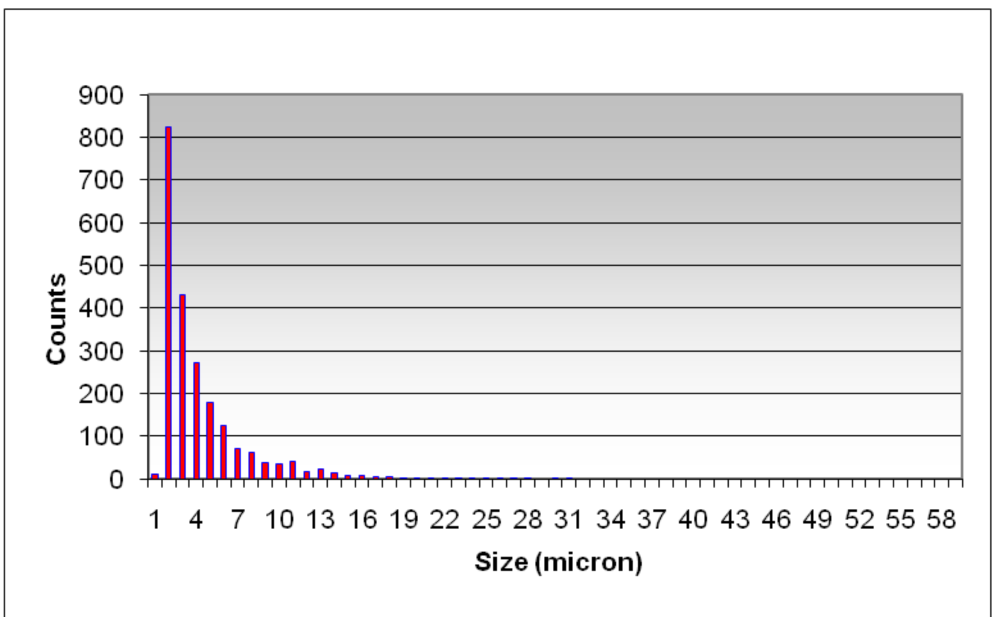

Figure 9. Size distribution of magnetite lost via product magnetic separator

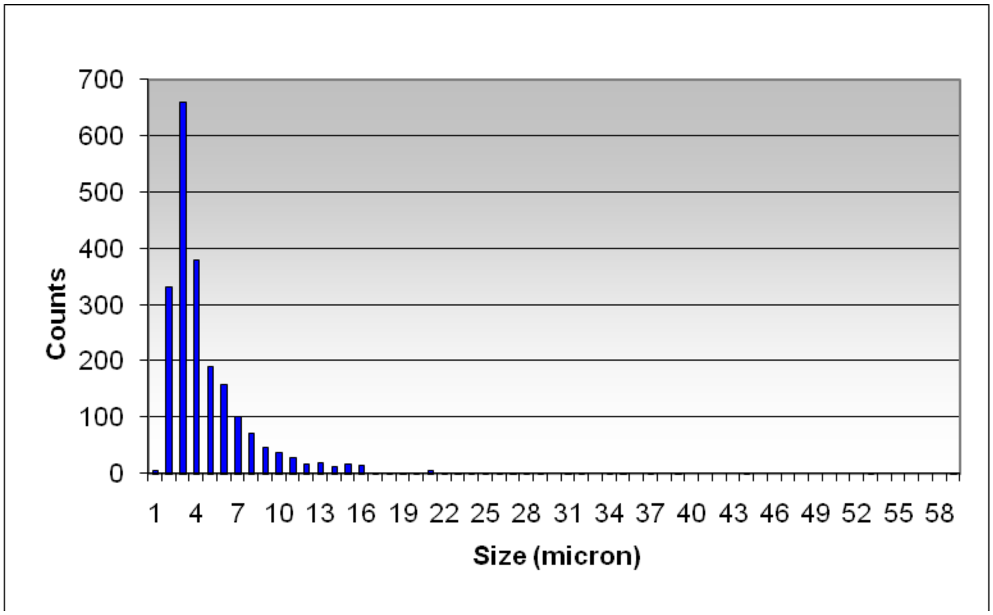

Figure 10. Size distribution of magnetite lost via discard magnetic separator

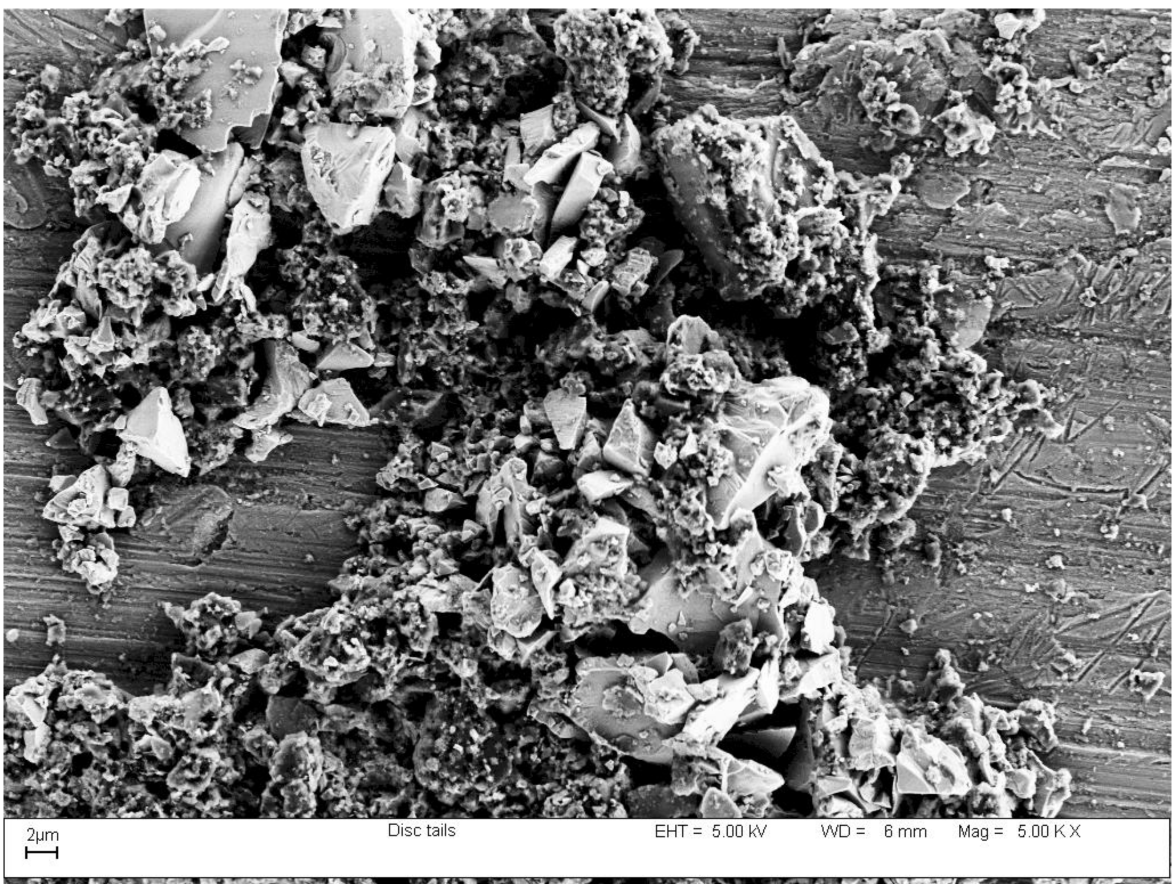

Figure 11. Photograph of magnetite in magnetic separator effluent

Particle Size of Coal Processed

From the work done on dense-medium processing of fine coal to date, it is clear that the process is not effective for the very fine sizes, especially below about 100 μm. Evidence of this can be seen from the work done by Deurbrouck (1974) using a 200 mm diameter cyclone operating at a feed pressure of 70 kPa and using a magnetite medium at a feed relative density of 1.30. A summary of the results is shown in Table 11 and in Figures 12 and 13. The density of separation is shown to increase with decreasing particle size and the EPM value also increases as the particles become smaller.

Table 11. Results obtained with 200 mm diameter cyclone (Deurbrouck 1974)

Particle size fraction (mm)	RD of separation	EPM
3 x 1.5	1.33	0.024
1.5 x 0.64	1.36	0.024
0.64 x 0.24	1.41	0.034
0.24 x 0.150	1.44	0.038
0.15 x 0.100	1.53	0.064
0.100 x 0.075	1.57	0.103

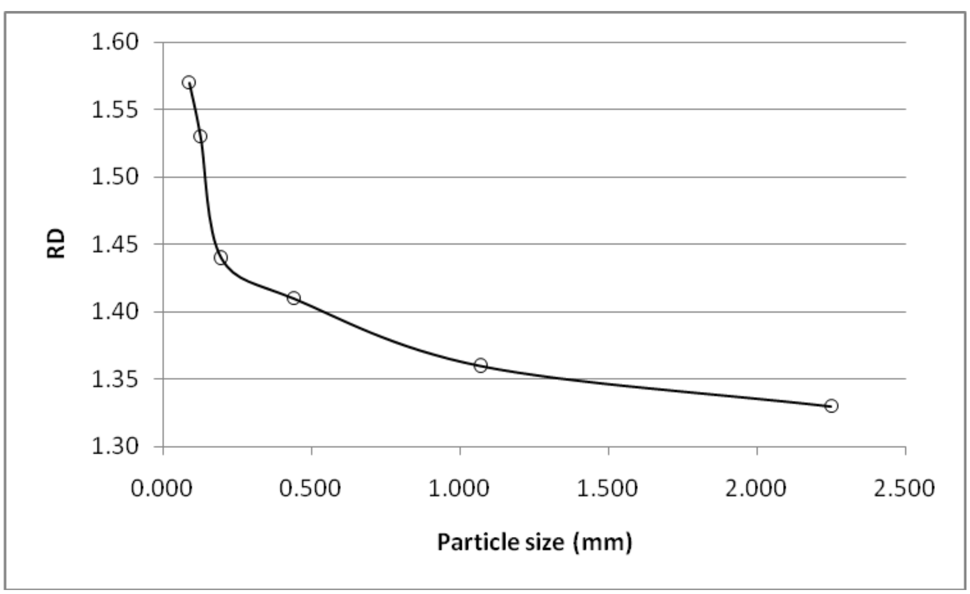

Figure 12. Increase in separation density vs. particle size (Deurbrouck 1974)

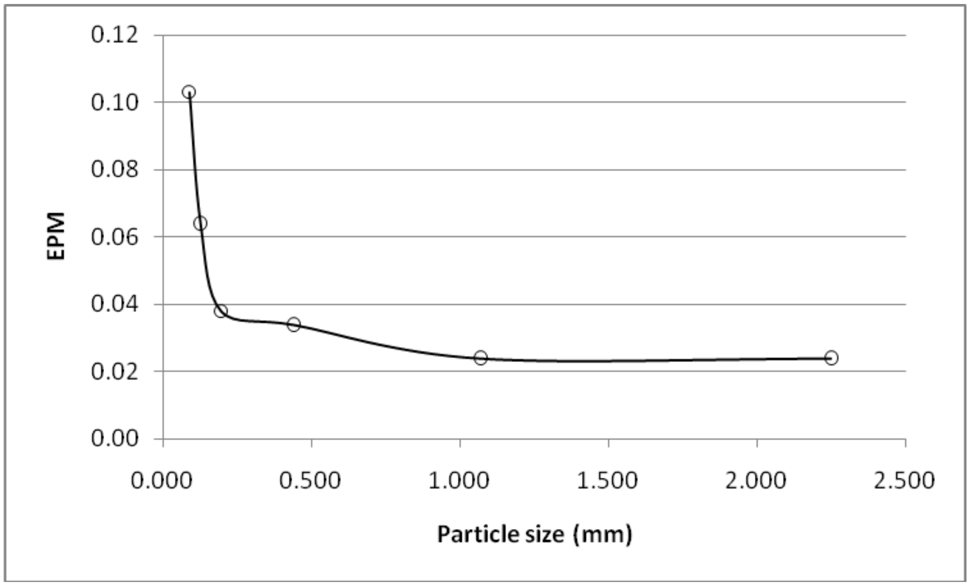

Figure 13. Increase in EPM vs. particle size (Deurbrouck 1974)

Processing of the coal finer than 100 μm results in poor separation efficiency and this size fraction should therefore, if possible, be excluded from the feed to fine coal dense-medium plants. In the case where conventional de-sliming of the plant feed is employed and the fine coal routed to a 'stand-alone' fine coal circuit, sieve bends or Derrick screens have been proven to be capable of removing the bulk of the minus 100 μm coal from the feed. In wash-to-zero plants, the minus 100 μm material can be removed from the product after beneficiation. The fine coal below 100 μm, being poorly separated and normally having an ash value higher than that of the required final product, can degrade the quality of the final product. Removal of the ultra-fines from the product will therefore improve its quality. This also applies in the case of other fine coal processes such as spirals or teetered-bed separators.

The presence of ultra-fine coal in the feed to dense-medium cyclones was found to have very little influence on the separation of the coarser particles in the feed (King and Juckes 1986). On the other hand, Deurbrouck (1974) suggests that the presence of coarse particles in the feed to a dense-medium cyclone could negatively influence the separation of smaller particles due to crowding – especially in the apex area of a cyclone. This seems to be confirmed by the fact that better separation is obtained in fines-only processing than in wash-to-zero circuits where the coarse and fine coal is processed together.

One other consideration in favor of dense-medium processing of fine coal is the fact that any ‘stray’ oversized particles in the feed will be correctly separated in a dense-medium cyclone. In water-only processes, oversized particles end up in the reject stream, irrespective of quality or density.

CONCLUSION

Dense-medium processing of fine coal is still the most efficient method of fine coal cleaning available. It has been successfully implemented at several plants around the world in the past and is presently in use in South Africa and China. Provided that the appropriate combination of cyclone geometry, magnetite medium and cyclone feed pressure is applied, very good separation efficiency and accurate control over final product quality can be obtained when processing fine coal in dense-medium cyclones.

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