Dense-medium beneficiation of fine coal revisited

by G.J. de Korte*

Introduction

Dense-medium beneficiation of fine (minus 0.5 mm) coal is not a new concept and has been used in South Africa previously. The dense-medium fine coal plant at Greenside Colliery operated for almost 18 years and, despite proving a difficult plant to operate, did succeed in producing a fine coal product with a low ash content of 7%. No other beneficiation process available could achieve this.

Dense-medium beneficiation of fine coal was also used in other countries, of which the plants at Homer City in the USA and Curragh in Australia were the best known. The first application of dense-medium cleaning of fine coal was, however, at the Tertre plant in Belgium[1]. This plant was built in 1957. About nine years later, a second fine coal dense-medium plant was built at the Winterslag Mine, also in Belgium. According to reports, this plant operated satisfactorily for a period of some 17 years.

Today, not one of these dense-medium plants remains operational.

Spirals were introduced into the South African coal industry in the early 1980s and soon became accepted as the fine coal beneficiation process of choice. Currently, almost every coal processing plant in South Africa employs spirals to beneficiate fine coal.

Although spirals are normally capable of yielding products of acceptable quality, there are some instances, especially in the case of the No. 4 Seam coal, where spirals cannot produce the required product quality. It then becomes more economical to discard the raw fine coal than to process it with spirals. Obviously, this practice does not make the best use of the available coal reserves.

There is a definite need to produce fine coal at a higher product quality than that which is possible with spirals. For this reason, dense-medium beneficiation of fine coal was reconsidered.

Motivation

In past years, much of South Africa's export coal was produced from the No. 2 Seam. The fine fraction from this seam is relatively easy to beneficiate in spirals. In future years, however, a large proportion of coal will be mined from the No. 4 Seam. The fine coal fraction from the No. 4 Seam is difficult to beneficiate and spirals are not capable of yielding product coal of a sufficiently high quality to allow the fine coal to be included in the final export product.

Dense medium has the potential to beneficiate the fine coal from the No. 4 Seam to the required quality and further has the potential to be more efficient than spirals. The process also offers better control over product quality.

Dense-medium cyclone cleaning of fine coal has been used previously in South Africa at Greenside Colliery. At Greenside, the process was used to produce a low-ash coal containing 7% ash and a middling fraction containing 16% ash.

The Greenside plant employed small (150 mm diameter) cyclones operated at relatively high feed pressures of about 150 kPa. Very fine magnetite (50% finer than 10 micron) was specified for the optimum operation of the plant. The plant proved difficult to operate but nonetheless delivered the required products.

The need for a better separation of the fine coal fraction motivated the drive to re-evaluate dense-medium cyclone beneficiation of fine coal. Despite its past history, it is still the only process available with the potential to provide the required separation.

However, the process needs to be made more 'practical' by using larger cyclones, lower pressures and commercially available super-fine magnetite, yet should still give a sharp separation.

This is quite a challenge and formed the basis of a project sponsored by CoalTech 2020.

CoalTech 2020

CoalTech 2020 is a collaborative research programme launched by the South African coal industry in 1998. The aim of the programme is to carry out research that will assist in the optimal use of South Africa's coal reserves.

CoalTech 2020 funds a number of research projects in the areas of coal geology, underground and surface mining, coal preparation, and the impact of coal mining on the environment and on water resources, as well as into the human and social issues related to coal mining and the coal industry.

A study aimed at re-evaluating dense-medium cyclone processing of fine coal was motivated to the CoalTech 2020 Steering Committee and they agreed to sponsor the project.

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Approach adopted

The project plan incorporated three main phases, namely a literature survey, the construction of a pilot plant and the practical testing of the process on the pilot plant.

From the first stage of the project, it was confirmed that dense-medium beneficiation of the fine coal from the No. 4 Seam could be an economically viable option. To prove the process technically viable, however, it was necessary to test it on a practical scale. This meant that a pilot plant would first need to be constructed and tested.

The project team developed a conceptual flow sheet for the envisaged plant. Contracting firms were then invited to submit tenders for the construction of the pilot plant. After due consideration, Jim Harrison Design Associates were awarded the contract.

A number of local equipment suppliers offered equipment for the plant on a 'free-on-loan' basis. In particular, the following companies made valuable contributions in this regard:

- Magnapower and Malvern Engineering each supplied a magnetic separator
- Multotec supplied the required dense-medium cyclones, as well as the densifier cyclones
- Delkor offered the use of a Delkor Fast Screen for desliming of the plant feed
- Warman supplied all the pumps for the plant
- Process Automation provided and installed a density controller.

The plant was designed in modular form to enable it to be moved to different locations. The intention is to test the plant at one site and then move it to another colliery for further testing.

Ingwe Coal offered to test the plant first at Koornfontein Colliery. The plant was constructed in the Middelburg area and, on completion, was moved to Koornfontein Colliery, some 20 km away.

Design of plant

The design of the plant is unique in that dense-medium cyclones are used in a rougher-cleaner-scavenger arrangement. This design follows from previous work carried out on spirals[2] and from computer simulation studies[3] carried out as part of the initial phase of the project.

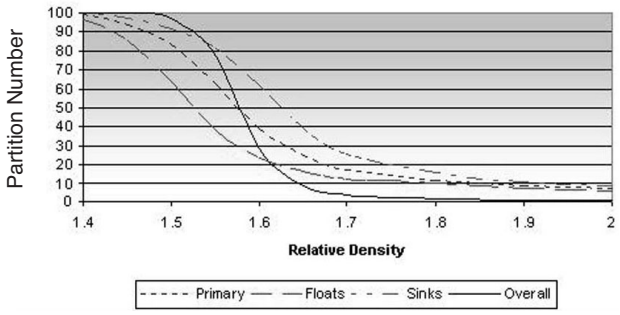

Figure 1—Simulated partition curves for three dense-medium cyclone stages

It was found, from the simulation studies conducted, that the Ecart Probable (Moyen) (Epm) could be lowered significantly by employing three stages of cyclones rather than a single cyclone as has been used in all previous dense-medium fine coal plants. It was anticipated that this would allow larger cyclones, lower feed pressures and slightly coarser magnetite to be used.

Figure 1 shows the results of one of the simulation runs conducted during the first phase of the project. It can be seen that the partition curve representing the overall separation has a lower Epm value than the three individual partition curves representing the rougher, cleaner and scavenger cyclones.

It was also observed from the simulation studies that the amount of coal circulated within the system could easily become a problem unless very careful control is exercised over the density of the feed medium.

A further concern was that of magnetite recovery. It was required that the loss of medium be kept to a minimum, that contamination of the circulating medium with non-magnetic material be kept at low levels and that the density of the medium be controlled within a narrow range. This prompted the installation of counter-rotation multi-pole magnetic separators which were supplied for the project by Malvern Engineering and Magnapower.

It was deemed necessary to effectively de-slime the feed coal at 100 micron to enable the magnetite recovery to meet the above objectives and to ensure that the separation in the cyclones was as effective as possible. The Delkor Fast Screen was chosen to perform this duty.

A flow sheet of the plant is shown in Figure 2.

A portion of the existing Koornfontein spiral plant feed is used as feed to the test plant. This coal is de-slimed at 100 micron using the Delkor Fast Screen.

Head feed to the plant is 25 tons per hour. The de-slimed feed amounts to approximately 20 tons per hour and is dewatered using a conventional Vibramech dewatering screen.

The dewatered feed is mixed with the medium and pumped to the primary (rougher) dense-medium cyclone. The overflow from the primary cyclone is mixed with circulating medium and pumped to the floats (cleaner) cyclone. The primary cyclone underflow is mixed with circulating medium and pumped to the sinks (scavenger) cyclone.

The overflow from the floats cyclone reports to a static screen. Part of the medium is recovered through the screen and this medium is pumped to a densifier cyclone for cleaning. A portion of the densifier cyclone overflow is sent to the product magnetic separator. The densifier underflow is returned to the circulating medium tank.

The product screen overflow is diluted with water and sent to the product magnetic separator. The magnetic separator underflow constitutes the final product. This product, in slurry form, is pumped back into the main plant to join the existing spiral product prior to dewatering. The recovered magnetite is gravitated to the circulating medium tank.

The underflow product from the floats cyclone is recirculated back to the primary cyclone feed.

The sinks (scavenger) cyclone processes the primary cyclone underflow stream. The sinks cyclone underflow is

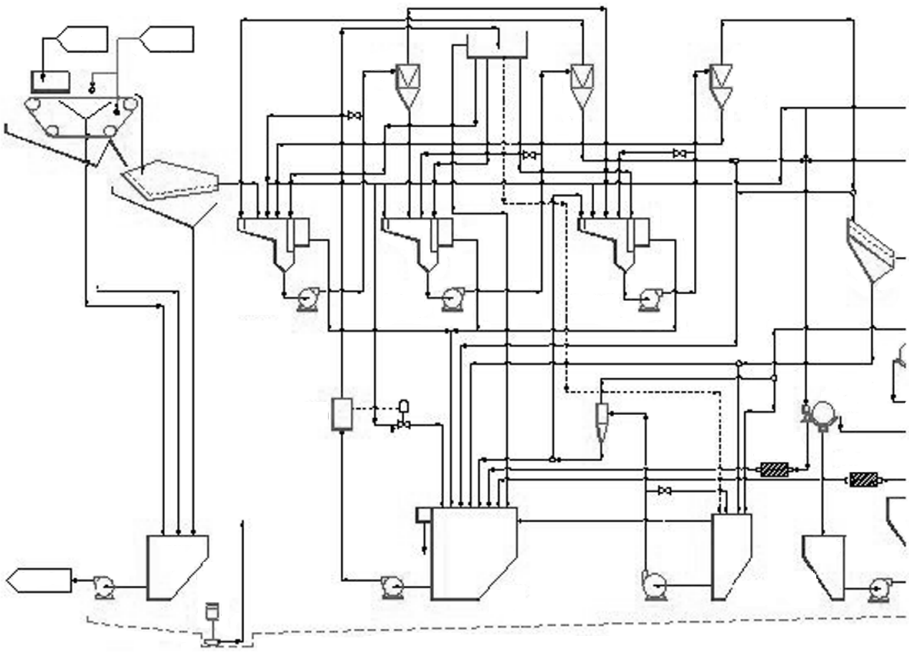

Figure 2—Flow sheet of the test plant

Figure 3—View of the test plant at Koornfontein Colliery

diluted with water and sent to the sinks magnetic separator. The magnetic separator underflow constitutes the final discard. The discard is pumped to the main plant where it joins the existing spiral plant discards. The recovered magnetite is sent to the circulating medium tank.

The sinks cyclone overflow is recirculated back to the primary cyclone feed.

Performance of the test plant to date

The plant was commissioned during November 2001 and is currently still in its early testing phase.

A view of the test plant is shown in Figure 3.

Figure 4 shows the three dense-medium cyclones in use. The cyclone in the foreground is the primary cyclone, the floats cyclone is furthest from the camera and the sinks cyclone is in the middle.

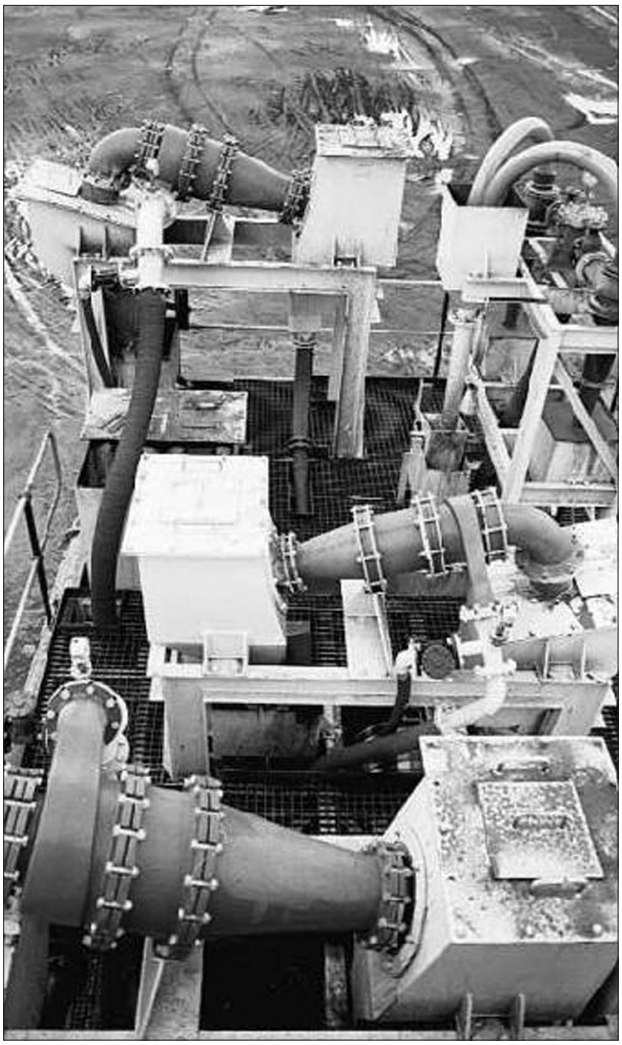

Figure 4—Dense-medium cyclones in test plant

Table I

Summary of efficiency test results
Efficiency test results: CoalTech 2020 test plant

	Test 1: 30 Nov. 2001	Test 2: 30 Jan. 2002
Feed % ash	21.2	21.5
Product % ash	17.8	15.6
Discard % ash	55.9	58.2
Product yield %	91.2	86.1
D_{50}	2.1439	1.8251
Epm	0.0509	0.0658
Organic efficiency %	98.9	98.5
Sink in float %	1.06	1.64
Float in sink %	3.70	2.37
Total misplaced %	4.76	4.01

Early indications are that the plant is operating effectively and that it is capable of producing the required product quality. However, one must bear in mind that the testing programme has just begun.

Only limited data pertaining to the efficiency of the plant were available at the time this paper was written.

Two efficiency tests have been conducted to date. The results obtained from these tests are shown in Table I.

The partition curves obtained are shown in Figures 5 and 6.

The performance of the magnetic separators has been found to be very good. The magnetite consumption measured to date is about 1.5 kg per ton.

The way forward

A test program for the plant has been agreed on and is presently being executed. The program aim is to quantify the critical plant parameters.

Acknowledgements

The CoalTech 2020 Steering Committee is gratefully acknowledged for supporting and funding the project.

Gratitude is also expressed towards the management of Koornfontein for allowing the plant to be tested at Koornfontein Colliery.

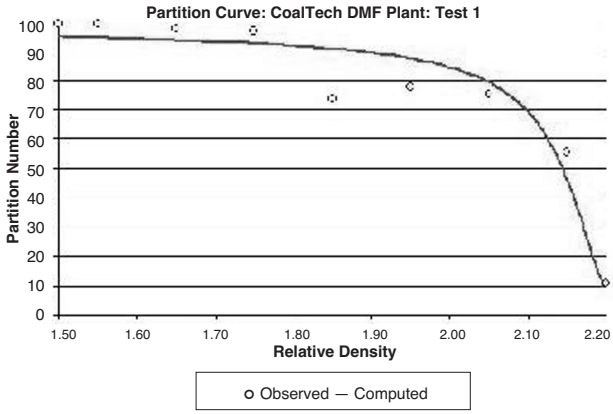

Figure 5. Partition curve for Test 1

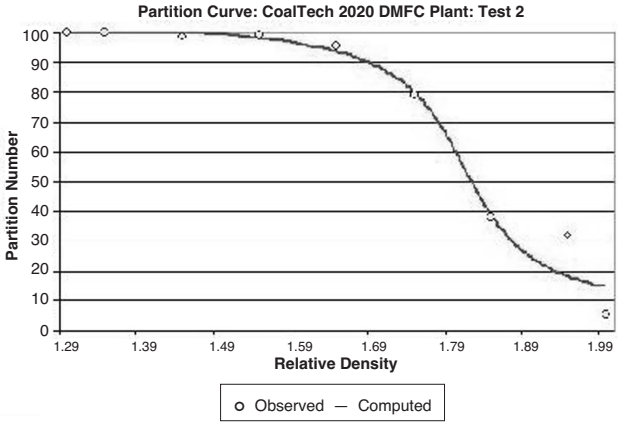

Figure 6. Partition curve for Test 2

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