

# **DENSE MEDIUM SEPARATION USING A MAGNETIC CYCLONE**

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## **ABSTRACT**

It is a well-known fact that good quality coal is being depleted due to the high demand of this product. What is left is coal of less favourable quality, and it is necessary to make efficient use of such coals. Since the majority of washed coals are produced by dense medium cyclones world-wide, there is as clear motivation to research any improvements in this technology. In this paper, the application of a magnetic field around a dense medium cyclone has proven to increase the sharpness of separation within such a cyclone, and has also made it possible to make use of coarser media during the process. Thus, the coal cleaning process can be made more efficient with higher yields and less misplaced material.

## **INTRODUCTION**

The ever-decreasing run-of-mine coal qualities have rendered it necessary for coal beneficiation processes to be continuously optimised in order to make efficient use of the value of the coal. The most popular coal beneficiation method is dense medium separation, a process that exploits the differences in density between the coal and the gangue in order to separate these materials. Dense Medium Separation (DMS) cyclones form part of this dense medium beneficiation process and, as the name indicates, makes use of a medium (a suspension of magnetite in water) in conjunction with the forces acting within such a cyclone to efficiently clean the coal that is being treated.

Traditionally, fine magnetite is used in DMS cyclones, as magnetite which is too coarse tends to settle out within the cyclone, causing instability (England *et al*, 2002). The challenge with fine magnetite, is that it can become viscous, also causing instability. It is more expensive than coarse magnetite, and its losses are also prevalent within the medium recovery process.

The application of a magnetic field around a DMS cyclone influences the medium stability (Svoboda *et al*, 1998). If the medium is unstable, it would influence the separation within a DMS cyclone and consequently render the process inefficient and costly (Myburgh, 2001). Due to an increased stability of the medium with the application of a magnetic field, the possibility to use a coarser media under such circumstances will reduce magnetite costs as well as increase the recovery efficiencies thereof. Coarse magnetite is more readily washed from DMS cyclone products and recovered in magnetic separators.

The solenoid unit used for this application, the SpecSep™, requires a wide Particle Size Distribution (PSD) range in order for magnetite to be stable within the DMS cyclone. SpecSep™ allows for coarser magnetite to be used in conjunction with fine magnetite for effective commissioning. This study aims to prove that coarser, cheaper magnetite can be used in a coal dense medium process by applying a magnetic field around a DMS cyclone, which consequently stabilises the coarse medium.

## EXPERIMENTAL PROCEDURE

The test work process focused on the application of a weak magnetic field around a dense medium cyclone. The tests were done using medium only.

### Magnetite Samples

For the test work, both commercial (fine) and coarse magnetite were used. Refer to Table 1 for information on the used magnetite.

Table 1: Magnetite Information

|                                | <b>Fine Magnetite</b> | <b>Coarse Magnetite</b> |
|--------------------------------|-----------------------|-------------------------|
| <b>Supplier</b>                | Martin and Robson     | Kimony (Pty) Ltd        |
| <b>Material D<sub>95</sub></b> | 75 µm                 | 150 µm                  |

### Magnetic Dense Medium Separation Cyclone Rig

The DMS cyclone rig can be seen in the following figures:

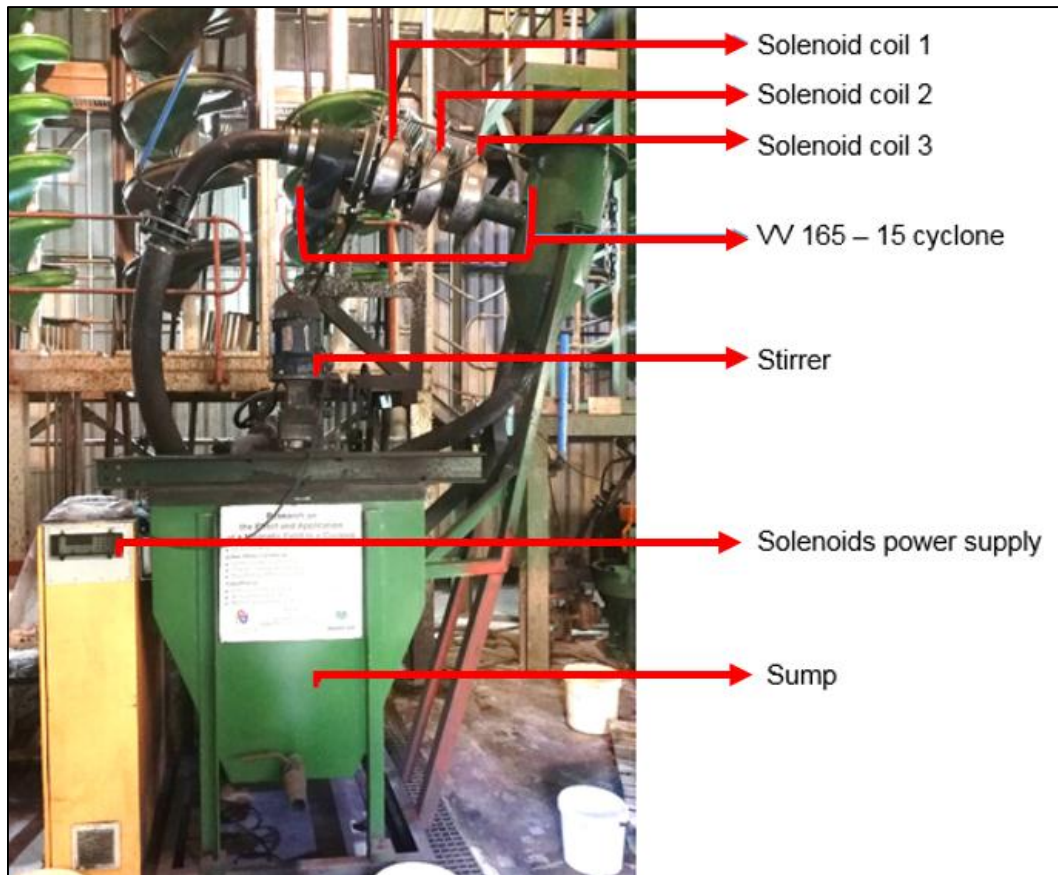


Figure 1: Magnetic DMS Cyclone Rig (Front View)

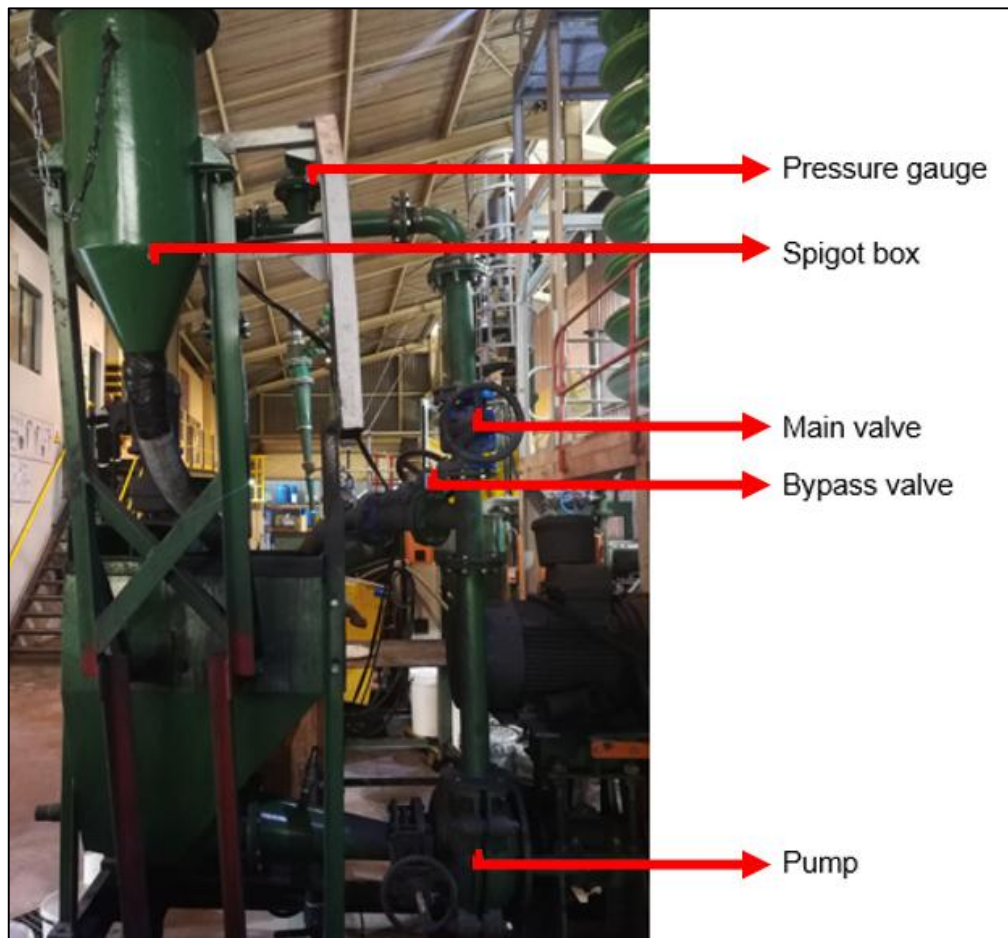


Figure 2: Magnetic DMS Cyclone Rig (Side View)

Test work was performed using the cyclone rig as shown above. The rig includes a polyurethane VV-165-15 cyclone installed with a 35 mm spigot. A polyurethane cyclone was chosen as it contains no metal parts, which is preferred due to the application of a magnetic field to the system. The cyclone has a diameter of 165 mm and is inclined to 15°. The front and side views of the DMS cyclone rig can be seen in Figure 1 and Figure 2 respectively:

The overflow and underflow streams of the cyclone reported to the sump where it was recirculated back through the cyclone. During operation, the main valve was closed and by opening the bypass valve the feed density could thus be measured using a volumetric cylinder. The density differential between the underflow and overflow streams was similarly measured

The cyclone rig is equipped with a pressure gauge, which was controlled at a constant head of 9D (Honaker, 2011), using a variable speed drive to control the flow through the cyclone.

### **SpecSep™ Solenoids**

From Figure 1 it can be seen that the solenoids installed on the VV-165 cyclone rig is a three unit system, with the solenoids spaced equal lengths from each other. This was done to enable testing the effects of the position and strength of the three magnetic

fields simultaneously. Test work was done by varying the current through the solenoids so that a suitable density differential would be obtained for the coarse and fine magnetite, respectively, as well as a mixture of both. The density differential is the difference between the cyclone overflow and underflow stream densities, and is an indicator of cyclone separation efficiency. Ideally, this differential should be between 0.2 and 0.5 g/cm<sup>3</sup> (Campbell & Coetzee, 1997:6). When the differential is too high, the separation efficiency decreases due to a longer retention time of near-density material.

The SpecSep™ solenoids were supplied by Eco-nomic Innovations Ltd and was designed as a three-unit system for this specific cyclone. The triple output DC power supply used to power the solenoids is an Aim and Thurlby Thandar Instruments MX100T.

## **Test method**

A suitable mixture of fine and coarse magnetite, together with water, was added to the sump of the cyclone rig in a ratio that would result in a feed Relative Density (RD) of 1.74 g/cm<sup>3</sup>. Non-magnetic tracers with densities ranging from 1.5 to 2.2 g/cm<sup>3</sup> at 0.1 g/cm<sup>3</sup> increments, was used to determine the partition curves. The tracers were 2 mm, colour coded cubes for ease of sorting.

Initially, a known amount of fine magnetite was added to the cyclone rig's sump, where coarse magnetite was added incrementally with density tests conducted after each addition of coarse magnetite. It was found that settling problems occurred as the density measurements were inconsistent. A stirrer was then installed to keep the coarse magnetite in suspension. Such a stirrer would not be necessary where the bottom of the sump is conical to prevent coarse media settling.

An amount of fine (conventional sized) magnetite, 95% passing - 45 µm, was introduced to the cyclone rig sump where tracer tests were done without the application of a magnetic field. Incremental amounts of coarse magnetite (Eves, 2015) were added to obtain the suitable coarse medium, where tracer tests followed, with the application of a magnetic field. A triple output DC power supply allowed for the solenoid coils to be operated independently from each other.

Medium density measurements were taken for the overflow and underflow streams and the feed density was measured and maintained throughout. Partition curves were plotted for the fine magnetite test work to obtain a base case to compare results with the case where coarse media was added to the fine media.

## **RESULTS AND DISCUSSION**

During the solenoid calibration phase, it was concluded that by using the two solenoids furthest from the spigot (Solenoids 1 and 2 in Figure 1), better medium stability could be obtained compared to the case where all three solenoids were used together.

The addition of coarse magnetite was halted when approximately half of the total medium was coarse. At this ratio and a feed RD of 2.29 g/cm<sup>3</sup>, the measured density differential between the overflow and the underflow was 0.9. This density differential

was obtained with no magnetic field being induced over the cyclone. A current of 0.8 amps was then applied to both Solenoid 1 and Solenoid 2. It was evident that, at this current, the best differential was obtained with a value of 0.5. The results showed that by increasing the coarse medium resulted in an increase in the differential regardless of the strength of the current applied to the magnets.

A further test was done where a known amount of coarse magnetite was added to the cyclone rig's sump, and fine magnetite was added incrementally. The differential indicated that stability was obtained when 43 % of the total media was coarse. With no magnetic field exerted onto the cyclone, this differential was found to be 1.14, whereas applying a current of 1.35 A resulted in a reduction of the differential to 0.48. The difference in results between the two approaches (incrementally adding coarse magnetite versus adding fine magnetite) can be due the fines generated by the attrition of coarse media since the first test was conducted over approximately a week. Less fines were generated during the reverse test when the test unit was operating smoothly.

Better separation efficiencies were evident while using coarse media, since the coarse media promotes lower viscosity. To validate the improvement, fine magnetite was added to the cyclone rig to obtain a baseline. The media was diluted to deliver a typical cut point found in the coal industry. The  $E_p$  value was then determined by using the 2 mm non-magnetic tracers. To compare results, the density differential for the test without the magnetic field was kept between 0.2 and 0.5, which is the acceptable range obtained from literature (Scholtz, 2015).

The average of three tracer tests is shown in Figure 3 as follows:

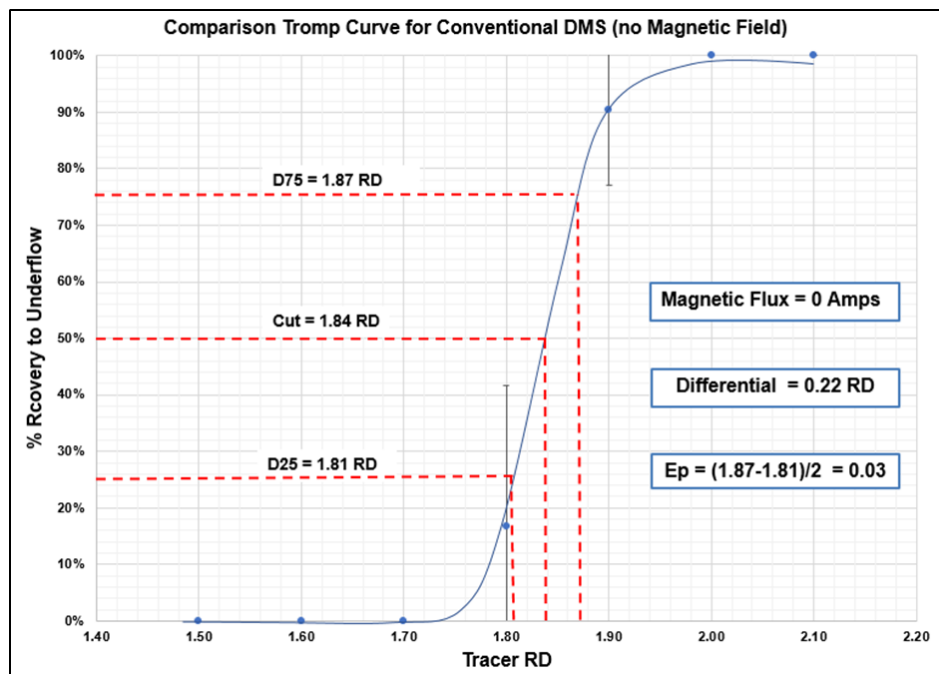


Figure 3: Partition Curve for Fine Magnetite Test Work without Magnetic Field

As calculated from the graph above it was obtained that the  $E_p$  value was 0.03 at a cut point density of  $1.84 \text{ g/cm}^3$ . The cyclone was set to run at 9D, thus giving a pressure of 25 kPa and a feed density of  $1.71 \text{ g/cm}^3$ .

For the test work with the application of a magnetic field, a suitable coarse medium mixture with feed density of  $1.74 \text{ g/cm}^3$  was prepared. Test work was carried out to determine the optimum magnetic field from which to conduct tracer tests on. By varying the current of both solenoid coils from 0 to 1.35 A, the differential was recorded as can be seen in Figure 4:

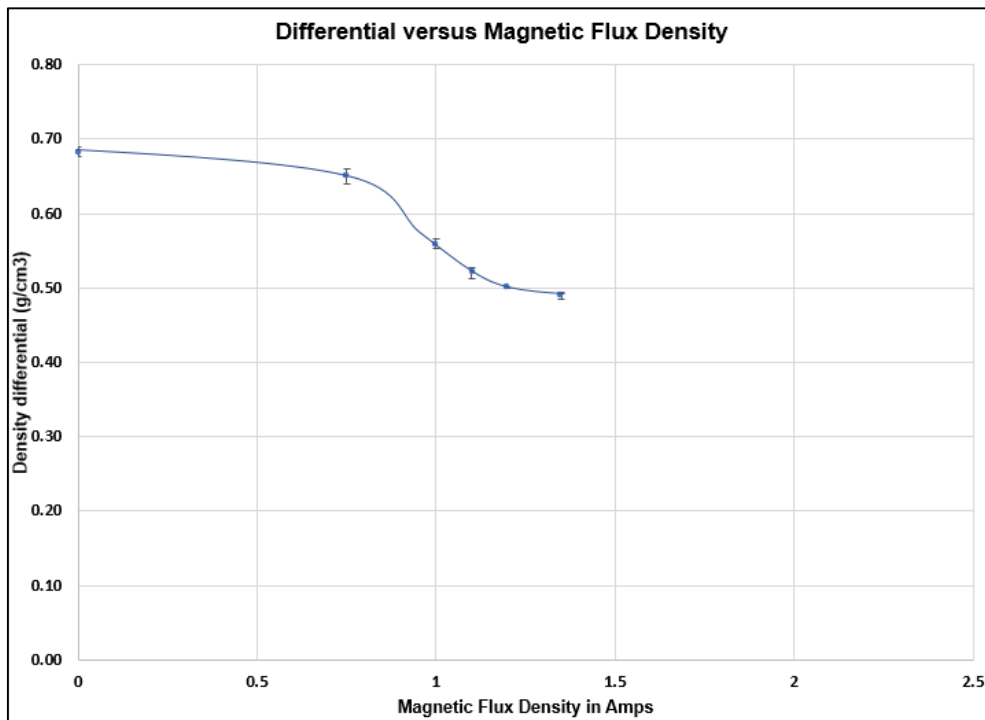


Figure 4: Density Differential versus Magnetic Flux Density

As evident from the figure above, the lowest differential obtained was 0.48 but it is suggested to run the test work at a differential of 0.52 to ensure there is no magnetic flocculation occurring in the cyclone. This chosen value was slightly beyond the upper limit as the magnetic field results in increased stability thus allowing operation at a slightly higher differential.

A tracer test was done by inducing a current of 1.1 A through the solenoid coils. The partition curve for this test is shown in Figure 5:

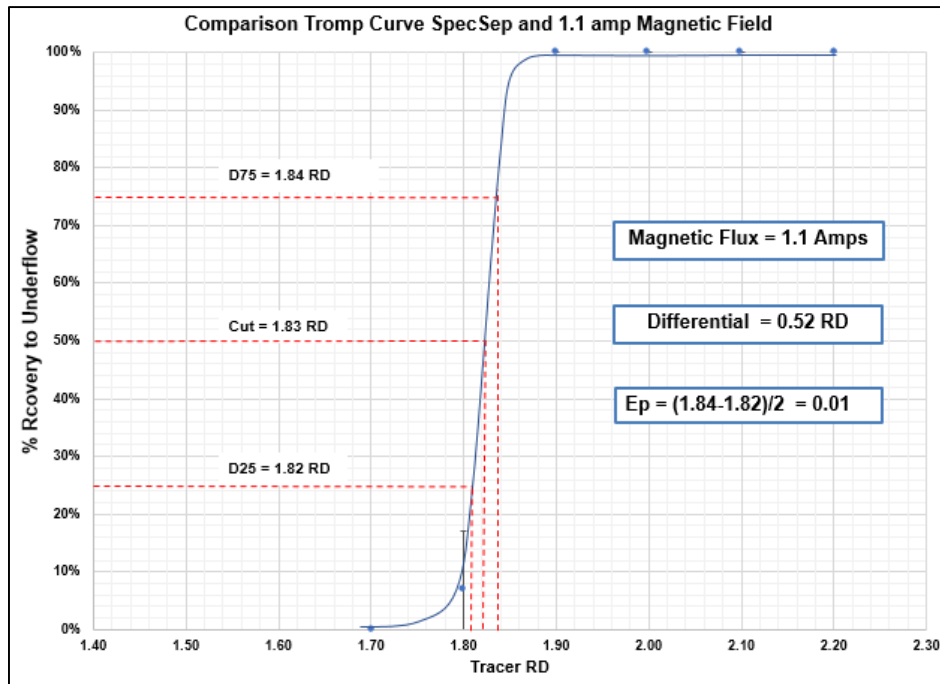


Figure 5: Partition Curve for Coarse Magnetite and a 1.1 A Magnetic Field

Comparing the base case partition curve with the partition curve with the added coarse magnetite, it can be noted that the  $E_p$  value decreased from 0.03 to 0.01 at similar cut points of 1.84 g/cm<sup>3</sup> and 1.83 g/cm<sup>3</sup>. Table 2 below is a summation of the test work results obtained for the fine and coarse magnetite:

Table 2: Results for fine- and coarse magnetite

|                                     | 100 wt% Fine Magnetite | 43 wt% Coarse Magnetite |
|-------------------------------------|------------------------|-------------------------|
| <b>Solenoid current (A)</b>         | 0                      | 1.1                     |
| <b>Cut-point (g/cm<sup>3</sup>)</b> | 1.84                   | 1.83                    |
| <b>Differential</b>                 | 0.22                   | 0.52                    |
| <b><math>E_p</math></b>             | 0.03                   | 0.01                    |

## CONCLUSIONS

To conclude, by using the SpecSep™ Technology (Eves, 2015), the separation efficiency of the cyclone increased as a result of the decrease in the  $E_p$  value from 0.03 to 0.01. This is a significant decrease in  $E_p$ , and proves that the use of this technology enables the stabilisation of cheaper, coarse media within a dense medium cyclone resulting in improved separation efficiency, cost saving in the processing of coal due to reduced magnetite consumption. It is thus recommended that further work be done with the addition of coal and media to the cyclone, to determine what the actual cost saving is for a large scale application and more importantly, the value of the additional coal recovered.

## ACKNOWLEDGEMENTS

The authors would like to thank Multotec Process Equipment (Pty) Ltd Technology Division for the use of their facilities, as well as the assistance of their dedicated staff. Furthermore, special thanks are in order for Eco-nomic Innovations Ltd. and the North-West University for planting the seed many years ago and whose support has made this project come to fruition.

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