Processing strategy for different coal types

by I. du Plessis*

Synopsis

The metallurgical response of a difficult to treat coal and an easy to treat coal orebody were investigated in terms of the coal yield and the coal quality in a basic coal recovery flowsheet. The purpose of this paper is to show trends and derive principles for the treatment of different coal types. This investigation entailed using the LIMN simulator to simulate the metallurgical response by varying the plant operational parameters. The controllable plant variables investigated were:

- Cyclone size
- Screen and hydrocyclone cut points
- Medium cut density
- Feed particle size distribution.

The following general principles can be derived from the work:

- Crushing finer can significantly improve the overall metallurgical performance, especially for a difficult to treat ore
- The strategy of crushing finer works better when there is a flotation stage in the circuit as it minimizes losses to fine discard
- Smaller cyclones result in slightly better performance because of the greater centrifugal force generated giving a smaller breakaway size.

Keywords

Coal yield, coal quality, LIMN, coal types, processing strategy, liberation.

Introduction

The metallurgical response of a difficult to treat coal resource and an easy to treat coal resource were investigated in terms of the coal yield and the coal quality. This entailed investigating the metallurgical response of the ores for a basic flowsheet using the LIMN simulator. The controllable parameters were varied to establish the effects of these variables on the metallurgical performance. The controllable variables investigated were:

- Cyclone size
- Screen and hydrocyclone cut points
- Medium cut density
- Feed particle size distribution.

A study of the metallurgical response of different ores implies briefly investigating the different feed properties.

Feed material

Two different feed materials were studied, each of them being representative of difficult to treat coals and easy to treat coals.

Difficult to treat coal

Figure 1 shows the mass washability by size for a difficult to treat coal. The legend is shows the different coal size fractions.

What is of particular interest in the difficult to treat coal is the difference in the shape of the +2 mm size coal compared to the -2 mm size fraction, which is U-shaped. This is indicative of liberation, which splits the coal into a high density and a low density fraction as the size decreases.

Figure 2 shows the ash washability by size for a difficult to treat coal.

The increased ash in the higher density fractions is to be expected. The close correlation of the ash content in a specific density class for the different size classes is interesting to note.

Easy to treat coal

Figure 3 shows the mass washability by size for an easy to treat coal.

What is of particular interest in the easy to treat coal when compared to the difficult to treat coal (Figure 1) is that all size classes exhibit the U-shape. This indicates that coal liberation may not have as big an influence on the easy to treat coal compared to the difficult to treat coal.

Figure 4 shows the ash washability by size for an easy to treat coal.

The increased ash in the higher density fractions is to be expected. It is also interesting to compare the difficult to treat coal (Figure 2),

* *Multotec.*

 This paper was first presented at the SAIMM Conference, Physical Beneficiation 2010, *4–6 May 2010.*

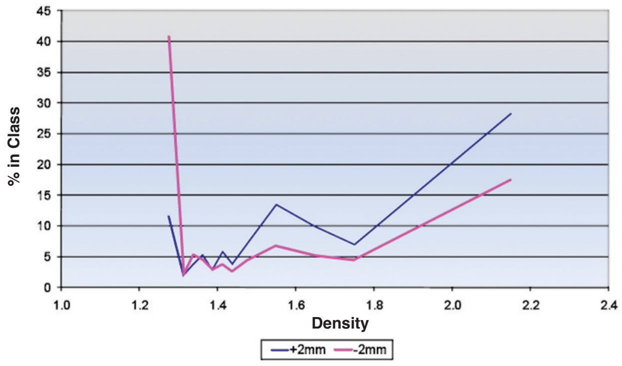

Figure 1—Mass washability for a difficult to treat coal

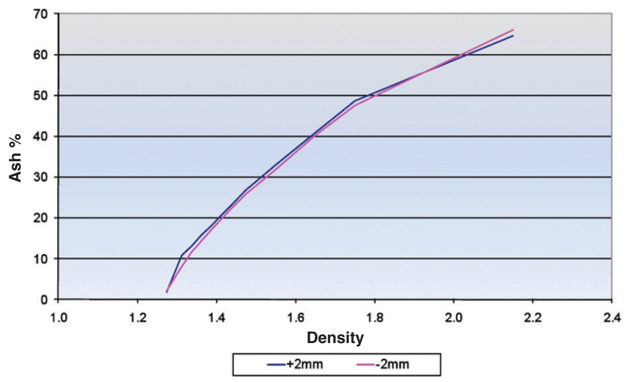

Figure 2—Ash washability for a difficult to treat coal

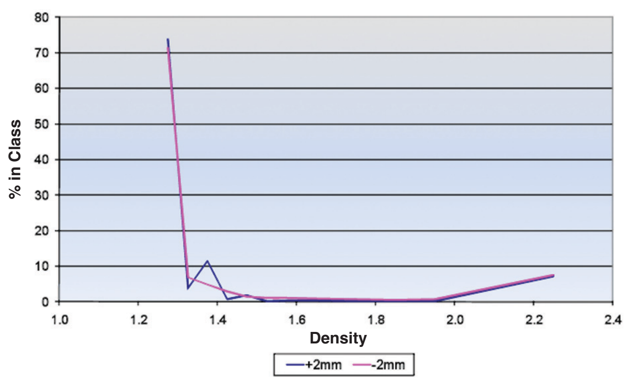

Figure 3—Mass washability for an easy to treat coal

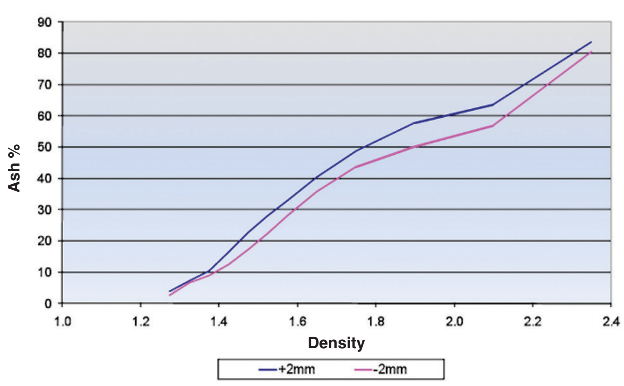

Figure 4—Ash washability for an easy to treat coal

where the ash contents for the different sizes closely correlate and the easy to treat coal (Figure 4), where the ash contents for the different size classes diverge slightly.

Influence of breakage on coal washabilities

Figures 1 to 4 above discuss only the run of mine (ROM) washabilities. If the ROM were comminuted, the comminuted products should have new washabilites. If a large particle breaks, some of its progeny would report to the same density class as the parent particle, but some would report to a higher density class and some to a lower density class, due to liberation of the stones from the coal. For the purposes of this study a simplified model was developed to calculate the new washabilites. Work done in the Australian Coal Association Research Programme (ACARP) provided significant guidance and data in this regard[1].

Table I below was constructed from the abovementioned report, to define if a parent particle breaks, what fraction would report to a higher and what fraction to a lower density class.

Table I below shows the model parameters that were developed.

Table I can best be explained by way of an example. If a parent particle breaks in half, its progeny have a 0.3% chance of reporting to a higher density class, 59.8% chance of reporting to the same density class as the parent and a 39.9% chance of reporting to a lower density class. If a parent particle breaks into quarters (0.25), its progeny have a 2.1% chance of reporting to a higher density class, 64.4% chance of reporting to the same density class as the parent and a 33.5% chance of reporting to a lower density class.

Plant feed particle size distributions

Four different plant feed particle size distributions (PSD) were investigated.

Figure 5 shows the four PSDs, namely:

- Fine
- Medium fine
- Medium coarse
- Coarse.

Plant flowsheets

The performance of the ores described above was evaluated in terms of the coal yield and quality for a basic coal recovery flowsheet.

Table I

Ratio for the redistribution to calculate the washabilities of a breakage product

Ratio of progeny size to parent particle size	Density class		
	Higher density class, %	Same %	Lower density class, %
1		100%	
0.50	0.3	59.8%	39.9
0.25	2.1	64.4%	33.5
0.13	11.1	63.8%	25.0
0.06	31.7	50.6%	17.7
0.03	45.6	45.7%	8.6
0.02	40.1	40.9%	19.0

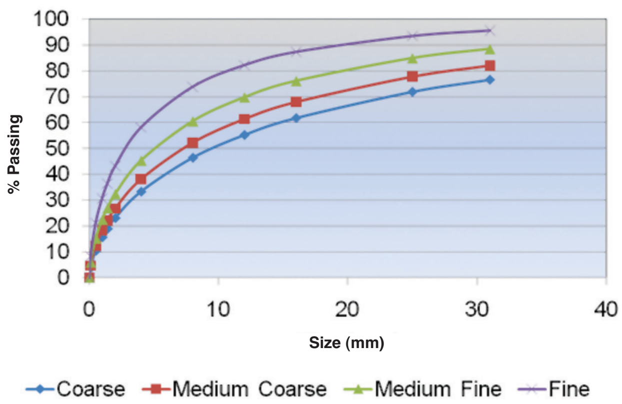

Figure 5—Plant feed PSDs

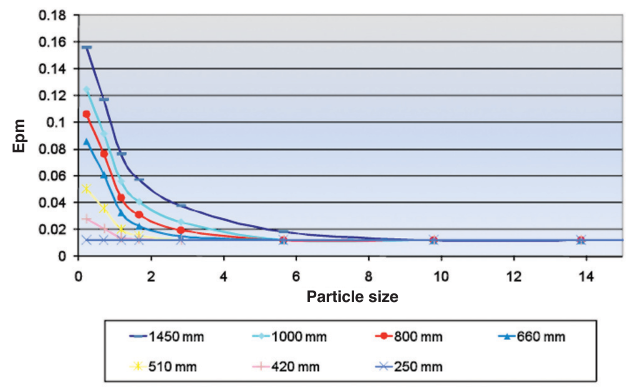

Figure 7—Epm vs. particle size for different cyclone sizes

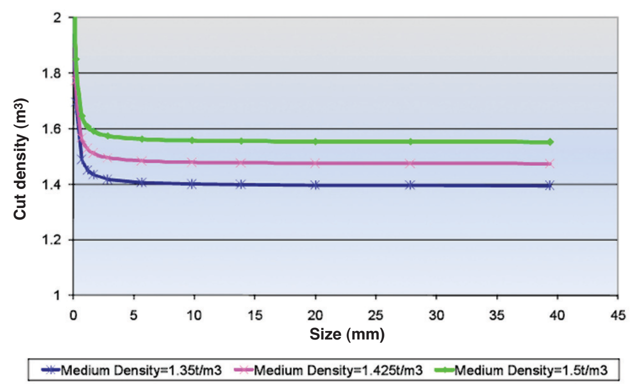

Figure 8—The cut points for different particle sizes

Flowsheet

Figure 6 shows the basic flowsheet that was investigated.

The areas marked in red show the plant equipment that was varied:

- ➤ DMS cyclone size
- ➤ Hydrocyclone cut point
- ➤ Screen 1 cut size.

The performance for the DMS is best described by the following two graphs in Figures 7 and 8. Figure 7 shows the well-known cyclone size versus Epm for different particle sizes. The shape of these curves is supported by reports in the literature.[2,3]

Figure 8 also shows another important parameter describing cyclone performance, the cut points that shift for different particle sizes.[4]

Table II shows the performance of the spirals used in this simulation study.

Table III shows the operating parameters for the different units that were varied to assess their effect on metallurgical performance.

Since four of the parameters had three operating levels and one four, this means that 324 $(3^4 \times 4)$ scenarios were simulated for both the difficult to treat coal and easy to treat coal.

Table II

Spiral performance parameters

Size (mm)	Ep	Cut density
1.18	0.10	1.68
0.71	0.10	1.68
0.22	0.14	1.88
0.07	1.02	2.14

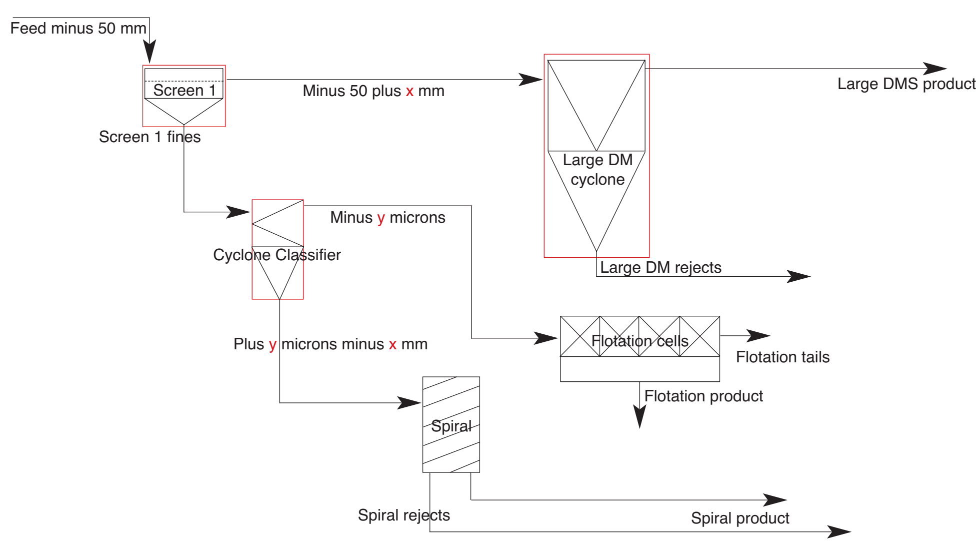

Figure 6—Flowsheet

Table III

Operating parameters for the basic flowsheet

Medium density	Screen 1 cut size, mm	Hydrocyclone cut size, mm	Feed PSD	Cyclone size, mm
1.35 1.45 1.55	0.50 0.75 1.00	0.07 0.08 0.09	Fine Medium fine Medium coarse Coarse	660 1000 1450

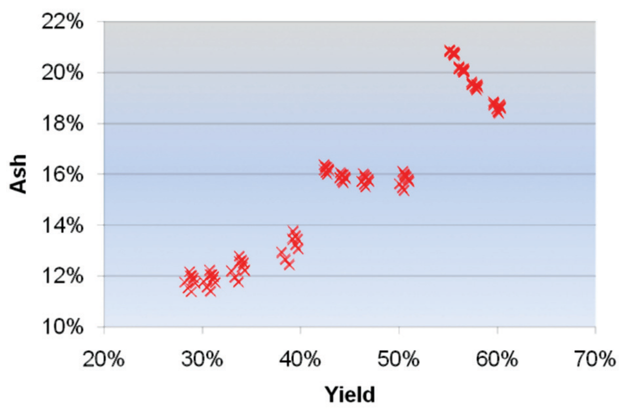

Figure 9—Performance of the difficult to treat coal

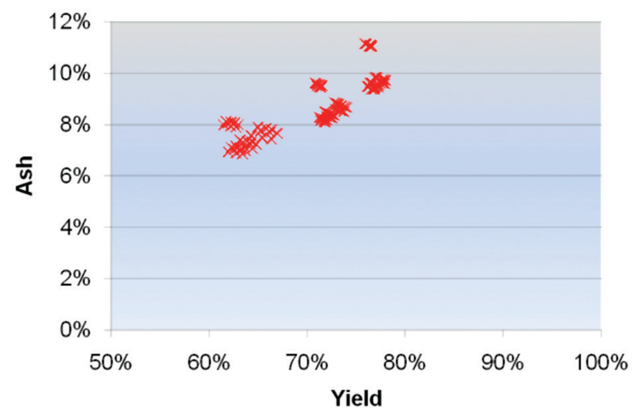

Figure 10—Performance of the easy to treat coal

Simulation results

The simulation results for the basic and the split DMS were compared for the difficult to treat coal and easy to treat coal and the effect of different parameters were analysed.

Total performance

Figure 9 shows the coal recovery and coal ash content for each of the 324 scenarios for the difficult to treat coal ore. The y-axis shows the coal quality in percentage ash and the x-axis shows the recovery.

Figure 10 shows the coal product tons and coal yield for each of the 324 scenarios for the easy to treat coal ore.

Comparing Figures 9 and 10, a few observations can be made:

- ➤ There is a considerable spread in the performance of the difficult to treat and easy to treat coals.
- ➤ The spread in the coal quality for the easy to treat coal is significantly less than the difficult to treat coal.

Effect of liberation

Figure 11 shows the coal recovery and product ash content for each of the 324 scenarios for the difficult to treat coal ore. Each dot is coloured based on the plant feed PSD.

Figure 11 shows that liberation (feed PSD) has a considerable impact on the performance in terms of coal quality and yield which improves at finer PSDs.

Figure 12 shows the coal recovery and coal ash for each of the 324 scenarios for the easy to treat coal. Each dot is coloured based on the plant feed PSD.

From Figure 12 it can be seen that PSD also has an influence on the coal quality and yield, but it is not as pronounced as in the case of a difficult to treat coal.

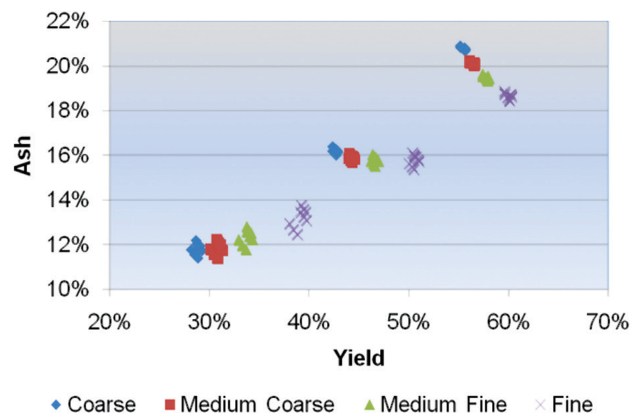

Figure 11—Effect of liberation on the performance a difficult to treat coal

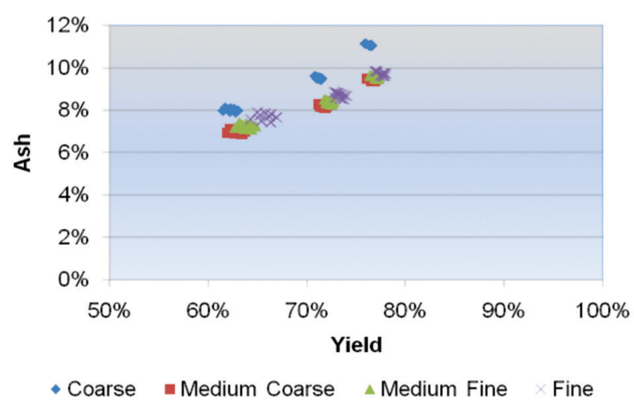

Figure 12—Effect of liberation on the performance of an easy to treat coal

Processing strategy for different coal types

Table V summarizes the performance of the difficult to treat coal and easy to treat coals. Fromg Table V it can be seen that liberation has a significant influence, especially on a difficult to treat coal.

Effect of cyclone size

Table VI summarizes the effect of cyclone size on the performance of the difficult to treat coal and easy to treat coals.

For the easy to treat coal there is less than 1% difference in the yield between using a large (1 450 mm diameter) versus a small (660 mm diameter) cyclone, with negligible difference in the coal quality. For the difficult to treat coal there is a 0.2% difference in the yield and a minor improvement in coal quality using a smaller cyclone.

Effect of liberation and medium density

Figure 13 shows the combined influence of liberation and medium density in the DMS on coal yield and quality for a difficult to treat coal.

From Figure 13 it can be seen that there is an interplay between coal quality and yield by varying medium density. From the figure it can also be seen that at a specific medium density the coal quality and yield can be improved with liberation.

Table V

Performance of the difficult to treat coal and easy to treat coal

Easy to treat coal			Difficult to treat coal	
	Yield, %	Ash, %	Yield, %	Ash, %
Fine	72.2	8.7	49.9	15.9
Medium-fine	71.0	8.4	46.0	15.9
Medium-coarse	70.4	8.2	43.8	15.9
Coarse	69.9	9.6	42.3	16.3

Table VI

Performance of the difficult to treat coal and easy to treat coals

Easy to treat coal			Difficult to treat coal	
	Yield, %	Ash, %	Yield, %	Ash, %
660 mm diameter cyclone	71.2	8.7	45.7	15.9
1000 mm diameter cyclone	70.9	8.7	45.5	16.0
1450 mm diameter cyclone	70.5	8.7	45.4	16.1

Table VII summarizes the results for the difficult to treat coals in terms of medium density and ore liberation. There is a 10% improvement in yield, i.e. between the finest and coarsest feed material, at a medium density of 1.35, with a slight increase in ash content at finer grinds. There is an 8% improvement in yield at a medium density of 1.45, with a slight decrease in ash content. There is a 5% improvement in yield at a medium density of 1.55, with a slight decrease in ash content.

Table VII shows that liberation has a significant influence on overall plant performance for a difficult to treat ore if the medium cut density is taken into account.

Figure 14 shows the coal yield and coal ash for each of the 324 scenarios for an easy to treat coal. From Figure 14 it can be seen that there is an interplay between coal quality and yield by varying medium density. From the figure it can

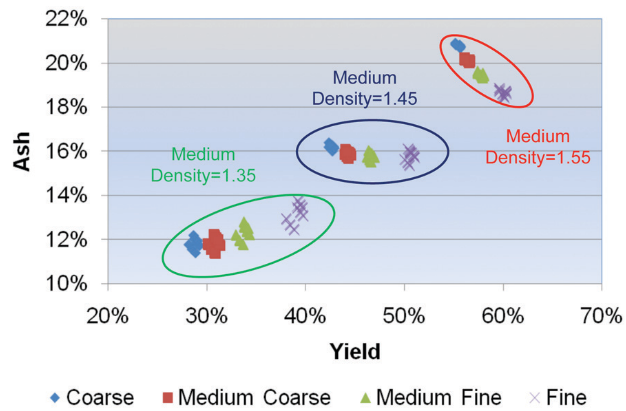

Figure 13—Effect of medium density in the DMS cyclone and liberation on the performance a difficult to treat coal

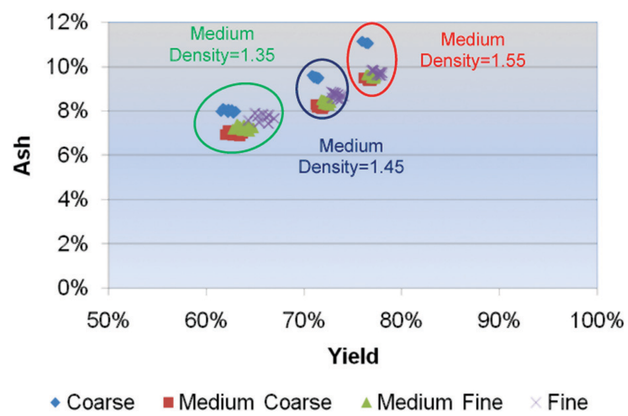

Figure 14—Effect of medium density in the DMS cyclone and liberation on the performance of an easy to treat coal

Table VII

Summary of the effect of medium density and ore liberation on the yield of a difficult to treat ore.

	Coarse		Medium coarse		Medium fine		Fine	
	Yield, %	Ash, %	Yield, %	Ash, %	Yield, %	Ash, %	Yield, %	Ash, %
Density=1.35	28.8	11.8	30.8	11.8	33.8	12.3	39.1	13.2
Density=1.45	42.6	16.2	44.3	15.9	46.6	15.8	50.6	15.8
Density=1.55	55.4	20.8	56.4	20.1	57.7	19.5	60.0	18.6s

Table VIII

Summary of the effect of medium density and ore liberation on the yield of a easy to treat ore.

	Coarse		Medium coarse		Medium fine		Fine	
	Yield, %	Ash, %	Yield, %	Ash, %	Yield, %	Ash, %	Yield, %	Ash, %
Density=1.35	62.3	8.0	62.9	7.0	63.9	7.3	65.7	7.7
Density=1.45	71.2	9.5	71.6	8.2	72.3	8.4	73.4	8.7
Density=1.55	76.3	11.1	76.6	9.4	77.0	9.6	77.5	9.7

also be seen that at a specific medium density the coal quality and yield can be improved with liberation. In this particular case it seems that there is a step jump from the coarse to the medium coarse size fraction and thereafter there is minimal improvement in coal recovery by crushing finer.

Table VIII summarizes the results for the difficult to treat coals in terms of medium density and ore liberation. There is a 3% improvement in yield at a medium density of 1.35, with a slight decrease in ash content at finer grinds. There is a 2% improvement in yield at a medium density of 1.45, with a slight decrease in ash content. There is a 1% improvement in yield at a medium density of 1.55, with a slight decrease in ash content.

Table VIII shows that liberation has a influence on overall plant performance for an easy to treat ore, although not as pronounced as a difficult to treat ore, if the medium effect is taken into account.

The flowsheet without flotation

Excluding the coal from the flotation stage allows us to evaluate the performance of coals in terms of gravity concentration devices only. The reason for this is that the fine coal may sometimes not be economical to recover due to the cost of moisture removal from fine particles.

Figure 15 shows the coal quality and coal yield for each of the 324 scenarios for the difficult to treat coal for the basic flowsheet without a flotation stage.

Figure 15 shows that liberation (finer feed PSD) has a considerable impact on the performance in terms of coal quality and yield, which improves as the feed PSD is reduced.

Figure 16 shows the coal quality and coal yield for each of the 324 scenarios for an easy to treat coal for the basic flowsheet without a flotation stage.

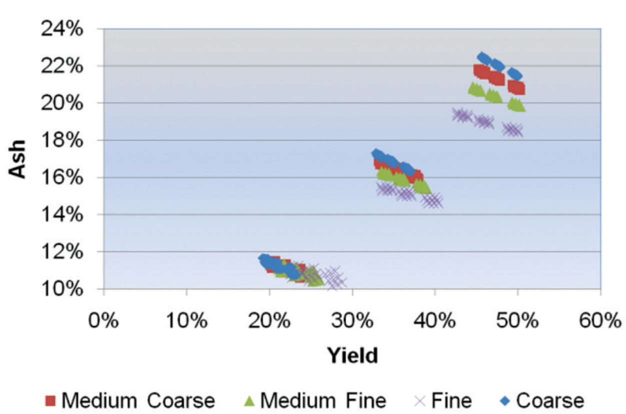

Figure 15—Effect of liberation on the performance a difficult to treat coal ore in a Basic Flow sheet without flotation

Whereas Figure 16 shows that a finer grind results in improved coal quality, there seems to be a reduction in coal yield for an easy to treat coal at a finer grind. This is due to some of the coal being lost as fine discard at a lower plant feed PSD.

Table IX compares the average yield and grade results for difficult to treat coal and easy to treat coal for different grinds.

Analysing the results in Table IX above and comparing these results with Table V, a few observations can be made, viz.:

- ➤ The yield for the easy to treat coal decreases at finer grinds if the recovery of the coal from flotation is not taken into account.
- ➤ The quality of the easy to treat coal does improve with finer grind with and without flotation. However, the effect on coal quality is more pronounced when there is no flotation.

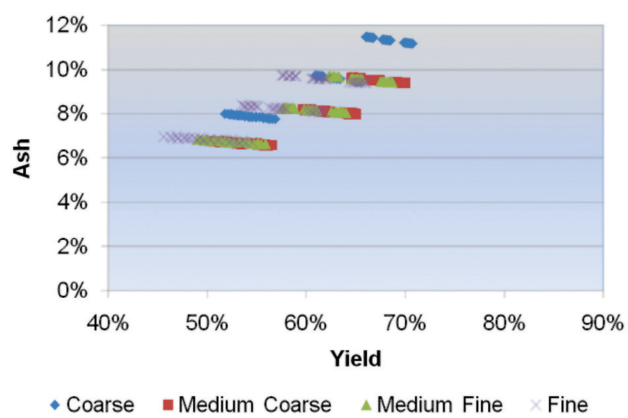

Figure 16—Effect of liberation on the performance an easy to treat coal without flotation

Table IX

Comparison of the average values for difficult to treat coal and easy to treat coal for the basic flow sheet without flotation

	Easy to treat coal		Difficult to treat coal	
	Yield, %	Ash, %	Yield, %	Ash, %
Fine	56.3	8.2	36.1	14.9
Medium-fine	59.4	8.2	35.6	15.7
Medium-fine	61.0	8.1	35.0	16.3
Coarse	61.9	9.6	34.7	16.7

- The yield and coal quality for a difficult to treat coal is improved with and without flotation. The improvement is more pronounced in terms of yield when there is a flotation module.

Conclusions

The results from a yield perspective are summarized in Table X below. These values focus only on the yield as it is difficult to summarize both ash and yield in the same table. On average the ash content in the table is 9% for easy to treat coal and 16% for difficult to treat coal.

From Table X the following can be concluded:

- The yield for the difficult to treat coal improves considerably when you liberate the ore better by generating a finer plant feed PSD, approximately 5% when using no flotation.
- The flotation step improves the yield for the difficult to treat ore by 22%.
- When there is flotation the yield for the difficult to treat coal improves further on better liberation, namely 19%.
- With a flotation stage there is a slight improvement in yield of the difficult to treat coal when a smaller cyclone is used, *ca*. 0.7%.
- There is a decrease in the coal yield for the easy to treat coal ore using a finer grind and no flotation stage of, *ca* 9%. This is due to the loss of coal as a fine discard.
- Using a smaller DMS cyclone has a positive influence on the coal yield for the easy to treat coal of *ca*. 0.7%.
- The flotation stage has a positive influence on the coal yield for the easy to treat coal, *ca*. 13%.
- Crushing finer for the easy to treat coal with a flotation step improves the yield by 3.4%.

Table X

Summarized yield results for the performance of difficult to treat coal and easy to treat coals

	Easy to treat coal	Difficult to treat coal
Baseline	61.6%	34.4%
Finer grind without flotation	55.8%	36.2%
With flotation	69.7%	42.1%
Smaller cyclone with flotation	70.2%	42.4%
Finer grind with flotation	72.6%	50.1%

The following general principles can be derived from the above results:

- Crushing finer can significantly improve the overall metallurgical performance, especially for a difficult to treat ore.
- The strategy of crushing finer works better when there is a flotation stage.
- Smaller cyclones result in slightly better performance because of the smaller breakaway size.

This study has shown general trends; each plant will need to do its own techno-economic study to assess the benefits of improved liberation of its ore.

References

1. Kojovic, T., O'Brien, G., Shi, F., and Esterle, J.S. Predicting washability as a function of Breakage. ACARP report (C5054), September 1999.
2. Swanson, A. Performance of Large Diameter Dense Media Cyclones—An Easy to treat coal Perspective. *Coal Pep 2009 Conference*, Lexington, USA.
3. Bosman, J. and Engelbrecht, J. Does size really Count? *6th Samancor Symposium on DM Separation*, 1997.
4. Wood, C. Coal-Washing Dense Medium Cyclones-A JKMRC Handbook for operators and plant designers, October 1990. ◆

Winners of the 2010 Nedbank Capital Green Mining Awards announced

The winners of the fifth annual Nedbank Capital Green Mining Awards—which aim to acknowledge and celebrate the invaluable contribution that responsible mining and mineral beneficiation make to the economic development of Africa—were announced in October at an awards presentation held at Nedbank's head office in Sandton.

The winning projects for 2010 are:

- *Environmental category*—AfriSam's CO_2 Footprinting initiative.
- *Socio-economic category*—Joint-winners: - Lonmin Plc's Silindini Thusong Service Centre and Silindini Bridge; and Exxaro's Zikhulise Community Upliftment project.
- *Sustainability category*—E Oppenheimer & Son and De Beers Consolidated Mines Diamond Route.

BHP Billiton's Dreamfields Project was a runner-up in the Socio-economic category and Exxaro's Lephalale Eco-housing was a runner-up in the Sustainability category. No awards were made in the Limited Resources category.

'It is extremely pleasing to see how seriously mining companies are taking their commitment to reducing their impact on the environment, uplifting their communities, and ensuring that sustainability has a critical bearing on everything they do,' says Peter van Kerckhoven, joint-head of Mining & Resources at Nedbank Capital.

'This year's awards again evidence the fact that mining companies are aware they do not operate in a vacuum and are increasingly honouring their wide-ranging social, economic and environmental responsibilities. It is gratifying for us to be able to showcase some of these achievements that have required enormous dedication and application from the companies and the many special individuals working for, and alongside, them.' ◆