Differences in Australian and SA coal processing

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Executive Summary

The metallurgical response of a Southern African and an Australian ore body were investigated in terms of the coal yield and the coal quality, through two different types of flow sheets. The two flow sheets were, a basic flow sheet, that uses a cyclone, a spiral and a flotation process to recover the coal, and a split DMS. The difference between it and the basic flow sheet is that there is a coarse and fine DMS sections. This investigation entailed using the LIMN simulator, to simulate the metallurgical response of the two different flow sheets on the two different ore types by varying the plant operational parameters. The controllable plant variables investigated were:

- Cyclone size
- Screen aperture and hydro-cyclone cut points
- Medium cut density
- Feed particle size distribution

The conclusions drawn from this study indicated that the following characteristics of a coal flow sheet were desirable to improve coal yield and quality:

- There is considerable scope to improve the performance of a Southern African coal by optimizing the plant feed PSD. A finer PSD seems to be generally better as it is indicative of an improved liberation of the coal from the gangue. This study showed that the overall plant coal yield can be improved by as much as 15%, with no deterioration in coal quality.

- The split DMS improves the coal yield for both the Australian and Southern African coal, i.e. 7.1 % and 9.1 % respectively. This reason for this is threefold;

    - the fines DMS can be a smaller cyclone which has a greater centrifugal force which allows it to be a better device to recover the fines which can lead to inefficiencies due crowd issues in the cyclone,

    - the medium to ore ratio of the fines and coarse circuit can be varied independently; there are indications in the literature that the treatment of fine material requires a higher medium to ore ratio,
    - the cut densities of the coarse and fine circuit can be varied independently to optimize the overall plant coal yield and quality.

- The performance of the split DMS flow sheet could be improved further by optimizing the liberation; finer PSD seems to be generally better for the Southern African coal. This also seems to be the case with the Australian coal, however not as pronounced.

- The size range sent to the fines cyclone in the split DMS flow sheet should be maximized especially the lower size range as a small DMS will have a considerably better Ep than a spiral or TBS.

Introduction

The metallurgical response of a Southern African coal resource and an Australian coal resource were investigated in terms of the coal yield and the coal quality. This entailed investigating metallurgical response of the ores in two different flow sheets using the LIMN simulator. In each of the flow sheets a number of controllable parameters were varied to establish the effects of these variables were on the metallurgical performance. The controllable variables investigated were:

- Cyclone size
- Screen aperture and hydro cyclone cut points
- Medium Cut density
- Feed particle size distribution

The investigation of two different circuit configurations implied that the effect of circuit configuration was also investigated. A study of metallurgical response of different ores implies briefly investigating the different feed properties.

Feed Material

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

Southern African Coal

Figure 1 below shows the mass washability by size for a Southern African coal. The legend is shows the mean size of the coal in a size fraction.

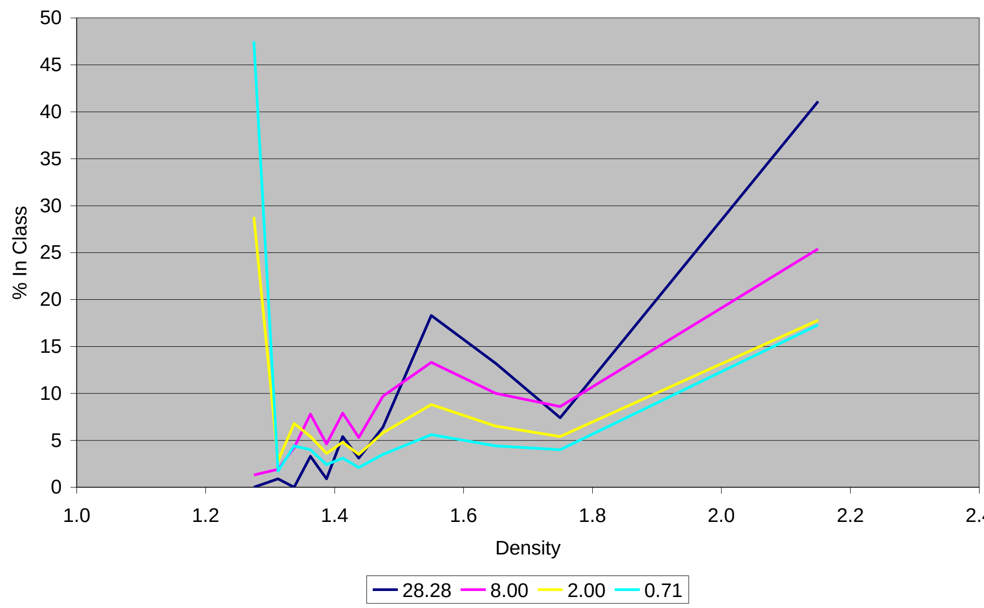

Figure 1 – Mass Washability for a Southern African Coal

What is of particular interest in the Southern African coal is the difference in the shape of the 28mm size coal compared to the rest which are U-shaped. This is indicative of liberation, which splits the coal out into a high density and a low density fraction as the size decreases.

Figure 2 shows the ash washability by size for a Southern African coal.

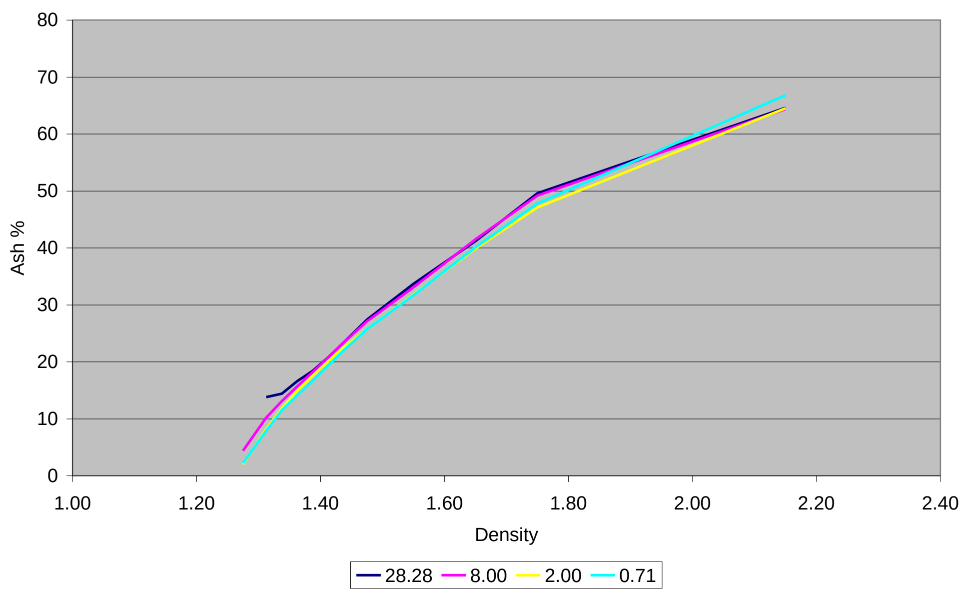

Figure 2- Ash Washability for a Southern African coal

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.

Australian Ore

Figure 3 below shows the mass washability by size for an Australian coal

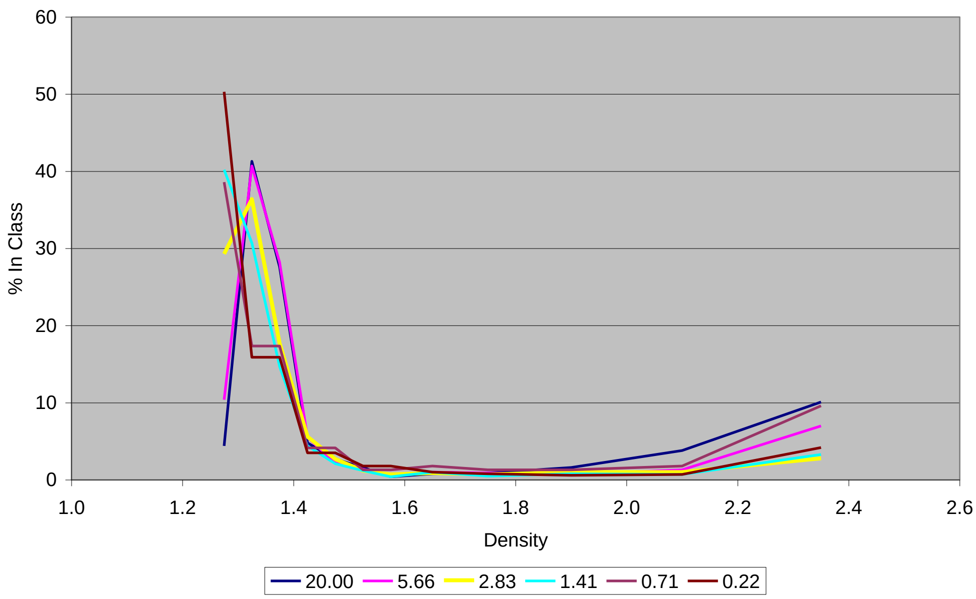

Figure 3 – Mass Washability for an Australian coal

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

Figure 4 shows the ash washability by size for an Australian coal.

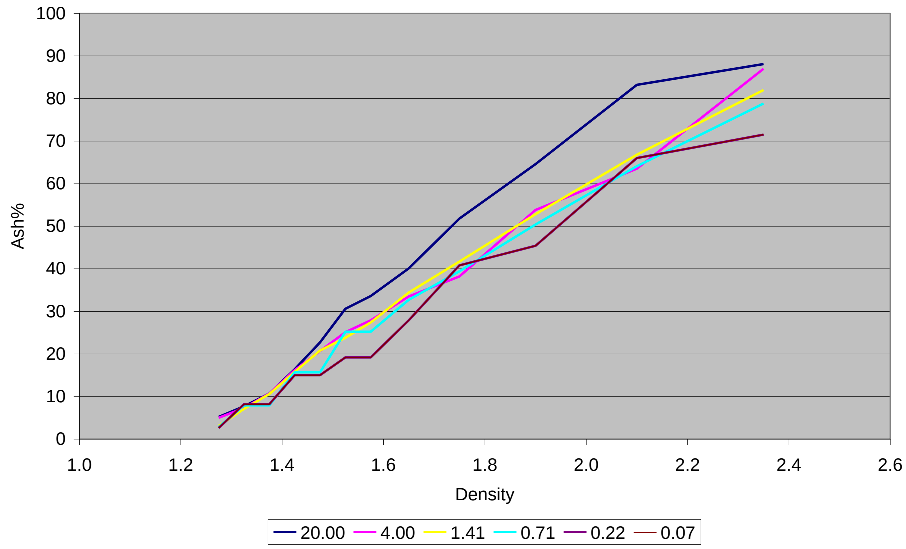

Figure 4- Ash Washability for an Australian Coal

The increased ash in the higher density fractions is to be expected. It is also interesting to compare the Southern African (figure 2), where the ash contents for the different sizes closely correlates and the Australian coal (figure 4); where the ash contents for the different size classes diverge slightly.

Plant Feed Particle size distributions

Three different plant feed particle size distributions (PSD) were investigated. Figure 5 below shows the three PSDs, viz.:

- Fine
- Medium
- Coarse

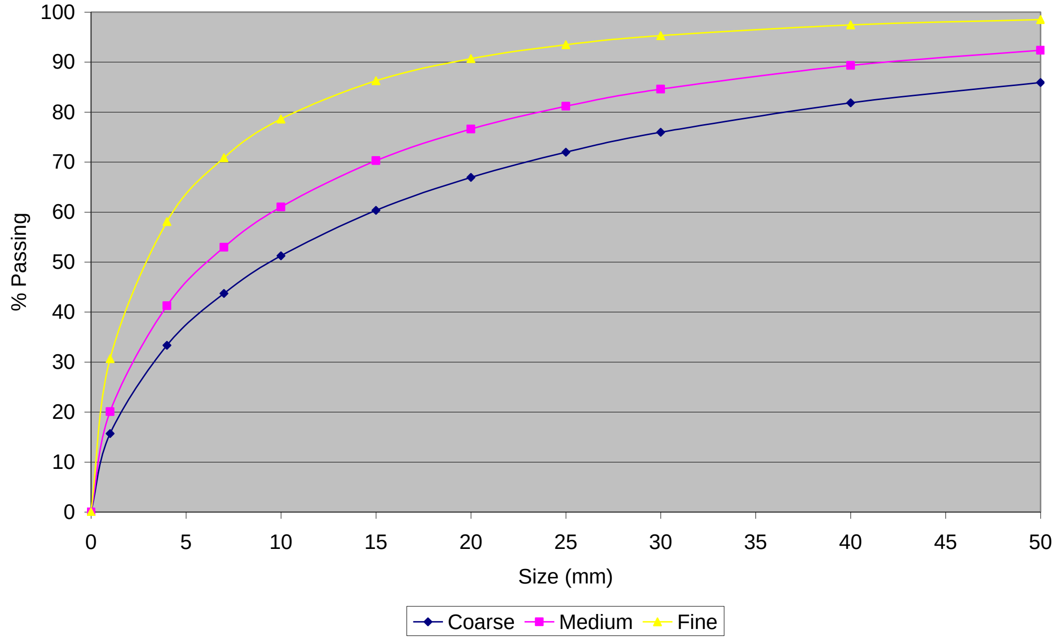

Figure 5 – Plant Feed PSDs

Plant flow sheets

The performance of the ores described above was evaluated in terms of the coal yield and quality for two flow sheets, viz.:

- The basic flow sheet
- The split DMS flow sheet

Basic Flow sheet

Figure 6 below shows the basic flow sheet that was investigated.

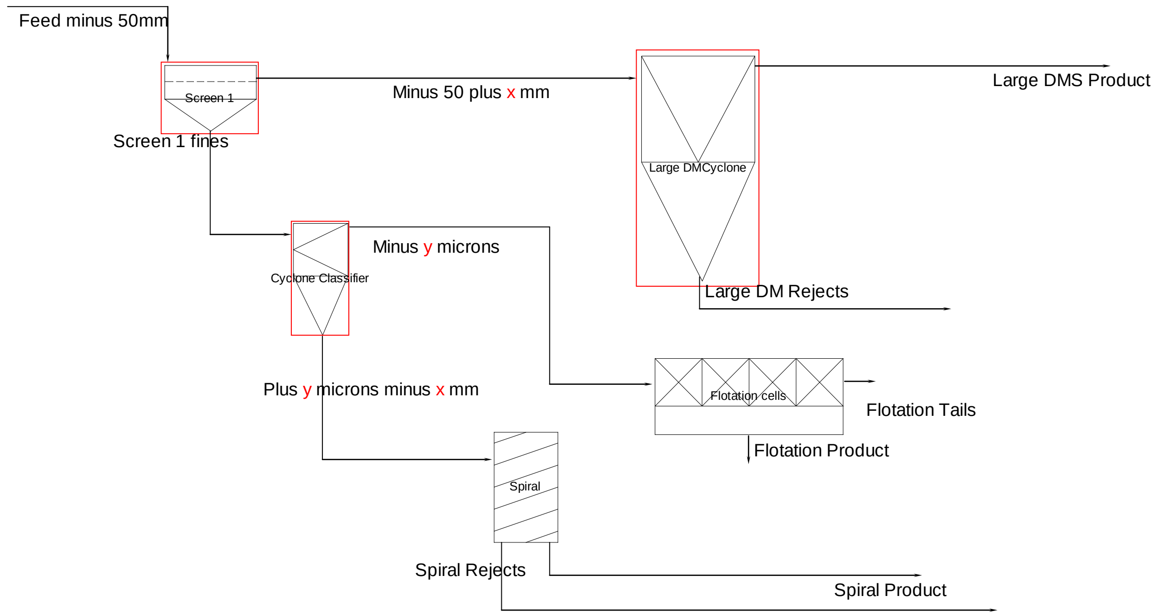

Figure 6 – Basic Flow sheet

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

- DMS Cyclone size
- Hydro cyclone cut point
- Screen 1 cut size

The performance for the DMS is best described by the following two graphs. 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.(1)(2)

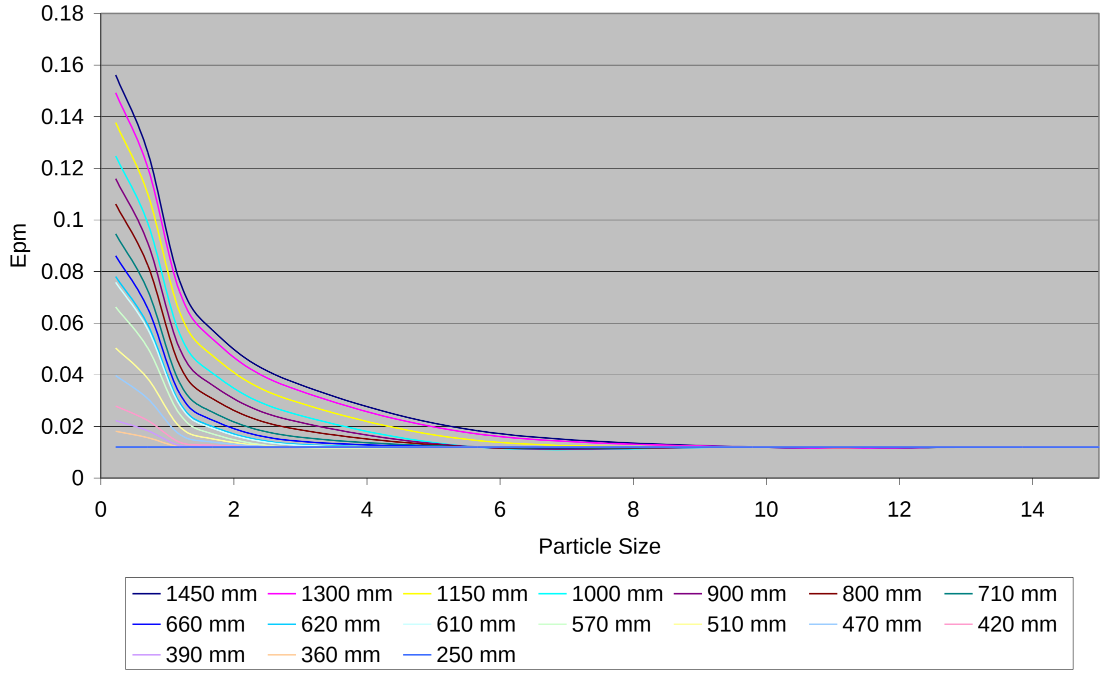

Figure 7 – Epm vs. Particle size for different cyclone sizes

Figure 8 also shows another important parameter describing cyclone performance, viz. the cut points that shift for different particle sizes.[3]

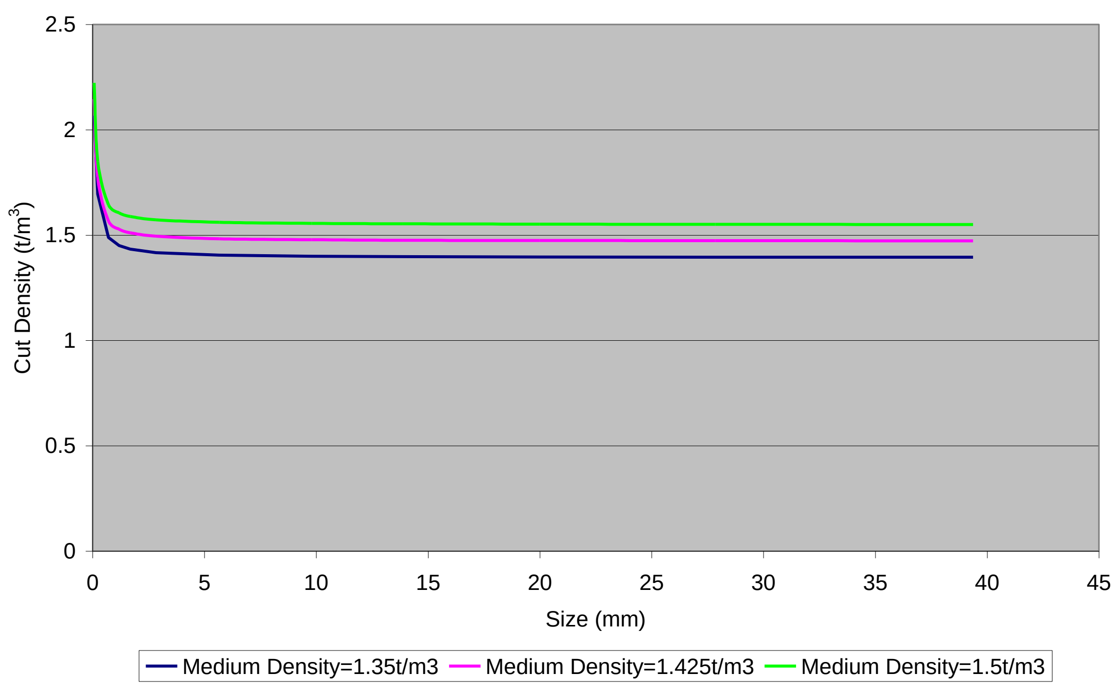

Figure 8 – The cut points for different particle sizes

Table 1 below shows the performance of the spirals used in this simulation study.

Table 1: 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

Table 2 below shows the operating parameters for the different units that were varied to assess their effect on metallurgical performance.

Table 2: Operating Parameters for the Basic Flow sheet

Medium Density	Screen 1 cut size	Hydro Cyclone Cut size	Feed PSD	Cyclone Size
1.35	0.7 mm	0.07 mm	Fine	420 mm
1.425	1.5 mm	0.1 mm	Medium	900 mm
1.5	3 mm	0.13 mm	Coarse	1450 mm

Since each of the parameters had three operating levels; this means that 243 (3^5) scenarios were simulated for the Southern African and Australian coals respectively.

Split DMS Flow sheet

Figure 9 below shows the split DMS concept. The red marked sections of the flow sheet were the parameters that were varied to assess their impact on plant performance.

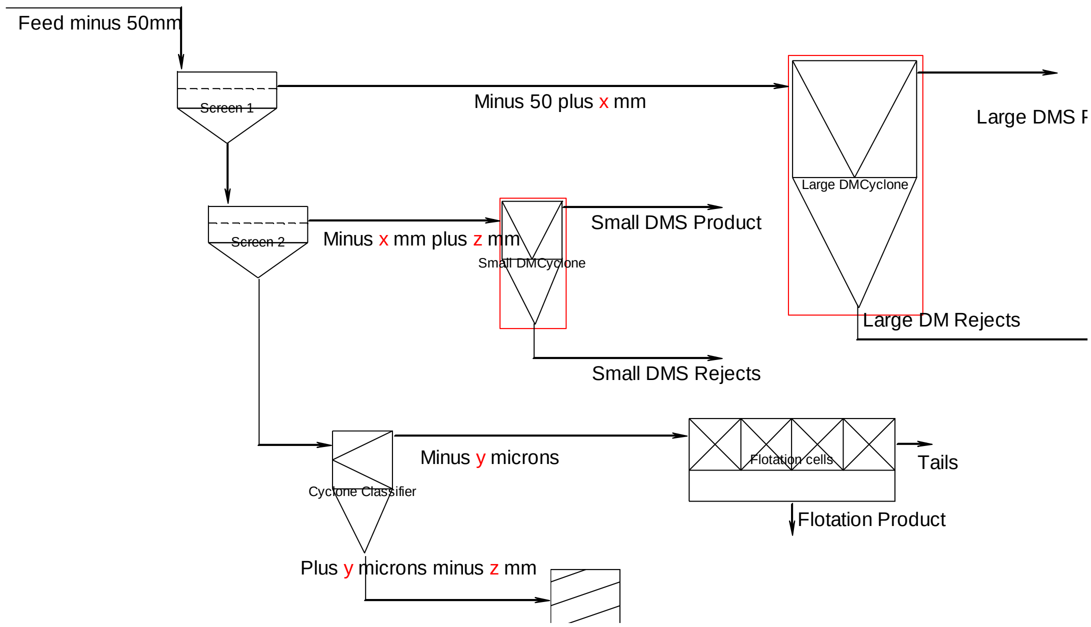

Figure 9 – The spilt DMS Flow sheet

Comparing Figures 6 and 9 it is noted that there is a small DMS for the fine fraction in Figure 9. The DMS and spiral performance parameters are the same as shown in Figures 7 and 8 and Table 1.

Table 3 below shows the operating parameters that were varied for the split DMS flow sheet in order to assess their impact on plant performance.

Table 3: Operating Parameters for the Split DMS Flow sheet

			Large Cyclone		Small Cyclone	
Screen 1 cut size	Screen 2 cut size	Feed PSD	Cyclone Size	Medium Density	Cyclone Size	Medium Density
2 mm	0.6 mm	Fine	710 mm	1.35	250 mm	1.35
3.5 mm	0.9 mm	Medium	1000 mm	1.425	510 mm	1.425
5 mm	1.2 mm	Coarse	1450 mm	1.5	660 mm	1.5

Again each of the parameters had three operating levels; which meant that 2187 (3^7) scenarios had to be simulated for the Southern African and Australian coals respectively.

Simulation Results

The simulation results for the basic and the split DMS were compared for the Southern African and Australian coal and the effect of different parameters were analyzed.

The Basic Flow sheet

Total Performance

Figure 10 below shows the coal product tons and coal yield for each of the 243 scenarios for the Southern African ore. The Y-axis shows the coal quality in percentage ash and the x-axis shows the product tons generated. Each scenario had the same feed tonnage of 1000 tph.

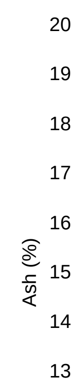

Figure 10 - Performance of the Basic Flow sheet on the Southern African Ore

Figure 11 below shows the coal product tons and coal yield for each of the 243 scenarios for the Australian ore.

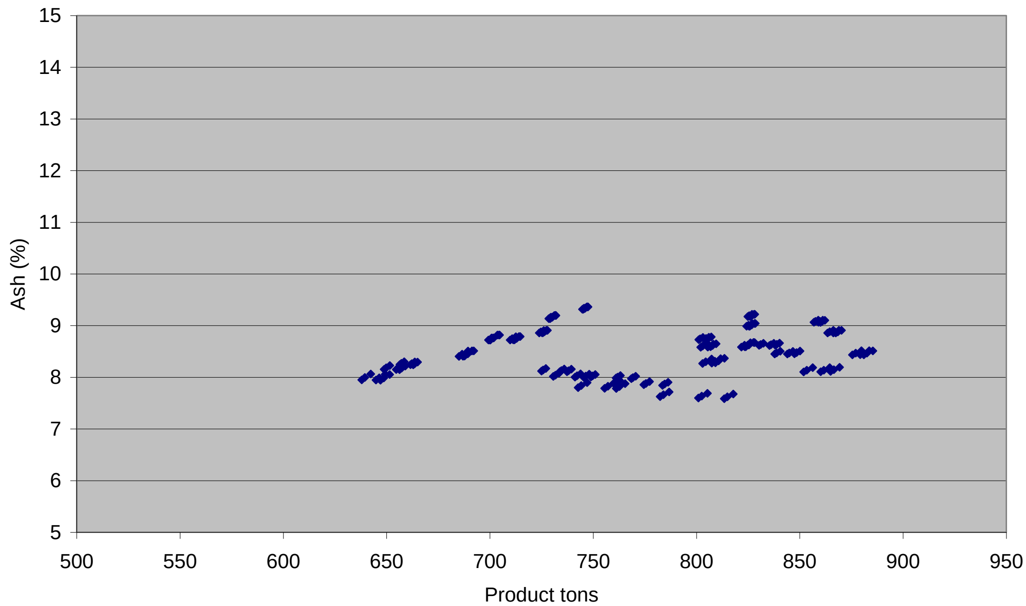

Figure 11- Performance of the Basic Flow sheet on an Australian Ore

Comparing figures 10 and 11 a few observations can be made, viz.:

- There is a considerable spread in the performance of both the Southern African and Australian coals in terms of coal quality and coal yield.
- The spread in the coal quality for the Australian coal is less than that of the Southern African coal.

Effect of Liberation

Figure 12 below shows the coal product tons and coal yield for each of the 243 scenarios for the Southern African ore. Each dot is colored based on the plant feed PSD.

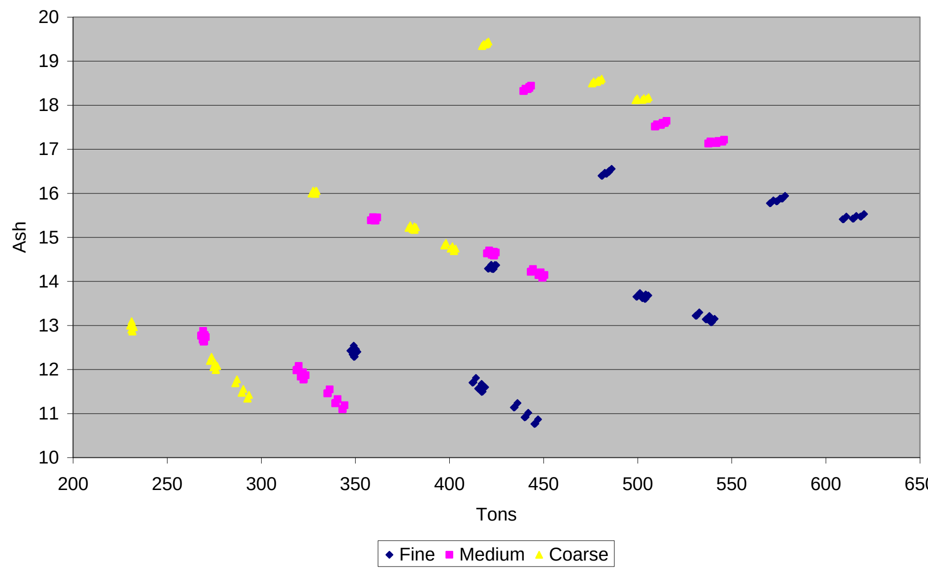

Figure 12 – Effect of Liberation on the performance a Southern African coal in a Basic Flow sheet.

Viewing Figure 12 it can be seen that liberation (feed PSD) has a considerable impact on the performance in terms of coal quality and yield which improves at finer PSDs.

Figure 13 below shows the coal product tons and coal yield for each of the 243 scenarios for the Australian coal. Each dot is colored based on the plant feed PSD.

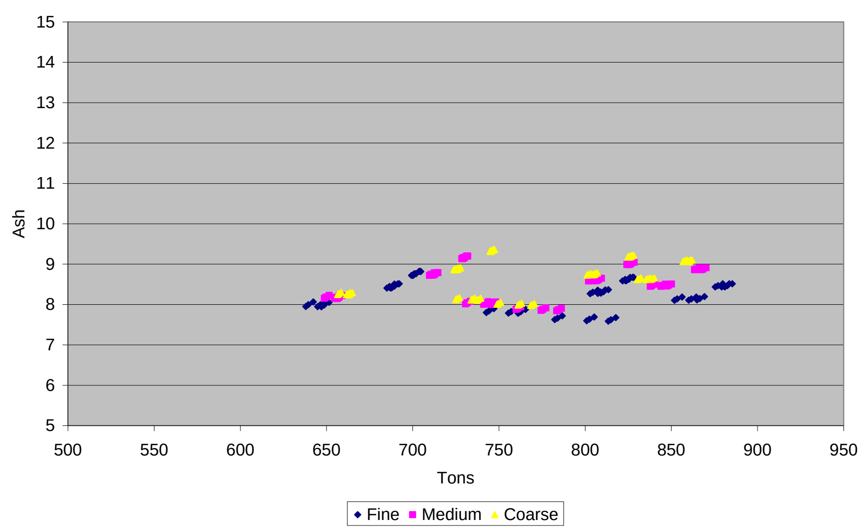

Figure 13 – Effect of Liberation on the performance of an Australian coal in a Basic Flow sheet.

From Figure 13 it can be seen that PSD also has an influence on the coal quality and yield, but not as pronounced as in the case of a Southern African coal.

Table 3 summarizes the performance of the Southern African and Australian coals.

Table 3: Performance of the Southern African and Australian Coals

	Australian		Southern African	
	Tons	Ash	Tons	Ash
Fine	774.07	8.25	482.14	13.77
Medium	772.76	8.56	406.16	14.8
Coarse	772.51	8.7	367.18	15.41

Effect of Cyclone Size

Figure 14 below shows the coal product tons and coal yield for each of the 243 scenarios for the Southern African ore.

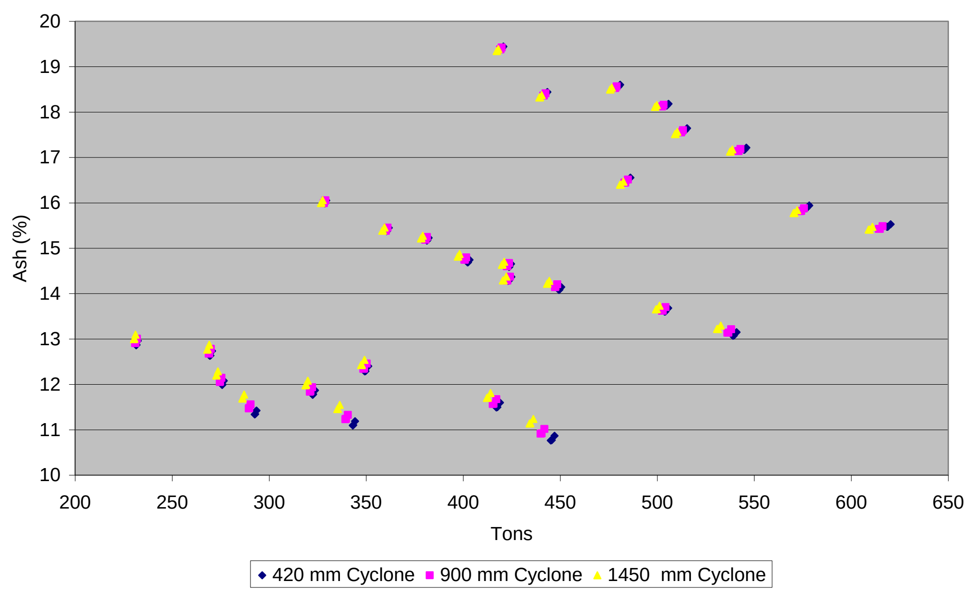

Figure 14 – Effect of DMS cyclone size on the performance a Southern African coal in a Basic Flow sheet.

Figure 14 shows that cyclone size does in some cases result in a marginal improvement in the overall plant performance. This is because of the breakaway size effect where cyclone performance for a large cyclone deteriorates at a larger particle size as compared to that for a small cyclone.

Figure 15 below shows the coal product tons and coal yield for each of the 243 scenarios for an Australian coal.

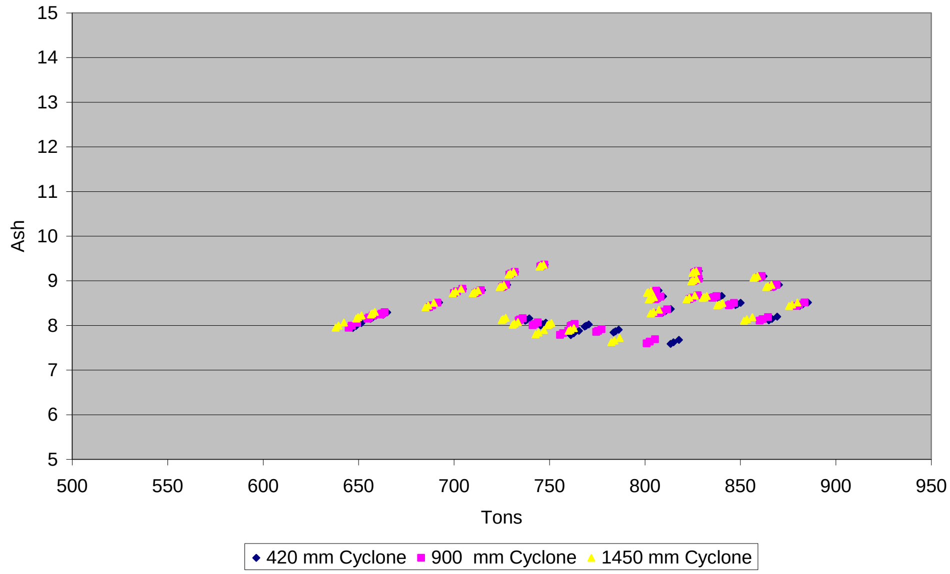

Figure 15 – Effect of DMS cyclone size on the performance of an Australian coal in a Basic Flow sheet.

Viewing figure 15 it can be seen that cyclone size does in some cases result in a marginal improvement in the overall plant performance for an Australian coal as well.

Table 4 summarizes the effect of cyclone size on the performance of the Southern African and Australian coals.

Table 4: Performance of the Southern African and Australian Coals

	Australian		Southern African	
	Tons	Ash	Tons	Ash
420mm Diameter Cyclone	776.62	8.5	420.65	14.62
900mm Diameter Cyclone	774.02	8.5	418.84	14.65
1450mm Diameter Cyclone	768.68	8.5	415.99	14.7

In both the Australian and Southern African ore using a 420 mm instead of a 1450 mm cyclone results in a 1% improvement in coal yield on average.

Effect of Cyclone Size and screen cut point

Figure 16 below shows the coal product tons and coal yield for each of the 243 scenarios for the Southern African coal.

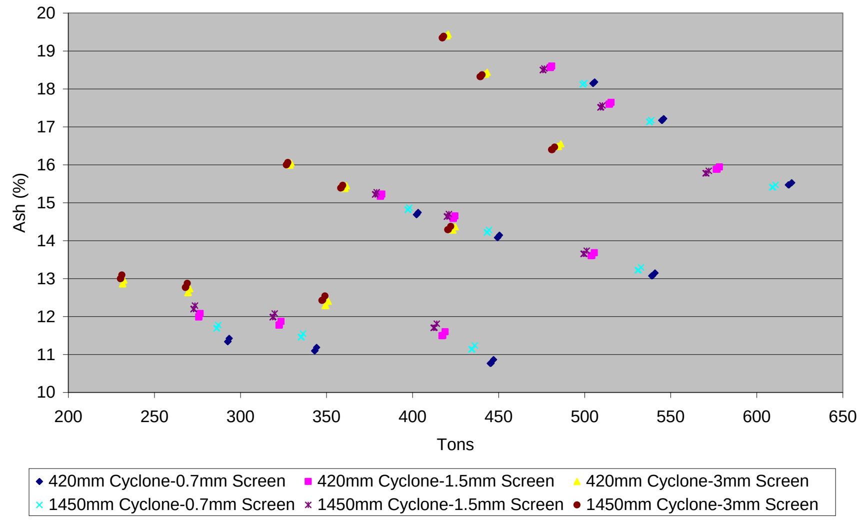

Figure 16 – Effect of DMS cyclone size and screen cut size on the performance a Southern African ore in a Basic Flow sheet.

From Figure 16 it can be seen that cyclone size does have an influence, but decreasing the screen aperture size has a bigger positive influence on the performance of the plant. The reason for this is that even large cyclones are better concentration devices for small particles than a spiral.

Figure 17 below shows the coal product tons and coal yield for each of the 243 scenarios for an Australian coal.

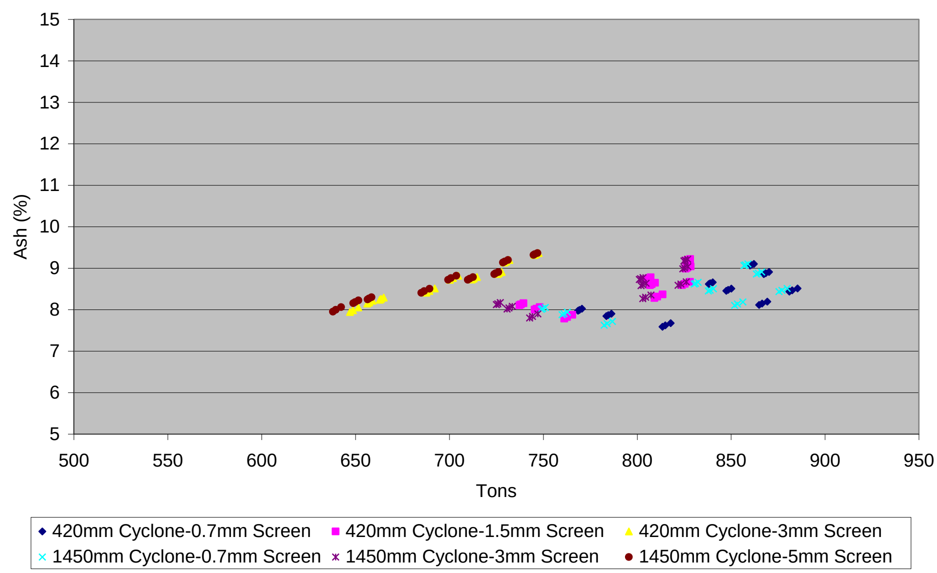

Figure 17 – Effect of DMS cyclone size and screen cut size on the performance of an Australian ore in a Basic Flow sheet.

Viewing Figure 17 it can be seen that cyclone size does have an impact on the performance of the plant, but that decreasing the screen size magnifies the positive effect even for Australian coal.

The Basic Flow sheet without Flotation

Excluding the coal from the flotation stage allows us to evaluate the basic flow sheet without flotation. The reason for this is that the fine coal may sometimes not be economical to recover due to the cost of moisture removal on fine particles.

Figure 18 below shows the coal product tons and coal yield for each of the 243 scenarios for the Southern African coal for the basic flow sheet without a flotation stage.

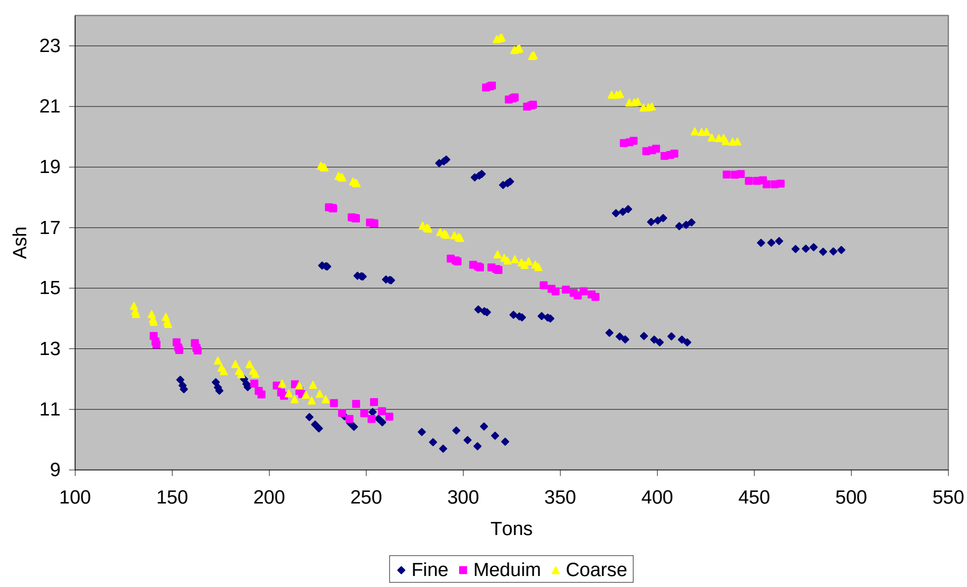

Figure 18 – Effect of liberation on the performance a Southern African ore in a Basic Flow sheet without flotation.

Viewing figure 18 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 19 below shows the coal product tons and coal yield for each of the 243 scenarios for an Australian coal for the basic flow sheet without a flotation stage.

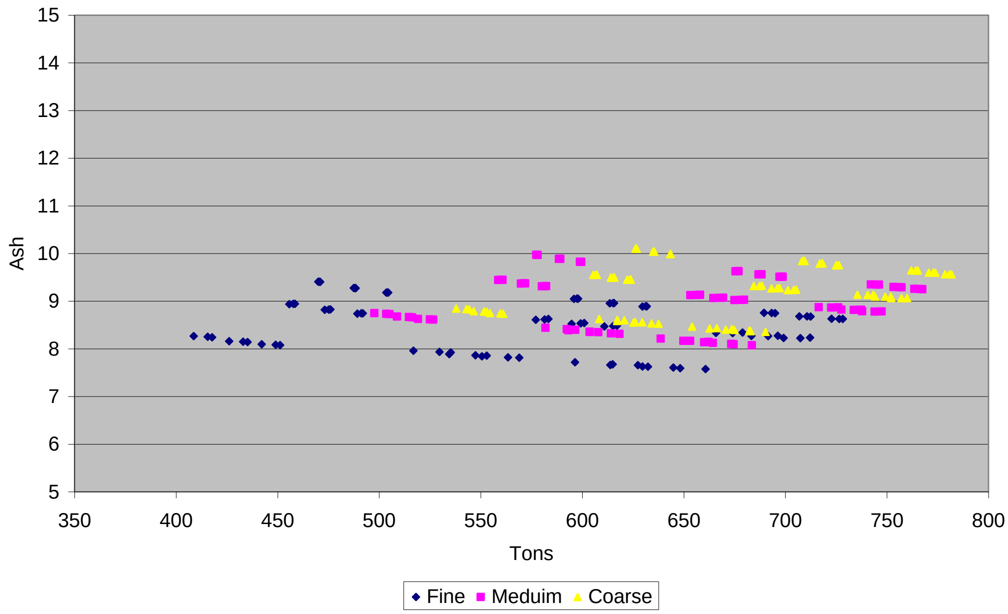

Figure 19 – Effect of liberation on the performance an Australian coal in a Basic Flow sheet without flotation.

While Figure 19 above shows that a finer grind results in improved coal quality there seems to be a reduction in coal yield for an Australian coal at a finer grind.

Table 5 compares the average yield and grade results for Southern African and Australian coals for different grinds.

Table 5: Comparison of the average values for Southern African and Australian coal for the basic flow sheet without flotation.

	Australia		Southern Africa	
	Tons	Ash	Tons	Ash
Fine	575.35	8.48	318.16	14.2
Medium	641.97	9.02	298	15.91
Coarse	670	9.23	282.34	17.05

Analyzing the results in table 5 above and comparing these results with table 3 a few observations can be made, viz.:

- The yield for the Australian coal decreases at finer grinds if the recovery of the coal from flotation is not taken into account.
- The quality of the Australian coal does improve for the basic flow sheet, with and without flotation. However the effect on coal quality is more pronounced when there is no flotation module in the basic flow sheet.
- The yield and coal quality for a Southern African coal is improved with and without flotation in the basic flow sheet. The improvement is more

pronounced in terms of yield when there is a flotation module in the basic flow sheet.

Split DMS

The performance of the Australian and Southern African coal in a split DMS circuit as shown in Figure 9 was assessed.

Effect of Liberation

Figure 20 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Southern African coal.

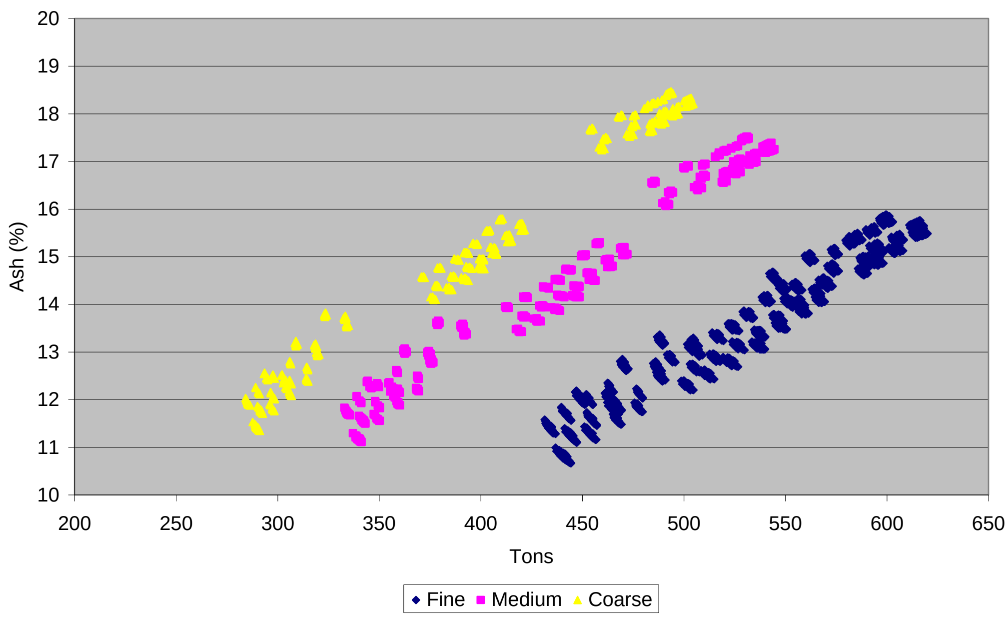

Figure 20 – Effect of liberation on the performance a Southern African coal in a split DMS flow sheet.

From Figure 20 it can be seen that liberation (finer feed PSD) has a considerable impact on the performance in terms of coal quality and yield which improves at finer PSDs.

Figure 21 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Australian coal.

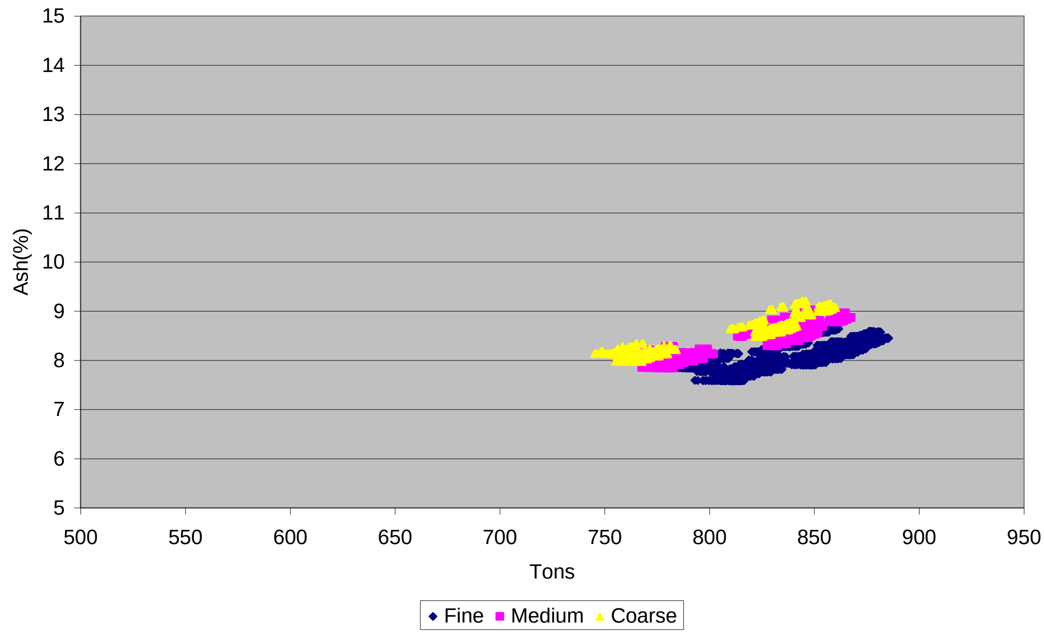

Figure 21 – Effect of liberation on the performance of an Australian coal a Split DMS Flow sheet.

Viewing Figure 21 it can be seen that a finer PSD has a positive influence on the coal quality and yield.

Table 6 summarizes the average liberation performance of the Southern African and Australian coals for a split DMS flow sheet.

Table 6: Performance of the Southern African and Australian Coals in the Split DMS flow sheet in terms of their plant feed PSD.

	Australia		Southern Africa	
	Tons	Ash	Tons	Ash
Fine	844.77	8.21	532.84	13.62
Medium	825.32	8.51	444.22	14.65
Coarse	816.13	8.65	398.95	15.24

From the data in table 6 the following can be noted:

- The finer the plant feed PSD the greater the yield and the better the coal quality for both the Southern African and Australian coals.
- The improvement in yield is more pronounced for the Southern African coal.

Effect of Cyclone Size

The effect of the size of the small cyclone, i.e. the cyclone treating the finer fraction, was also investigated and the results are summarized in table 7 below. The breakaway size and cut point shift illustrated in figures 7 and 8 above.

Table 7: Performance of the Southern African and Australian Coals in the Split DMS flow sheet in terms of the size of the cyclone treating the fine circuit.

	Australia		Southern Africa	
	Tons	Ash	Tons	Ash
660 mm Cyclone	832.48	8.36	486.61	14.16
250 mm Cyclone	833.63	8.36	487.56	14.15

From Table 7 it is clear that there is only a marginal improvement in the coal quality and yield when a smaller cyclone is used.

Effect of Size range sent to fines cyclone

The range sent to the fines cyclone was varied by varying the cut sizes of screen 1 and screen 2 as per Figure 9 above. Figures 22 and 23 show the largest, i.e. where screen 1 cut size is 5mm and screen 2 cut sizes is 0.6mm, and smallest range, i.e. where screen 1 cut size is 2mm and screen 2 cut size is 1.2mm.

Figure 22 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Southern African coal.

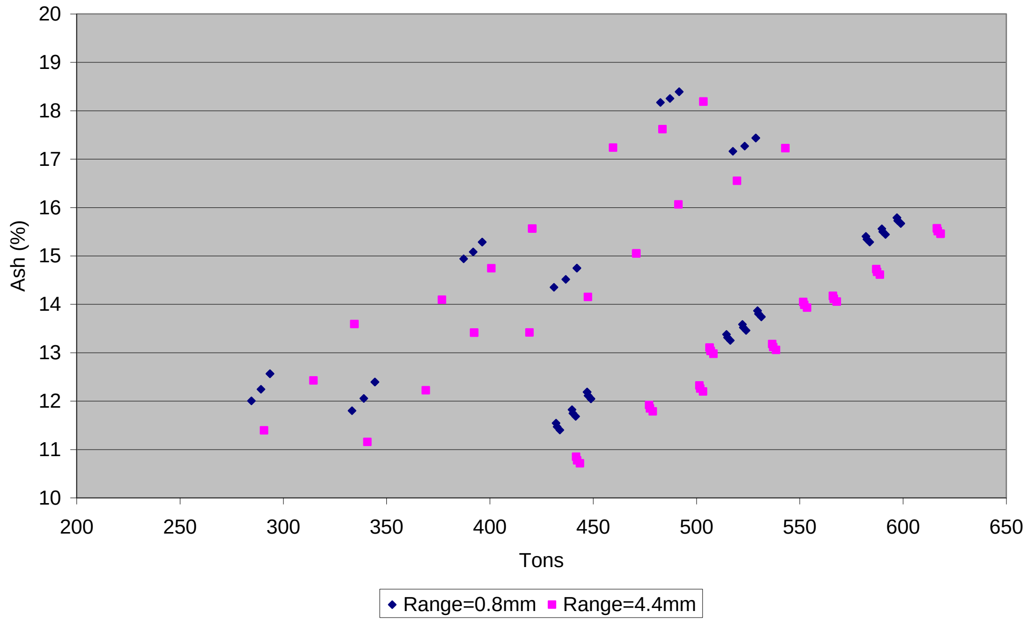

Figure 22 – Effect of size range sent to fines cyclone on the performance a Southern African ore in a Split DMS Flow sheet.

Viewing figure 22 it can be seen that liberation (finer feed PSD) has a considerable positive impact on the performance in terms of coal quality and yield.

Figure 23 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Australian coal.

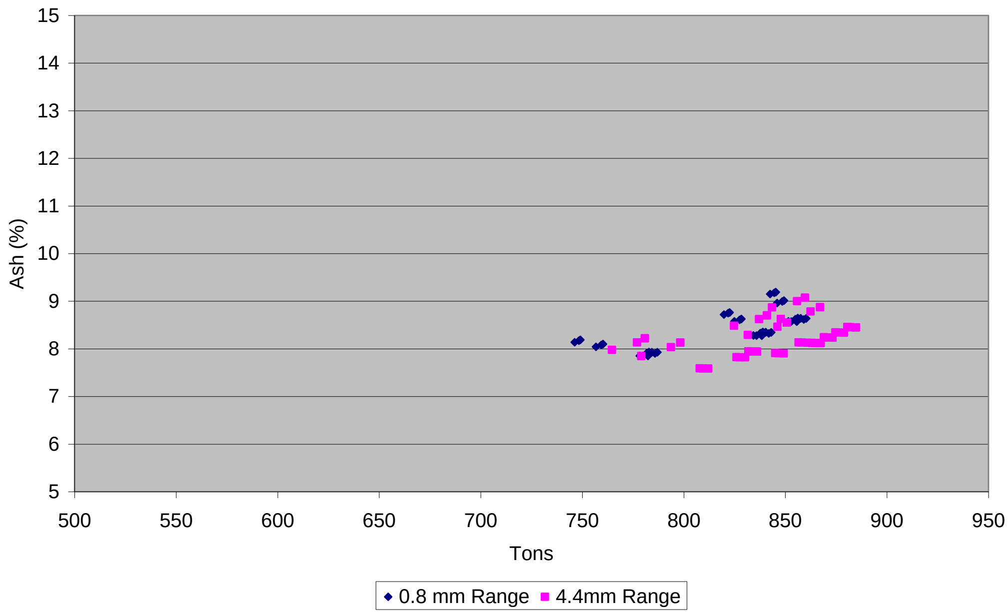

Figure 23 - Effect of size range sent to fines cyclone on the performance an Australian coal a split DMS Flow sheet.

Viewing Figure 23 it can be seen that sending a larger size range to the fines cyclone has a positive impact on the performance of the flow sheet.

Table 8 summarizes the average size range performance of the Southern African and Australian coals for a split DMS flow sheet.

Table 8: Performance of the Southern African and Australian Coals in the Split DMS flow sheet in terms of size range sent to fines cyclone

	Australia		Southern African	
	Tons	Ash	Tons	Ash
Size Range =4.4mm	843.9	8.26	494.86	14.05
Size Range =0.8mm	819.05	8.42	476.8	14.2

Viewing Table 8 the following can be noted:

- The larger the size range sent to the fines cyclone the better the coal yield for the Southern African and Australian coals.
- The larger the size range sent to the fines cyclone the better the coal quality for the Southern African and Australian coals.

This improvement in performance is due to the cyclone being a better concentration device than a spiral and using a small cyclone for the fines can also result in the breakaway size being at a smaller size than for a large cyclone.

There are two other factors that make a split DMS advantages, viz.:

- The cut density for the coarse and fine DMS can be varied independently which allows for some flexibility when treating a variable ore body.
- The head of the fine cyclone measured in D (diameter of the cyclone) could also be made greater for the cyclone treating the fine fraction. The greater head should increase the centrifugal force in order to overcome the crowding effect of fine particles.
- The medium to ore ratio of the fine and coarse DMS can also be varied. There are indications in the literature that the fine DMS would need a greater medium to ore ratio to increase efficiency

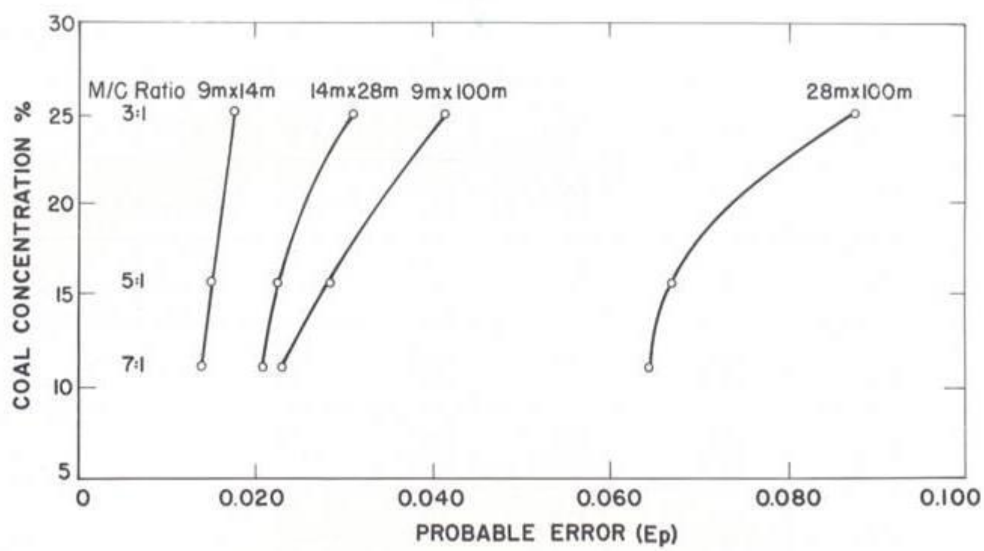

Figure 3.-Effects of concentration and particle size on probable error.

Figure 24- Effect of medium to ore the cyclone performance for fine particles[4]

Split DMS flow sheet without Flotation

Excluding the coal from the flotation stage allows us to evaluate the basic flow sheet without flotation. The reason for this is that the fine coal may sometimes not be economical to recover due to the cost of moisture removal on fine particles and the net resultant surface moisture.

Figure 25 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Southern African coal for the split DMS flow sheet without a flotation stage.

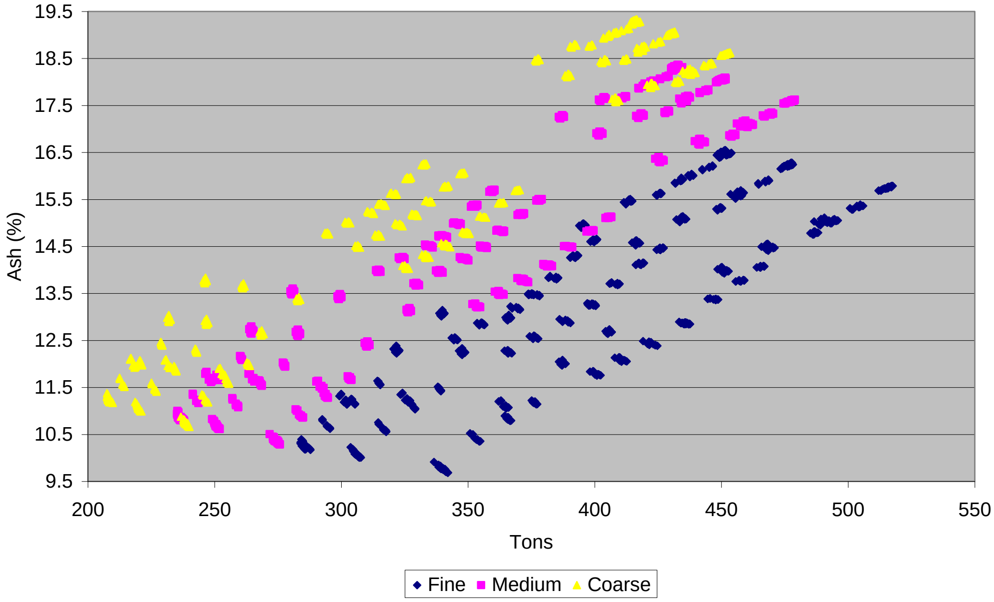

Figure 25 – Effect of liberation on the performance a Southern African coal in a Split DMS Flow sheet without a flotation stage

From Figure 25 it can be seen that liberation (finer feed PSD) has a considerable impact on the performance in terms of coal quality and yield.

Figure 26 below shows the coal product tons and coal yield for each of the 2187 scenarios for the Australian coal.

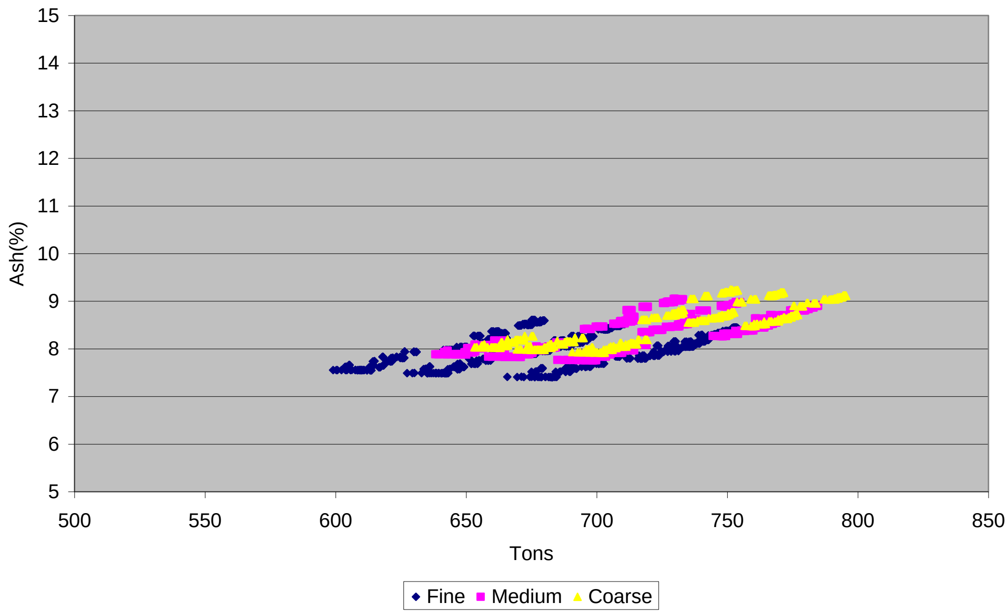

Figure 26 – Effect of liberation on the performance of an Australian ore in a Split DMS Flow sheet without a flotation stage

Viewing figure 26 it can be seen that the effect of plant feed PSD on overall plant performance is not as clear cut for an Australian ore, when the flotation stage is excluded.

Table 9 summarizes the average liberation performance of the Southern African and Australian coals for a split DMS flow sheet without a flotation stage.

Table 9: Performance of the Southern African and Australian coals in the split DMS flow sheet without a flotation stage in terms of their plant feed PSD.

	Australian		Southern African	
	Tons	Ash	Tons	Ash
Fine	721.67	8.47	388.56	13.52
Medium	734.88	8.64	359.38	14.71
Coarse	713.92	8.39	332.2	15.38

Viewing Table 9 the following can be noted:

- The finer the plant feed PSD the greater the yield and the better the coal quality for the Southern African coal.
- The Australian coal does not seem to benefit as much from changing the plant feed PSD, especially if it is considered that when the yield increases the ash content also increases.

Conclusions

The results from a yield perspective are summarized in table 10 below. These values only focus 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 8% for Australian coal and 14% for Southern African coal.

Table 10: Summarized yield results for the performance of Southern African and Australian coals.

		Standard		Split DMS	
		With Flotation	Without Flotation	**With Flotation**	With Flota

From table 10 above the following can be concluded:

- The yield for the Southern African coal improves considerably when you liberate the ore better by generating a finer plant feed PSD, approximately 15% ((48.2-41.8)/41.8), when using the basic flow sheet.
- The yield for the Southern African coal improves on better liberation for the basic flow sheet when there is no flotation step, viz. 6% ((31.8-29.9)/29.9), but this is not as pronounced as when there is a flotation step.
- There is a slight improvement for yield of the Australian coal on improved liberation using the basic flow sheet, ca. 0.1%.
- There is a decrease in the coal yield for the Australian ore using the basic flow sheet without a flotation stage, ca. 8%.
- Using a smaller DMS cyclone has a positive influence on the coal yield for the Australian and Southern African coal, 0.4% and 1.9% respectively.
- The flotation stage has a positive influence on the coal yield for the Southern African and Australian coals in the basic flow sheet configuration, i.e. 30% and 18% respectively.
- The split DMS improves the coal yield for both the Australian and Southern African coal, i.e. 7.1 % and 9.1 % respectively.
- The split DMS flow sheet gives a positive response to improved liberation for Southern African and Australian coal with and without a flotation stage.
- Increasing the size range sent to the fines cyclone improves the yield for the Southern African and Australian coal with and without a flotation stage.

- Decreasing the size of the cyclones for the fines cyclone in the split DMS improves the yield for the Southern African and Australian ore with and without a flotation stage.

These results can be used to construct an idealized flow sheet. Such a flow sheet would be:

- A split DMS flow sheet.
- The performance of the split DMS flow sheet could be improved further by optimizing the liberation, finer PSD seems to be generally better for the Southern African coal. This seems also to be the case with the Australian ore, however not as pronounced.
- The size range sent to the fines cyclone in the split DMS flow sheet should be maximized especially the lower size range as a small DMS will have a considerably better Ep than a spiral or TBS.
- Using a smaller cyclone for the fines treatment in a split DMS also improves the performance due to the smaller breakaway size of smaller cyclones.

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