

Advances in Spiral Automation and Ultrafine Processing

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ABSTRACT

Companies have been refining the design of spiral separators since the first cast iron models were developed in the 1940s. Research and development efforts have been focused on changing the profile and pitch of the modern fiberglass troughs, a recent development has been made in the LC3 model spiral which operates with a new flow profile compared to existing spiral technology. This new flow profile has opened up opportunities for automation and widening the size range that spirals traditionally operate.

In the coal industry spirals normally operate in a size range from 2mm to 0.1mm, with the -0.1mm fraction discarded or subjected to a form of froth flotation. As many thermal coal operations do not have flotation, material less than 100 micron is discharged to tailings dams as waste. Recent work has shown that the LC3 model spiral achieves operational efficiency beneficiating spiral feed to 40 micron, resulting in significant plant yield and opening up vast resources in processing of tailings material.

It is expected that when processing material from tailings dams there will be large variations in coal quality which must be accounted for by adjusting spiral operating parameters. Whilst some of these adjustments particularly concerning feed preparation and feed slurry characteristics are readily implemented, manual adjustment of spiral splitters would be slow to respond to changes in the feed quality, hence there is a requirement for centralization of the control adjustments and to reduce the amount of operator intervention required. This paper demonstrates the advances made regarding the processing of material less than 150 micron and the automation of both intermediate and final product splitters.

INTRODUCTION

There is a traditionally held belief in the coal industry that spiral technology can effectively process feed material down to approximately 100 micron however less than this size fraction minimal beneficiation occurs. The standard partition curves (Nicol 2001) for spirals by size fraction are shown below in Figure 1.

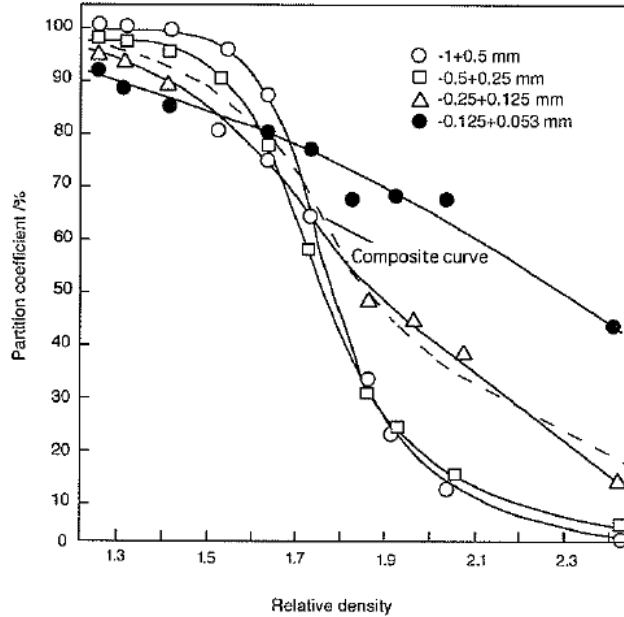


Figure 5.6
The Effect of Particle Size on Spiral Separation
 After Nicol (1992)

Figure 1 – Traditional partition performance data for spirals by size

The above figure indicates that the $-0.125+0.053$ mm partition curve has a partition coefficient of 50% at a relative density of 2.3, compared to partition coefficients of less than 10% for the $-1+0.25$ mm material. The data in Figure 1 although still considered standard was based on testing performed 25 years ago. Recent advancements in spiral technology particularly in the area of trough profile design such as the LC3 model spiral has seen a marked improvement in the performance of the sub 100 micron fraction down to as low as 40 micron.

LC3 Spiral Separator

Mineral Technologies focussed the development of the LC3 model spiral to cut at a low RD (range 1.45 to 1.6), subsequently however as a result of many site trials additional benefits of the trough profile have surfaced, including superior overall separating performance and the ability to effectively process finer material lowering the treatment particle size into the 40 micron region.

The LC3 spiral profile generates a flow regime in which a specific gravity profile develops across the particle bed (Palmer and Weldon, 2014). The flow regime can be seen as a concentric wave pattern, compared to the traditional radial wave pattern as seen on previous spiral models (Figure 2).

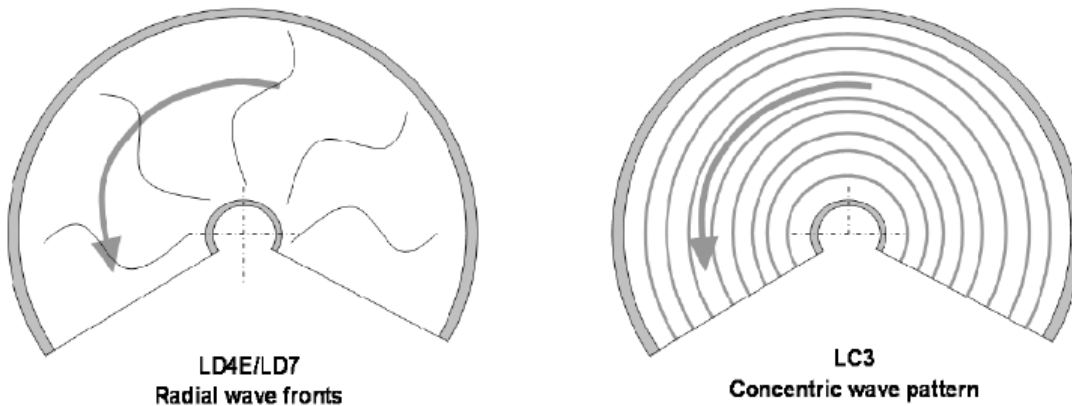


Figure 2 – Flow patterns of spirals

Dimensionally, although the LC3 has one more turn than the traditional compound spirals known to the coal industry, the reduced pitch results in an equivalent or slightly reduced overall height. One of the reasons for the significant improvement to the separation efficiency, apart from the change in flow pattern, is the approximately 16% additional residence time that the additional turn provides.

EFFECT OF FLOW PROFILE

The main cause behind spirals historically being unable to process ultrafine material is due to the small particles being transported at high velocity in the radial wave front of the spiral and not allowing the particles to separate on the basis of their density, effectively resulting in a bias of ultrafine material in the product of the spiral regardless of the particle density. As the LC3 has a concentric wave pattern profile instead of the radial wave front, the flow is more spread out across the spiral and hence the ultrafine particles now have an opportunity to beneficiate rather than report mainly to the product.

Figure 3 shows a photo taken from a site trial at Umlalazi coal preparation plant. While the goal of this trial was to prove the low cut-point capability of the LC3 the photo clearly shows the concentric wave pattern of the spiral. It must be noted that the trough of the spiral is smooth, no grooves have been cut into the spiral to cause the waves seen in Figure 3 are caused by the flow itself.



Figure 3 – Demonstration of concentric wave profile

Traditional spirals can produce cut-points ranging from 1.7 to 1.9 RD, however the concentric wave profile allows the LC3 to produce cut-points ranging from 1.4 to 2 RD (Thornton, MacKinnon, Narbutas and Swanson 2016). For large operations with multi-seam feeds, it would be advisable to automate the spiral stage so as to ensure and optimize the desired product quality instead of accepting average performance as the status quo.

SPIRAL AUTOMATION DEVICES

There have been recent advancements in spiral automation technology to allow for accurate controlling of spiral product. The two devices in this field are the spiral galaxy and the in-trough splitter.

Spiral Galaxy

The spiral galaxy operates by using a set of electric actuators mechanically driving the dart splitter handles which can be operated by a signal from the control room or local PLC. The actuator feeds back the position indicator to the control logic confirming that the handle is in position.

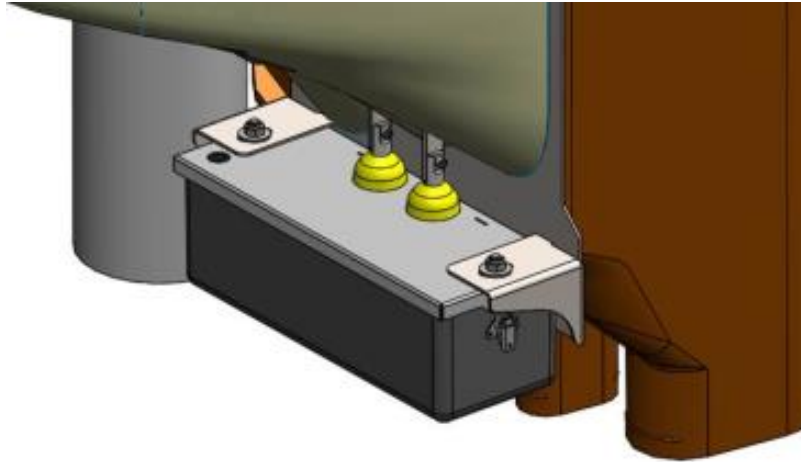


Figure 4 – Drawing of Spiral Galaxy

A major advantage of this spiral automation device is that it can be retrofitted onto any type of spiral. The spiral galaxy has recently been tested onsite at New Acland (van Niekerk and Rashleigh 2014) on a conventional spiral technology (Mineral Technologies LD7 spiral).

In-Trough Splitter

The in-trough splitter has a unique design in which the splitter sits above the trough and contains an air bladder which inflates proportionally downwards diverting variable flow to the reject.

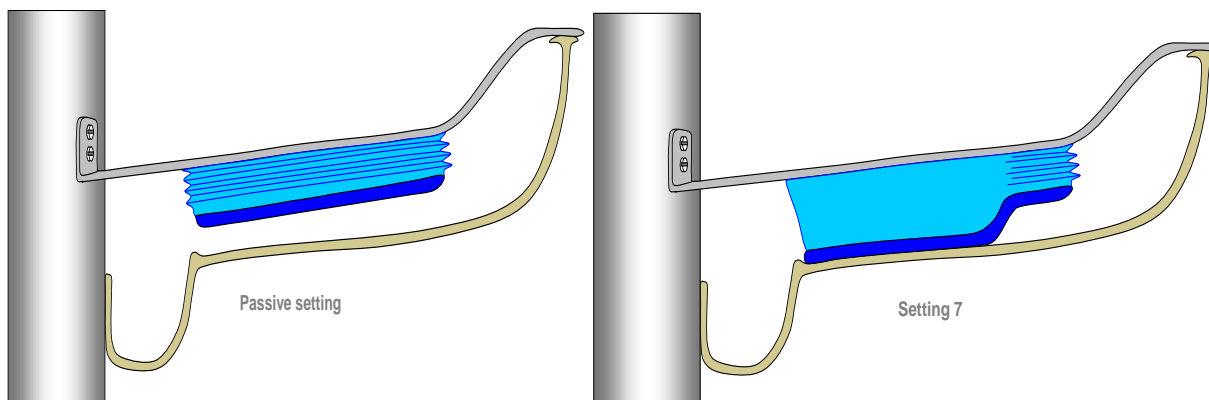


Figure 5 – Demonstration of In-Trough Splitter

The in-trough splitter has proven to be extremely effective in diverting reject material on the concentric wave pattern of the LC3. The in-trough splitter has been trialled under laboratory conditions to produce an ash/recovery curve (Figure 6).

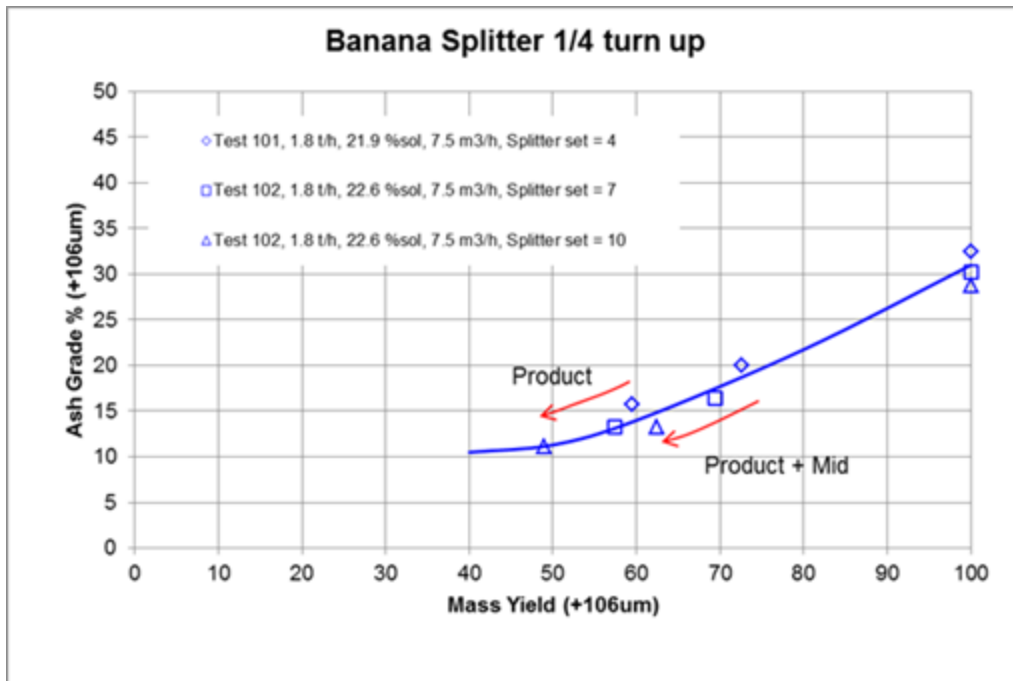


Figure 6 – Ash/Recovery curve for In-Trough (Banana) Splitter

From the lab trials there is a clear trend that the in-trough splitter (nicknamed the banana splitter) will produce a variable yield and ash on an Australian coal.

These data were extended to illustrate the dependence of product yield to feed grade along with achieving a nominal target product grade as depicted in Figure 7

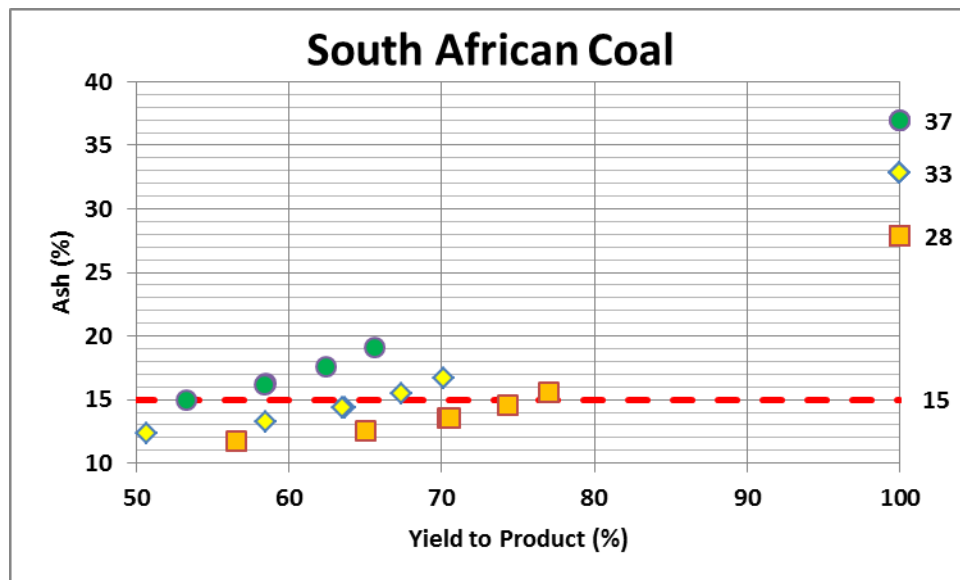


Figure 7 – Ash/Recovery Curve for a Simulated Coal

This indicates that a shift in feed grade of only $\pm 5\%$ ash results in a $\pm 10\%$ change in product yield at a target grade of 15%ash. Although it has been found that spiral separators in mineral sands applications can to a large degree, self-compensate for changes in feed grade without changing the splitter positions, this is not the case for coal beneficiation particularly when targeting low cut points, so a mechanism whereby the splitters (cut-point) can be quickly changed is essential.

Site trials are currently underway in the Hunter Valley in Australia to prove the performance of the in-trough splitter on a LC3 spiral in an industrial setting.



Figure 8 – Photo of In-Trough Splitter site trial

ULTRAFINE PROCESSING

In order to prove that the new flow profile of the LC3 could effectively process ultrafines, a sample was taken from a washery tailings dam in South Africa. The sample had a feed ash of 29.8% and it was determined that 87% passed 0.15mm and 71% passed 0.075mm.

Table 1- Ash by size test data on Tailings Dump

Seive size	Fractional				Cumulative			
	Product plus mid		Reject		Product plus mid		Reject	
	mass% retained	Ash grade %	mass% retained	Ash grade %	mass% retained	Ash grade %	mass% retained	Ash grade %
1000	2.22	23.5	2.31	62.5	2.22	23.5	2.31	62.5
500	7.00	9.3	19.67	41.6	9.22	12.7	21.98	43.8
250	10.82	8.0	26.56	38.6	20.04	10.2	48.54	41.0
150	15.98	9.0	16.85	40.3	36.02	9.7	65.39	40.8
106	13.66	10.8	9.08	40.2	49.68	10.0	74.47	40.7
75	18.60	14.3	10.32	42.8	68.28	11.1	84.79	41.0
53	14.87	19.9	7.55	45.3	83.15	12.7	92.34	41.3
38	14.00	25.0	6.03	46.1	97.15	14.5	98.37	41.6
-38	2.85	36.8	1.63	38.7	100.00	15.1	100.00	41.6
sub-total	100.00	15.1	100.00	41.6				

The data in Table 1 confirmed that the LC3 could process ultrafines more effectively than was demonstrated in Figure 1. It is important to note that there is significant additional beneficiation down to 53 micron, compared to conventional spiral processing with the added benefit of some beneficiation in the 53 to 38 micron size fraction.

Assuming that a 53 micron size cut-point is achieved Table 1 shows that a 12.7% ash product and 41.3%ash reject is achievable from a 29.9% head ash, the initial test indicates the LC3 can produce a saleable product from a tailings dam to 50 micron.

Using the new 53 micron lower limit as the bottom range for spiral processing, tests have been conducted on both South African and Australian coal types to establish the spiral performance producing a saleable product over a range of coal types.

SOUTH AFRICA COAL TRIAL

In South Africa there is a large domestic coal market (Eskom) that usually requires a 23 MJ/kg (a.d.) product quality. Mineral Technologies was engaged by a client to see if this specification could be met from an existing tailings dam. Samples were taken from the dam and sized at 50 micron and processed through a LC3 spiral. It was found that 80% of the sample passed 100 micron and 53% passed 45 micron.



Figure 9 – Photo of Tailings Sample Test

Figure 9 shows the trial progressing in the Mineral Technologies laboratory. It can be seen that there is a clear differentiation of coal on the outside of the trough (black) compared to the clay/mud on the inside of the trough (brown). The results from the trials are located in Table 2.

Table 2- Results from South African tailings dam trial

	Feed			Product			Middlings			Reject		
	Mass (TPH)	Ash (%)	CV (MJ/kg)	Yield (%)	Ash (%)	CV (MJ/kg)	Yield (%)	Ash (%)	CV (MJ/kg)	Yield (%)	Ash (%)	CV (MJ/kg)
Test 1	1.88	28.67	21.43	78.6	20.78	24.14	11.2	33.03	11.2	10.3	84.3	2.42
Test 2	1.85	29.64	21	55.2	21.22	24.09	31.1	23.94	31.1	13.7	76.6	3.42
Test 3	1.52	30.38	20.82	76.9	23.64	23.25	8.2	21.85	8.2	14.9	69.9	6.59
Test 4	1.47	26.14	22.17	85.7	19.93	24.41	6.7	40.84	6.7	7.5	83.5	1.25

From the above results it can be determined that the goal of 23 MJ/kg was not only met but exceeded and depending upon the spiral splitter position and feed rates product energies of 23.25 to 24.41 MJ/kg could be achieved. What is also interesting is while the product quality remains relatively consistent there is a large change in yield (from 55.2 to 85.7%) which can be related to splitter position.

AUSTRALIAN COAL TRIAL

Australian coals are traditionally a very clean coal type and therefore easy to process coal when compared to South African coals. For a Witbank coal it is not uncommon to have 80% of the feed material between a RD of 1.4 to 1.8, however for an Australian coal it is usual to have 80% of the material float 1.3 RD and 20% of the material sinks 2 RD. While these are approximations they do highlight how different Australian and South African coals are and therefore performing a trial on Australian coals should provide a good contrast when compared to the South African trials that were shown above.

The coal for the Australian trial was taken directly from thickener underflow from the Gunnedah basin. The sample was screened at 38 micron before being processed through the LC3. The head ash of the sample was measured to be 23.8% with 91.7% of the material passing 100 micron. Two trials were conducted (201 and 202) the difference between the two trials being the splitter position at the bottom of the spiral.

Table 3- Results from South African tailings dam trial

Screen Size µm	201 PRODUCT 74% Yield		202 PRODUCT 33% Yield		201 MIDLINGS 11% Yield		202 MIDLINGS 43% Yield		201 REJECT 15% Yield		202 REJECT 24% Yield	
	Ash %	% Dist.	Ash %	% Dist.	Ash %	% Dist.	Ash %	% Dist.	Ash %	% Dist.	Ash %	% Dist.
+63µm	10	79.68	9.75	76.01	15.15	74.62	11.69	76.29	81.4	84.4	61.8	80
+38µm	22.3	18	21.06	20.9	26.02	22	22.76	20.7	55.7	13.5	43.8	17.4
-38µm	43.75	2.3	41.93	3.1	43.79	3.4	43.13	3	61.5	2.1	54.7	2.6
total	12.99	100	13.11	100	18.51	100	14.94	100	77.5	100	58.5	100

Focussing on the + 63 micron material shows the trial produced product ashes of 10 and 9.75%, which can meet the existing site's product specification. Not only are the product specifications met Table 3 further shows the reject ashes of 81.4 and 61.8% giving a clear beneficiation.

While changing the splitters may not have produced a noticeable change in the product quality in this case it did produce a large change in the product yield (74% and 33%). This is also the same trend that was noticed in the South African tailings trial and highlights that if the splitter position is not controlled or adjusted the yield of the plant could be greatly affected.

CONCLUSION

From the data collected it has been shown that the long held belief that spirals cannot process material under 125 micron deserves to be challenged particularly on the basis of the development of the modern day spiral separators with focused design considerations. Current trials indicate that significant beneficiation can be achieved down to 38 micron establishing a new bench mark for spiral separators.

The results further demonstrate that there is a wide range of yields that can be produced depending on the spitter position which should be easily achieved in order to provide operators with the flexibility and control required. With the application of splitter

position control the complimentary automation of the splitter position set point is the next advancement in optimizing the operation of the washery.

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