ALLFLUX TWIN STAGE HYDROSIZER TESTWORK ON SOUTH AFRICAN HARD COALS AT MIDDELBURG MINE TO ENSURE RECOVERY OF A PSS EXPORT PRODUCT FROM THE –0.5MM FINE COAL

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Allflux twin stage hydrosizer testwork on South African hard coals at Middelburg mine to ensure recovery of a PSS export product from the –0.5mm fine coal.

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SUMMARY

Middelburg Mine does not consistently produce an export quality product of 14.5 % ash from the >0.5mm material contained in the export plant feed at the time of writing. The quality of the spiral product is also dependent on the quality of the feed to the spirals. This problem has existed since the commissioning of the spiral plant in 1986 [3].

The minus 0.5 mm material contains on average 60% export quality coal as shown by micro float and sink analysis but it is contaminated by high ash slimes in the –100um size range. The –0.5mm material is removed from the dense medium cyclone feed stream using sievebends and vibrating screens. The –0.5mm material is classified into a –0.5mm +0.150/0.200 mm fraction and a –0.150mm fraction using hydrocyclones. The largest volume (approximately 66%) of the 0.5mm x 0.150mm fraction at approximately 30% ash is currently treated in an existing two-stage spiral plant to produce an product with an ash content of 14.5%. The remaining material is diverted to a dewatering circuit to reduce the moisture content to approx. 12% before it is dispatched with the product from the middlings plant to the Duvha powerstation.

The spirals are however currently unable to consistently produce a 14.5% ash product at economical mass yields. The final product grade is very dependent on the quality of the feed to the spirals. This is due to –0.150 mm. Material with a high ash content still remaining in the spiral feed, thus firstly hampering the gravity separation process and secondly contaminating the spiral product with very high ash material (45% ash).

In order to compensate for the higher ash product from the spiral plant, the coarser streams have to be under-washed resulting in higher yield losses than the gains from the spiral plant.

Testwork was done at Middelburg Mine using an Allflux pilot unit supplied by Allmineral to determine if fine coal could be beneficiated in a single step by removing the contaminating slimes in an attempt to achieve a consistent incremental product quality.
The goal of the testwork at the outset was to produce a 14.5% ash product at a minimum yield of 50%.

The Allflux is a double stage teetered bed separator utilizing an upflowing current of water and an autogenous teetered bed of fine coal and impurities to separate the feed material. The upflow currents and the bed level can be adjusted independently and are the main control variables.

A portion of the spiral feed stream was diverted to the pilot unit. The test took place over a two-week period following a three-week installation period. Since the unit was only available for a limited time, an approach of incremental increases in the upflow current was followed. After the process had stabilized, sample increments of the streams were taken over a period of four hours for each test. These samples were submitted for size and ash analysis. A total of ten sample sets were generated with the last two being duplications of optimal conditions for the test period.

Conditions under which a single stage beneficiation could be effected could not be achieved during the test phase. This is due to some good coal still reporting to the final overflow stream of the unit that also contains the unwanted slimes. Fine silica and pyrite particles washed over from the first stage were also

visually observed to report to the underflow stream of the fine coal (second stage) section. This increases the ash content of that stream to high values making it unacceptable as product without treatment such as in spirals. Desliming, however, of the middle fraction was extremely good. This product did not even smudge hands on handling after drying.

Analysis of the results led to the development of a proposed spreadsheet that combines the Allflux unit with hydrocyclones, spirals and linear screens that will consistently produce a product of the required quality.

The relatively high fractions of material larger than 0.5mm was a concern as these particles should remain in the DSM cyclone circuit and not report to the fines circuit. Work is in progress at the time of writing to reduce the amount of this material in the fines circuit. The proposed flowsheet however caters for such material and even if it is present, it will be beneficiated and recovered. The Allflux produce yield at the correct export quality that makes the installation of such a unit economical even if the +0.5mm fraction is not included in the economical justifications.

The use of a unit such as the Allflux has the following operational and maintenance benefits:

- An operator easily varies the cutpoints in the unit by adjusting the upflow current velocities.
- The unit handles large volumes (the diameter is varied to adjust capacity).
- Moving and wear parts are limited.
- The unit is not very sensitive to feed rates and feed concentrations.
- Apart from desliming, improved classification benefits spiral operations.
- Capital and running costs are reduced as opposed to units like PANSEPS and Delkor Linear screens.
- The volume of material to be subjected to froth flotation could be increased through optimization of the separation in the second stage.
- The unit handles a wide variety of feed rates and pulp densities.
- Lower and variable cutpoints (1.43) could be achieved than with spirals (1.7 typically)

The Allflux testwork indicates that it is a machine that will classify and beneficiate the fine coal economically and produces fine coal at the right specification. It also has several operational and maintenance benefits over spirals and dense medium cyclones when operating parameters have been optimized. These optimal conditions had not yet been reached during the testwork at Middelburg Mines and a single stage beneficiation could not be effected.

A flowsheet is proposed, combining the Allflux with spiral concentrators, utilizing the desliming and beneficiation characteristics of the Allflux with the improved gravity separation of spirals fed with a narrow size range in the feed. Delkor linear screens deslime the product at 0.150mm to eliminate loss of light material from the circuit after beneficiation. The linear screens also ensure proper removal of all the 0.15mm material without being affected by densities.

A detailed plant design was done based on the revised proposed spreadsheet. The costs are relatively high due to the reinforcements and modifications necessary to install the Allflux into the current circuit. This is brought by through limited floor area available in the existing buildings, requiring extensive reinforcement of the current spiral building, or new civils outside the current plant.

The effect of the high ash content slime in the -0.200 and especially the -0.15mm material seems to have the greatest effect on the final product quality. The effectiveness of desliming of the product only either by improving the desliming by screenbowl centrifuge or by means of linear screens should be tested on a pilot scale basis over a sufficient period of time first.

This would show whether the installation of linear screens only would provide a more economical solution to providing a consistent export product from the spiral plant.

The proposed flowsheet is also a very feasible solution for new installation where capital savings could be effected by using single stage spiraling and possible reduced construction costs due to reductions in plant height.

BACKGROUND

Middelburg Mine does not consistently produce an export quality product of 14.5 % ash from the >0.5mm material contained in the export plant feed at the time of writing. The quality of the spiral product is also dependent on the quality of the feed to the spirals. This problem has existed since the commissioning of the spiral plant in 1986 [3]. There is also a tendency for larger particles to report to the overflows of the primary and secondary classification spirals to be misplaced to the cyclone overflows and report to the thickeners.

Continuous spiral sampling results done in 1986 after spiral plant commissioning.		
Date	Spiral Feed ash %	Spiral Product ash %
11/6/86	20.7	15.1
12/6/86	21.2	14.8
14/6/86	21.6	16.2
17/6/86	19.5	16.2
18/6/86	22.3	17.5

A portion of this material is processed in two stages of Multotec LD spiral and dewatered using classifying cyclones and screenbowl centrifuges. The rest is currently dewatered on vibrating dewatering screens and transported to Duvha power station along with the product from the middlings plant and the mined power station coal.

The minus 0.5 mm material contains on average 60% export quality coal as shown by micro float and sink analysis but it is contaminated by high ash slimes in the –100um size range. The –0.5mm material is removed from the dense medium cyclone feed stream using sievebends and vibrating screens. The –0.5mm material is classified into a - 0.5mm +0.150/0.200 mm fraction and a –0.150mm fraction using hydrocyclones. The largest volume (approximately 66%) of the 0.5mm x 0.150mm fraction at approximately 30% ash is currently treated in an existing two-stage spiral plant to produce an product with an ash content of 14.5%. The remaining material is diverted to a dewatering circuit using to reduce the moisture content to approx. 12% before it is dispatched with the product from the middlings plant to the Duvha powerstation.

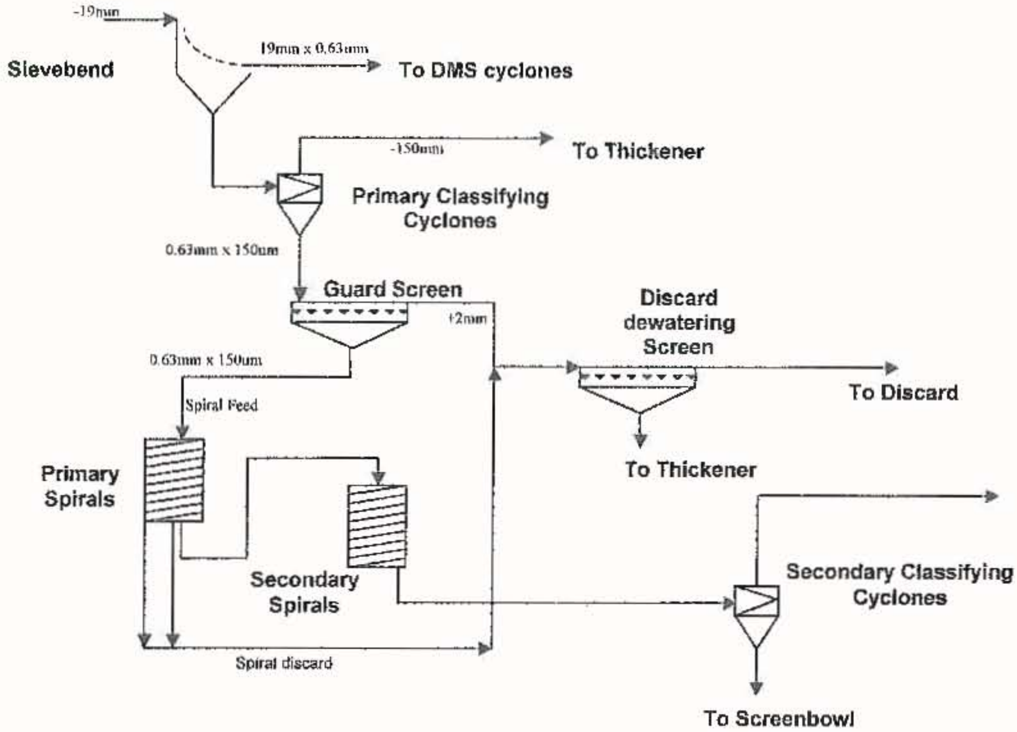
The spirals are however currently unable to consistently produce a 14.5% ash product at economical mass yields. The final product grade is very dependent on the quality of the feed to the spirals. This is due to –0.150 mm. material with a high ash content remaining in the spiral product, contaminating the spiral product with a small portion of very high ash material (45% ash).

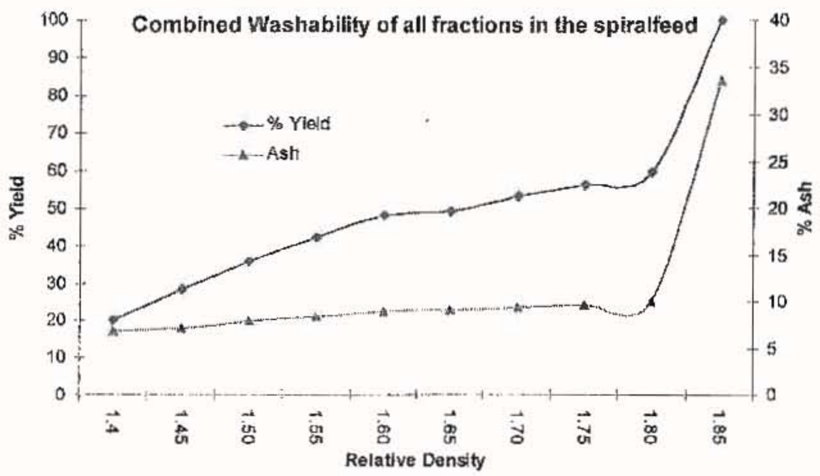
Similar problems existed at the Stratford Coal Preparation Plant in Australia till the commissioning of a 2.1m diameter Stokes Teetered Bed Separator. This reduced the primary spiral product ash from 15% to 11% ash.[1]
Optimum Colliery in South Africa had similar problems till the installation of Delkor linear screens This reduced the product ashes from between 14 and 17% to between 11to 13 % . A 12% ash product is required.

Testwork was done at Middelburg Mine using an Allflux pilot unit supplied by Allmineral to determine if fine coal could be beneficiated in a single step by removing the contaminating slimes in an attempt to achieve a consistent incremental product quality.
The goal of the testwork at the outset was to produce a 14.5% ash product at a minimum yield of 50%.

The Allflux is a double stage teetered bed separator utilizing an upflowing current of water and an autogenous teetered bed of fine coal and impurities to separate the feed material. The upflow currents and the bed level can be adjusted independently and are the main control variables.

Figure 1 Present flowsheet of fines circuit at Middelburg Mine.





TESTWORK

A portion of the spiral feed stream was diverted to the pilot unit. The test took place over a two-week period following a three-week installation period. The analysis of the fine coal was relatively slow due to limited resources and the labour intensity of wet screening the samples into the required fractions. Since the unit was only available for a limited time an empirical approach to the testwork was necessary. The feed rate and feed solids concentration was kept constant. The volumes of teeter water and the bed depth were adjusted. The pilot unit is fitted with windows on the compartments. Adjusting the bed level and teeter volume was monitored visually and then controlled constantly using bed level sensors and hydraulically operated valves via a Siemens PLC. After the process had stabilized, sample increments of the streams were taken over a period of four hours for each test. These samples were submitted for size and ash analysis. The teeter volume was then adjusted and another set of samples taken. A total of ten sample sets were generated with the last two being duplications of optimal conditions for the test period.

The samples were subjected to wet screening and the different size fractions were analyzed for ash content and heat value.

RESULTS

The results of tests done under optimal settings for the testing phase are shown in appendix 1 and 2.

Low ash coal is washed from the first stage along with the unwanted slimes at the upflow current velocities required to fluidize the bed, resulting in a high ash discard from the first stage. Some low ash ultra-fine coal is also washed from the second stage, along with the unwanted high ash slimes. This coal will have to be recovered by means of froth flotation or a similar process. The lower currents set in the larger second chamber of the Allflux however, allows more selectivity than is available in the first stage or a single stage machine and the majority of fine coal is recovered in the second or "fine coal stage".

Conditions under which a single stage beneficiation could be effected could not be achieved during the test phase. This is due to some good coal still report to the final overflow stream of the unit that also contains the unwanted slimes. Fine silica and pyrite particles washed over from the first stage were also visually observed to report to the underflow stream of the fine coal (second stage) section. This increases the ash content of that stream to high values making it unacceptable as product without treatment such as in spirals. Desliming, however, of the middle fraction was extremely good. This product did not even smudge hands on handling after drying.

Work done by Galvin, Pratten, Nguyen-Tran-Lam, and Nicol [2] indicates that a lot of scope exists for optimizing a teetered bed separator by the adjustment of the feedrate, feed concentration as well as the teeter volume and the bed level. The partition number is decreased as feed pulp density increased albeit at the cost of throughput rate. Cutpoints of as low as 1.43 and epm's of 0.10 have been achieved at Stratford[1].

Narrower classification of the particle sizes will also benefit spiral operation as found by Atasoy and Spottiswood [4].
They described three distinct regions on a spiral trough based on size distribution:

- The outermost stream where mostly coarse and light particles are placed.
- The innermost stream where mostly small and heavy particles are placed
- The transition region where mostly medium size and density particles are placed.

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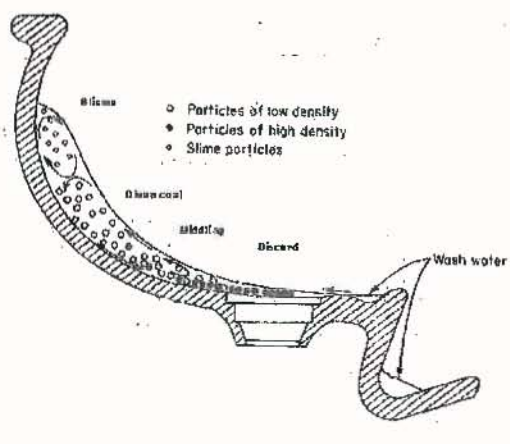
Slimes (if present) is trapped along with good coal in the spiral product and can not move to the centre and discard stream of the spiral.



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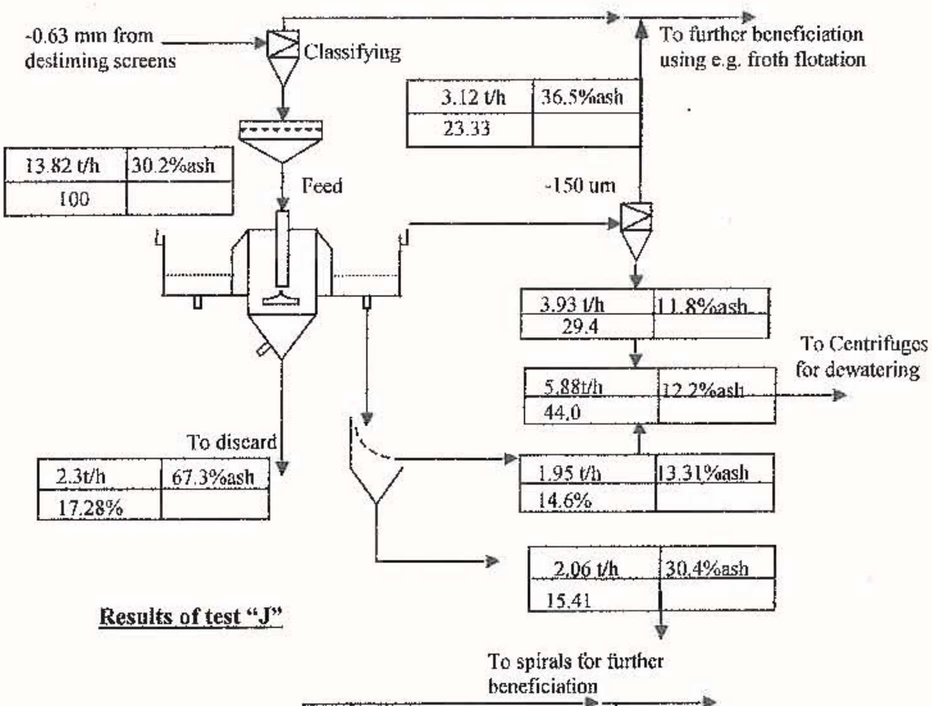
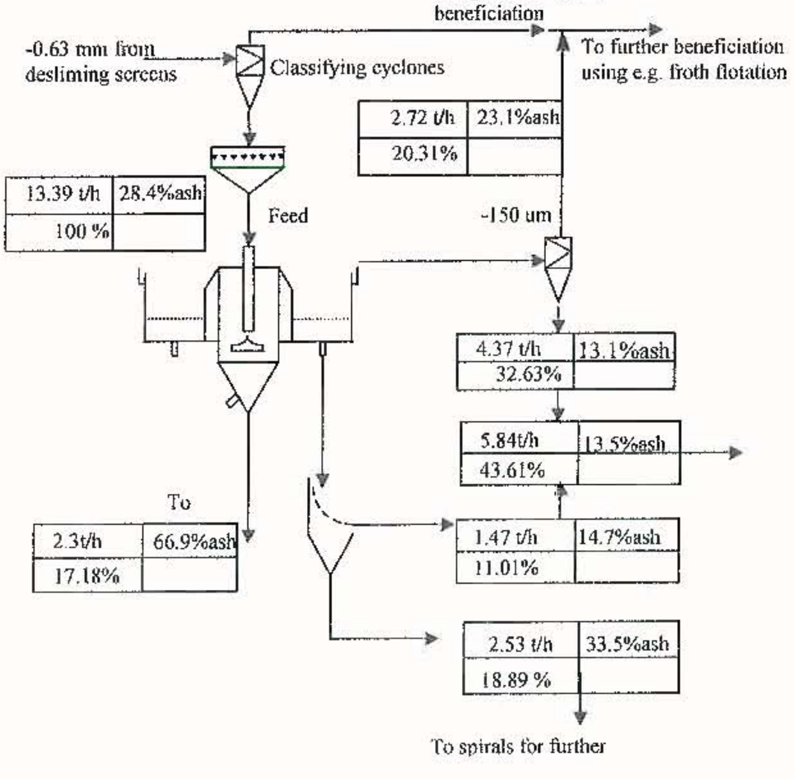
The relatively high fractions of material larger than 0.5mm was a concern as these particles should remain in the DSM cyclone circuit and not report to the fines circuit. Work is in progress at the time of writing to reduce the amount of this material in the fines circuit. The proposed flowsheet however caters for such material and even if it is present, it will be beneficiated and recovered. The Allflux produce yield at the correct export quality that makes the installation of such a unit economical even if the +0.5mm fraction is not included in the economical justifications.

Since commissioning of the spiral plant, misplaced particles in the primary and secondary classification cyclone overflows have been a concern. This misplacement still occurs but ash analysis of the fractions how that the ash content is relatively high.

Results of test "H"



Results of test "J"



Misplaced particle in the classification cyclone overflows.				
Size (mm)	**Fractional Mass in Primary cyclone overflow (%).**	**Ash in Size fraction (%)**	**Fractional Mass in Secondary cyclone overflow (%).**	**Ash in Size fraction (%)**
+1mm	0	0	0	32.6
-1mm+0.5mm	0	0	20.10	25.1
-0.5mm+0.3mm	0	0	5.48	22.7
-0.3mm+0.2mm	11.41	28.90	10.66	23.1
-0.2mm+0.1mm	63.00	30.90	26.80	37.5
-0.1mm	25.59	32.60	36.95	30.4

Loss of this material should thus not be a major concern. However, since density (and thus ash content) always plays a role in the classification cyclones and the quality of the particle in the overflow could very considerably, it was decided to modify the original proposed flowsheet to replace the secondary classification cyclones with Delkor linear screens.

This will allow positive separation based on size only and the risk of losing any low-density low ash coal after the spiral circuit will be eliminated. Although linear screens are not as operator friendly as cyclones, only three machines would be required for the total fines circuit, thus limiting the operating and maintenance concerns.

Some testwork is also being undertaken to reduce the slimes content of the primary cyclone underflow (spiral feed). The table below indicates that the slimes content of the underflow is low but the ash content of the slimes component is high. Some slimes will always report to the underflow of the cyclone since approximately 40% of the water feed to the cyclone reports to the underflow, carrying some slimes with it.

Primary Cyclone Underflow Size and ash analysis		
Size	**Mass fraction (%)**	**Ash content**
+1mm	33.49	27.4
-1mm+0.5mm	11.89	26.3
-0.5mm+0.3mm	23.42	28.9
-0.3mm+0.2mm	10.19	33.9
-0.2mm+0.1mm	14.41	36.7
-0.1mm	6.59	50.1

Operational and Maintenance considerations.

The use of a unit such as the Allflux has the following operational and maintenance benefits:

- An operator easily varies the cutpoints in the unit by adjusting the upflow current velocities.
- The unit handles large volumes (the diameter is varied to adjust capacity).
- Moving and wear parts are limited.
- The unit is not very sensitive to feed rates and feed concentrations.
- Apart from desliming, improved classification benefits spiral operations.
- Capital and running costs are reduced as opposed to units like PANSEPS and Delkor Linear screens.
- The volume of material to be subjected to froth flotation could be increased through optimization of the separation in the second stage.
- The unit handles a wide variety of feed rates and pulp densities.
- Lower and variable cutpoints (1.43) could be achieved than with spirals (1.7 typically)

Conclusion

The product quality of the spiral plant at Middelburg Mine is currently as inconsistent as after commissioning in 1986. Since the export markets have hardened and unit prices have dropped, it is important that all possible coal be recovered at the right quality. Failure to do so will lead to losses in income through contamination of good quality coal and subsequent yield losses due to compensation. Selling possible export coal into the local market also leads to losses in foreign revenue.

The Allflux testwork indicates that it is a machine that will classify and beneficiate the fine coal economically and produces fine coal at the right specification. It also has several operational and maintenance benefits over spirals and dense medium cyclones when operating parameters have been optimized. These optimal conditions had not yet been reached during the testwork at Middelburg Mines and a single stage beneficiation could not be effected.

A flowsheet is proposed, combining the Allflux with spiral concentrators, utilizing the desliming and beneficiation characteristics of the Allflux with the improved gravity separation of spirals fed with a narrow size range in the feed. Delkor linear screens deslime the product at 0.150mm to eliminate loss of light material from the circuit after beneficiation. The linear screens also ensure proper removal of all the 0.15mm material without being affected by densities.

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Since the effect of the high ash content slime in the -0.200 and especially the -0.15mm material seems to have the greatest effect on the final product quality, the effectiveness of desliming of the product only should first be tested on a pilot scale basis over a sufficient period of time. This would show whether the installation of linear screens only would provide a more economical solution to providing a consistent export product from the spiral plant.

The proposed flowsheet is also a very feasible solution for new installation where capital savings could be effected by using single stage spiraling and possible reduced construction costs due to reductions in plant height.

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- Vernon O'Donovan and Owen Rademan and Elamarie Venter their efforts in generating data, operating the pilot plant, and sampling.

Screen/ash analysis from test no H/J

tests "H"	feed				coarse tailings				middlings				concentrate			
	m %	m %	% ash	% ash	m %	m %	% ash	% ash	m %	m %	% ash	% ash	m %	m %	% ash	% ash
+ 0,5	32,1	32,1	27,8	27,8	71,5	71,5	67,1	67,1	48,7	48,7	13,1	13,1	2,1	2,1	5,2	5,2
0,5 – 0,3	23,1		23,7		20,9		70,1		28,7		21,0		12,0		8,7	
0,3 – 0,212	25,7	56,3	22,3	24,1	4,6	26,8	63,3	68,4	13,6	47,9	33,4	28,2	16,0	53,2	11,3	12,1
0,212 – 0,150	7,5		31,5		1,3		59,7		5,6		52,6		25,2		14,2	
0,150 – 0,106	1,1	11,6	33,7	45,6	0,6	1,7	59,9	60,4	1,6	3,4	57,6	61,0	11,9	44,7	18,7	36,5
- 0,106	10,5		46,8		1,1		60,6		1,8		64,0		32,8		42,2	
total	100,0		27,8		100,0		67,3		100,0		22,0		100,0		22,6	

Screen/ash analysis from test no H/J

tests "J"	feed				coarse tailings				middlings				concentrate			
	m %	m %	% ash	% ash	m %	m %	% ash	% ash	m %	m %	% ash	% ash	m %	m %	% ash	% ash
+ 0,5	24,3	24,3	20,3	20,3	80,7	80,7	66,9	66,9	36,7	36,7	14,7	14,7	2,1	2,1	9,2	9,2
0,5 – 0,3	20,5		19,6		15,9		68,4		30,5		23,1		15,5		9,9	
0,3 – 0,212	14,5	51,6	20,9	20,7	2,2	18,7	61,9	67,3	16,8	57,5	37,4	32,3	18,5	59,5	12,0	13,2
0,212 – 0,150	16,6		21,8		0,6		58,3		10,2		51,5		25,5		16,1	
0,150 – 0,106	6,1	24,1	25,4	51,3	0,3	0,6	59,6	61,0	1,5	5,8	54,7	45,4	13,0	38,4	23,8	23,1
- 0,106	18,0		60,1		0,3		62,3		4,3		42,1		25,4		22,8	
total	100,0		28,0		100,0		66,9		100,0		26,6		100,0		16,9	