THE COAL PLANT OF THE 21ST CENTURY— A CONTRACTORS VIEW

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ABSTRACT

Technological advances in the design of dense medium separating devices are quite rare occurrences. Two advances in recent years are the use of large diameter dense medium cyclones and Larcodems. A plant module of 500tph or even more can now be built having a single washing device, replacing a previous large coal bath circuit combined with a small diameter cyclone circuit. The use of these high capacity devices coupled with developments in screening and magnetic separation technology could enable a reduced capital and operating cost plant to be built

Operating results from some of South Africa's plants, 'that are almost there' are discussed.

LARGE DIAMETER DENSE MEDIUM CYCLONES

Dense medium cyclones are presently utilised in all of South Africa's dense medium coal washing plants where small coal is washed. (There may still be one DWP plant in operation somewhere) The top size of coal being washed is normally between 10mm and-20mm, while the bottom size is usually 0.5mm.

The most popular dense medium cyclones in older plants are the 500mm, 600mm and 660mm diameter units. The larger plants having either two or three cyclones operated in parallel in a single module.

All dense medium cyclones on the larger mines were gravity fed at a static head of 9D (The minimum recommended by DSM for coal washing), it was only the small operators that practised pump feeding of dense medium cyclones.

Since the introduction of dense medium cyclones by DSM in the early 1950's, cyclones have progressively increased in size; today 800mm and 1000mm diameter units are gaining in popularity and use in South Africa as module sizes approach 300tph.

Cyclone Diameter (mm)	Medium Flow (m^3/h)	Capacity (t/hr)			Maximum Feed Size (mm)
		Feed	Floats	Sinks	
600	190	75	64	30	40
800	400	160	119	56	53
900	525	210	157	74	60
1000	625	250	196	92	67
1250	1030	412	333	160	83
1500	1477	591	480	225	100

TABLE 1
LARGE DIAMETER CYCLONE SELECTION AND CAPACITY GUIDE FOR COAL

As can be seen in Table 1, larger diameter cyclones can accommodate larger volumetric flows. Hence by maintaining a fixed medium to coal ratio for a given diameter cyclone one can immediately see that larger cyclones have increased capacities and with larger feed inlets can handle larger feed particle sizes.

Today, manufacturers can tailor make any size of cyclone to suit a users exact requirements by varying cyclone geometry such as inlet shape and spigot size and by using extended barrel sections. This is even truer now that the fabrication of dense medium cyclones from mild steel, lined with high alumina ceramic tiles, is becoming acceptable.

There are presently seven (or eight) plants in South Africa using large diameter cyclones (the name now accepted as any cyclone having a diameter of 800mm or larger). The majority of these plants are new, and have changed from the old standard of having gravity fed cyclones to being pump fed.

Twistdraai is probably the only plant having gravity fed cyclones, using both 800mm and 1000mm diameter units for respective primary and secondary separations.

Bank Colliery has retrofitted 800mm units into an existing plant for both high gravity and low gravity applications. Two 800mm cyclones replaced two 610mm cyclones for the high gravity application and four 800mm cyclones replaced nine 610mm cyclones for the low gravity application. Cyclones are fed via variable speed pumps, each pump distributing to two cyclones.

Operating results obtained from various installations are indicated in Table 2. Near density material refers to the percentage of material present in the feed 0.1 density points either side of the cut point, d_{50}.

Plant	Cyclone Diameter (mm)	Size Fraction (mm)	Pressure (kPa)	d_{50}	Epm	Near Density %
Forzando	1000	65 x 1	150	1.54	0.022	32.8
Greenside	900	60 x 0.5	96	1.50	0.031	N/A
Greenside	900	60 x 0.5	110	1.58	0.016	N/A
Greenside	900	60 x 0.5	130	1.57	0.022	N/A
Greenside	900	60 x 0.5	144	1.60	0.017	N/A
Bank	800	10 x 0.5	104	1.53	0.022	51.0
Bank	800	10 x 0.5	109	1.50	0.029	39.8
Bank	800	10 x 0.5	113	1.50	0.028	41.5
Bank	800	10 x 0.5	116	1.52	0.025	45.1
Bank	800	10 x 0.5	74	1.37	0.023	64.2
Bank	800	10 x 0.5	100	1.38	0.007	76.0
Bank	800	10 x 0.5	120	1.38	0.006	74.0

TABLE 2
LARGE DIAMETER CYCLONE INSTALLATION OPERATING RESULTS

Generally speaking all of the results are good, particularly those obtained for the low gravity separation at Bank Colliery, when the cyclones were operated at pressures above 9D.

Most large diameter cyclone operators in South Africa have found that the optimum operating pressure for these cyclones is not 9D, as initially specified by DSM for smaller units, but of the order of 10-12D (it makes you wonder that perhaps we have been doing it wrong all along). The fact that the majority of large diameter cyclone installations are pump fed probably assisted in this discovery (or was it the fact that a particular process engineer forgot that it requires a little more than 3 m/s in a delivery pipeline to suspend a 60mm rock).

Operating results obtained for various size fractions washed in large diameter cyclones are indicated for various installations in Tables 3, 4 and 5.

Although results are quite varied, trends do appear. The phenomenon known as density shift, the cut density of the finer particles being higher than that of the larger particles, cannot be seen in either the high density wash at Forzando or Greenside, but can in the low gravity wash at Bank. Reports indicating results obtained from Australian installations are also rather erratic and give no possible explanation as to the cause, one can only assume that it is related to medium characteristics.

Size Fraction (mm)	d_{50}	Epm	OE %	Near Density %
65 x 25	1.55	0.017	98.4	26.6
25 x 12	1.53	0.014	98.0	36.1
12 x 6	1.53	0.025	98.9	34.5
6 x 3	1.54	0.025	97.1	30.5
3 x 1	1.54	0.032	93.4	29.7

TABLE 3
PERFORMANCE BY SIZE FOR FORZANDO AT 150kPa

Size Fraction (mm)	d_{50}	Epm	OE %	Near Density %
60 x 25	1.63	0.013	99.2	N/A
25 x 12	1.60	0.015	99.6	N/A
12 x 6	1.58	0.022	98.9	N/A
6 x 3	1.58	0.071	97.8	N/A
3 x 0.5	1.62	0.082	96.4	N/A

TABLE 4
PERFORMANCE BY SIZE FOR GRENSIDE AT 120kPa

Size Fraction (mm)	d_{50}	Epm	OE %	Near Density %
10 x 6	1.39	0.008	89.4	82.5
6 x 3	1.40	0.015	78.2	96.9
3 x 0.5	1.43	0.018	86.3	75.9

TABLE 5
PERFORMANCE BY SIZE FOR BANK AT 80kPa

The efficiency of any cyclone deteriorates on the smaller size fractions being treated. The larger the cyclone and the wider the size range of material being treated then the greater one would expect the deterioration in efficiency to be.

This is seen quite readily in both the Forzando and Greenside results, nonetheless overall results were extremely good.

There is a definite trend in the Bank results but not as marked as those for Forzando and Greenside, possibly due to the smaller size range being washed. The rather poor organic efficiency results can be attributed to the low operating pressure of the cyclones and the quite horrendous amount of near density material present at the time of sampling.

THE LARCODEMS

One negative aspect of the dense medium cyclone is its limited spigot capacity. If we look at the figures quoted in Table 1, it can be calculated that for any given size of cyclone operating at its design feed capacity and pressure, that a minimum yield of only 60% can be tolerated, below this the efficiency of the cyclone drops off quite rapidly.

As with all things in life there are always exceptions to the rule. One being the discard retreatment plant at Goedehoop Colliery, which consistently washes 250tph through three 610mm-diameter cyclones at yields of 20% and below. Admittedly the cyclone feed pressure is at least 180kpa which is the full scale on the pressure gauge. The circulating medium density is of the order of 1.45 and the cyclone cut point is of the order of 1.80.

There are already a few plants in South Africa that have been built to wash run of mine coal at low yields and as reserves of high yielding coal reduce, more will follow.

If a cyclone plant were erected to wash a raw coal at such a low yield then it would be necessary to use a number of large diameter cyclones operated in parallel with an exaggerated screening capacity purely to cater for the increase in medium required.

In such a case the use of a Larcodems may be a suitable alternative to a number of large diameter dense medium cyclones.

One of the major drawbacks associated with the widespread use of Larcodems in South Africa is, unfortunately, its name - an acronym for **LAR**ge **CO**al **DE**nse **M**edium Separator. The Larcodems was not conceived as a vessel purely to process large material, but a vessel that could process a wide size range. The first installation was at the Point of Ayr Colliery in Wales, where 250 tph of 100 x 0.5mm raw coal was processed in a single 1000mm-diameter vessel.

While gathering information for this paper the author was asked on several occasions 'When will the SMALCODEMS be developed'.

The Larcodems is quite similar in appearance to the old Dyna-Whirlpool (DWP), with the additional sophistication of a vortex extractor to facilitate the removal of sinks material.

The medium flow and separation of the various density fractions of the feed material within a Larcodems is illustrated in Figure 1.

When operating, a 50/50 split in medium flow between float and sink can be expected with a Larcodems compared to the 80/20 split obtained in a dense medium cyclone. As with the cyclone, the geometry of the Larcodems can be varied, float and sink outlets can be modified to the extent that a 60/40 medium split can be achieved in any flow direction, dependant upon whether a generally low or high yielding coal is being washed.

The Larcodems efficiency is not compromised when handling large discard tonnages as is the case with cyclones, efficiency characteristics can be maintained from yields of 100% to as low as 20% when operating at design capacities.

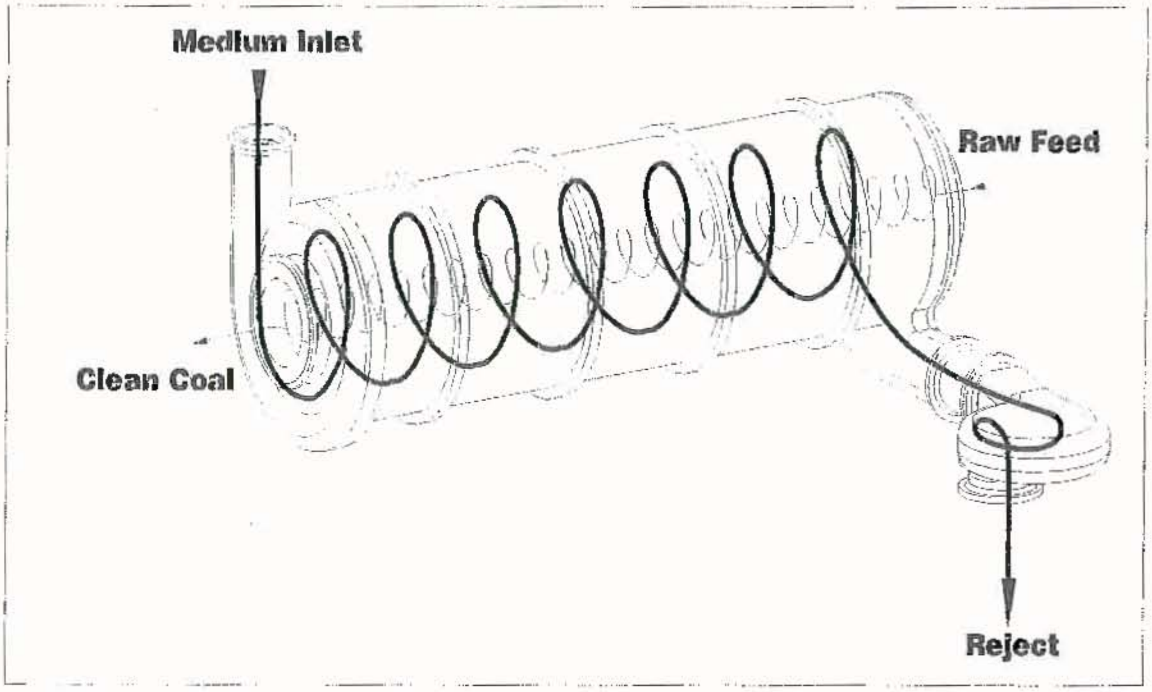

FIGURE 1
SCHEMATIC DIAGRAM OF A LARCODEMS SEPARATOR

The various sizes and capacities of Larcodems presently available are indicated in Table 6.

Vessel Diameter (mm)	Medium Flow (m^3/h)	Capacity (t/hr)	Maximum Feed Size (mm)
850	500	200	75
1000	700	250	85
1200	850	350	100
1350	1250	450	120

TABLE 6
LARCODEMS SELECTION AND CAPACITY GUIDE FOR COAL

Medium flows indicated are those expected when 'on coal', an increase in flow of approximately 15% can be expected when off coal.

Comparing figures quoted in Table 6 with those of large diameter dense medium cyclones in Table 1, it can be seen that units having similar capacities have similar medium flows, particularly so if the cyclone was operated at a pressure higher than 9D.

The vessel was introduced into the South African coal mining industry in April 1994 and at present there are two operational installations.

The first Larcodems installation in South Africa was at Duvha. The plant consists of two identical modules each having a feed capacity of 550tph. Within each module, raw coal is screened at 12mm, 100 x 12mm material is washed in a 1200mm diameter Larcodems, while the -12mm material bypasses the washing circuit.

Subsequently a 1000mm diameter Larcodems was retrofitted into the existing plant at Tavistock Colliery to replace a Norwalt separator. In this instance 80 x 10mm raw coal is washed.

Operating results obtained from both installations are indicated in Table 7.

Plant	Vessel Diameter (mm)	Size Fraction (mm)	d_{50}	Epm	Near Density %
Duvha (Module No.1)	1200	100 x 12	1.81	0.005	7.5
Duvha (Module No.2)	1200	100 x 12	1.88	0.011	9.0
Tavistock	1000	80 x 10	1.63	0.020	18.8
Tavistock	1000	80 x 10	1.47	0.007	46.1

TABLE 7
LARCODEMS INSTALLATION OPERATING RESULTS

Although the Larcodems is a relatively new separating device, it has already become an accepted fact that large coal can be washed more efficiently in a Larcodems than in a large diameter cyclone. Present belief is that the breakaway in efficiency experienced at small sizes in large diameter cyclones is more pronounced in a Larcodems.

Very little information regarding the separating efficiency of small size fractions within a Larcodems is available. The majority that is, is from operational plants washing British coals, which the author considered judicious to omit from this report. One set of results that is available, obtained while washing a coal similar to that found in South Africa is indicated in Table 8.

Size Fraction (mm)	d_{50}	Epm	OE %	Near Density %
25 x 4	1.373	0.007	-	-
4 x 2	1.375	0.021	-	-
2 x 0.5	1.385	0.023	-	-
25 x 0.5	1.375	0.008	96.0	70.0

TABLE 8
PERFORMANCE BY SIZE FOR LARCODEMS

Results were obtained using a 300mm-diameter vessel installed at a pilot plant facility in Australia.

The feed to the Larcodems consisted of 25 x 0.5mm raw coal, approximately 70% of the material being found between a density of 1.30 and 1.40.

The results prove that the Larcodems is also capable of producing good results when washing small coal and also when being operated at low densities with large amounts of near density material.

Manufacturers claim that no difference in performance would be expected when scaled up to a 1200mm vessel.

Just as the inefficiency in the washing of the smaller size fractions in a large diameter cyclone has become 'acceptable practice' today, it is the authors view that the same will be said for the Larcodems 'tomorrow' - particularly when larger single washing vessel modules are built.

IMPACT ON FUTURE PLANT DESIGN

Considering some of the preceding comments one can quite easily see the advantage of using either a large diameter cyclone or Larcodems in the design of a new coal processing plant. If we consider a 550tph module, which is probably the average module size in many of South Africa's larger plants, one can see that single washing units are now available that have the capacity to replace what was previously washed in a bath separator, and either two or four small dense medium cyclones.

SCREENING

It is a fact that the design and use of large diameter cyclones has followed closely behind the development of large screens, possibly not as energetically in South Africa as Australia, but non the less a fact. There are many installations in South Africa at present using 3,6m wide horizontal screens, but the use of "Banana" or multislope screens for either desliming or drain and rinse applications has yet to hit the big time in the South African coal industry.

Multislope screens have been used for many years, but only for sizing applications, either wet or dry, the oversize being fed to a bath type dense medium separator and the underflow being fed to further horizontal screens for desliming prior to being fed to dense medium cyclones.

The use of multislope screens to replace sievebend and horizontal screen combinations may have been restricted due to a lack of understanding as to how to size a multislope screen for any given application. Old DSM standards such as volumes of water required for efficient desliming, mean particle size, bed-depth and the division of a screen underpan $^{1}/_{3}$rd for drainage and $^{2}/_{3}$rd's for rinsing are no longer applicable, many early installations were on a trial and error basis. It is now accepted that multislope screens can provide a minimum 50% increase in dewatering capacity as compared to a similar width sievebend and horizontal screen installation.

Two plants in South Africa are presently using multislope screens for desliming and drain and rinse applications, namely Forzando and Middelburg.

The use of large screens has the drawback that large support structures are required. The potential to use multiple modular screens to replace a single large screen is presently gaining much attention.

One such modular type of screen is the Omni screen. Multiple units having different deck slope's can be arranged in series to replicate a particular multislope screen. The modular arrangement has amongst its many reported advantages over a large screen, a lower total weight and hence transmits lower dynamic loads to support structures. This has a major impact on reducing the amount of structural steel required for a plant and hence the cost.

Again considering a 550tph module, it can be seen that three large screens can now be used to replace eight screens, five of which would have had prior drainage sievebends.

MAGNETITE RECOVERY

One would assume that a single large dense medium circuit would require an abnormally large dilute medium circuit to cater for both the large correct medium bleed necessary for density control and the large volumes of spray water required on drain and rinse screens

With the recent development of the Permax style magnetic separator this is not necessarily true. The separator is being tested on many plants at the moment with very good results.

Basically the Permax separator is a counter rotation machine having a different magnet configuration to the normal. Results obtained so far show that the machine is capable of efficiently handling feed volumes as high as $150m^3/h$ per metre width, a magnetic loading of 30tph per metre width and can consistently produce a concentrate of 2.4 SG. It is also claimed that a higher percentage of non-magnetic material can be tolerated in the feed and that ultra fine magnetite can be recovered.

Many of South Africa's existing plants have both primary and secondary stages of magnetic separation generally using co-current 5 or 6 pole machines, usually with an intermediate cyclone or settling cone to concentrate magnetite prior to the secondary stage. Some of the more recent plants built have only a primary recovery circuit and have maintained very good magnetite consumption results.

Again considering our hypothetical 550tph module, it can be seen that two new style magnetic separators can now be used to replace five conventional magnetic separators and any intermediate recovery circuitry.

CONCLUSIONS

With the introduction of large diameter dense medium cyclones and Larcodems into the South African coal mining industry within the last few years the potential to design and build a coal processing plant of 500tph capacity or even larger having a single dense medium separation device exists.

This coupled with the use of large multislope screens or modular screens and with recent developments in magnetic separator technology, can dramatically reduce the number of major items of equipment within a plant. This will enable the plant of the 21st century to have a greatly simplified flowsheet and reduced capital and operational costs.

When large diameter cyclones were first introduced into the South African industry the general attitude was one of extreme nervousness, the potential loss of fine coal was greatly debated. Present installations having 800mm and 1000mm diameter cyclones have performed better than prior expectations.

The Larcodems has, probably due to bad press, found a niche market in the beneficiation of large coal where excellent results have been obtained, whereas testwork has shown it to be a match for the large diameter cyclone.

Attaining the maximum possible yield from a plant and minimising operating costs are always the first priority on any plant managers' mind. The time will soon come when operating costs cannot be further reduced on present plants unless sacrifices are made that may negatively impact on the operation of that plant in some way. It will then be the time to reconsider our standard designs

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