

THE USE OF LARGE DIAMETER CYCLONES

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ABSTRACT

Since the mid 1990's, the Australian Coal Preparation Industry has successfully operated large diameter dense medium cyclones i.e. cyclone units with diameters greater than 1000mm. The use of large diameter cyclones designed to suit large capacity single module wash plants, has enabled the Australian Coal Industry to remain competitive within the world coal market by driving down both the capital and operating costs.

Contrary to dense medium cyclone theory, Sedgman plant audit and performance data taken since 1998 has provided no evidence that the E_p for the full size range; worsens as the cyclone diameter is increased, nor is there any evidence of a significant "breakaway" point for the size range that is being processed.

Numerous performance tests on high capacity large diameter dense medium cyclones have reaffirmed the design limits for acceptable cyclone configuration. In addition the operational data at a number of wash plants indicates that the spigot capacity of large diameter cyclones is significantly higher than the theory predicts.

MULTIPLE WASH PLANT MODULES VS. SINGLE LARGE MODULE

Plants built in the 1970's and 80's were large in capacity, typically 1,000 to 2,000 t/h in total, but were only able to achieve these production levels by installing multiple items of relatively small equipment to be operated in parallel. These plants were generally designed with 4 to 8 modules housed within a common wash plant structure and fed by complicated distribution methods. Typical dense medium cyclone diameters were 710mm which had a solids feed capacity slightly in excess of 100 t/h. In modular dense medium cyclone plants, individual modules only achieved plant feed capacities of around 250 t/h by operating a pair of 710mm cyclones in parallel. Each cyclone having dedicated desliming and product screens with a common rejects screen. Each screen did not generally exceed 2.4 m in width and was preceded by a sieve bend.

Since 1997/8, the Australian coal preparation industry has accepted that a large diameter single cyclone performs more efficiently than two smaller cyclones operating in parallel. Several papers have been published reporting such comparisons in performance, including that of Leach, Carretta, Graham and Meyers (1998).

Table 1 provides data from operational plants in Queensland Australia, which clearly demonstrate the difference in performance of a dense medium plant comprised of a

single large 1m diameter cyclone in place of two 710mm smaller units operating in parallel.

Table 1 Comparison in Ecart Probable Number (Ep) at Goonyella and Riverside
(After Leach et al., 1998)

	<i>Goonyella</i>		<i>Riverside</i>	
	Twin 710mm	Single 1m	Twin 710mm	Single 1m
Pressure(cyclone diameters)	10	11	10	10
Size Fraction	Probable Error			
+16	0.028	0.025	0.020	0.014
-16+ 4	0.030	0.026	0.025	0.020
-4 + 2	0.038	0.028	0.045	0.026
-2 + 0.5 (ww)	0.055	0.045	0.070	0.049

As larger screens became available, coupled with the development of banana screen technology, it was realised that larger capacity modules could be built to employ single, large diameter dense medium cyclones in a very cost effective way with no loss of efficiency.

The capital cost of a plant is directly related to the overall volume of the structure. A suitable measure of capital efficiency would be illustrated by determining the wash plant structural volume as a function of the plant feed capacity i.e. m³/t/h. The traditional 1980's wash plants range between 30 to 50 m³/t/h compared to the modern single module large capacity plants that are significantly less at approximately 10 to 15 m³/t/h (refer Figure 1 below).

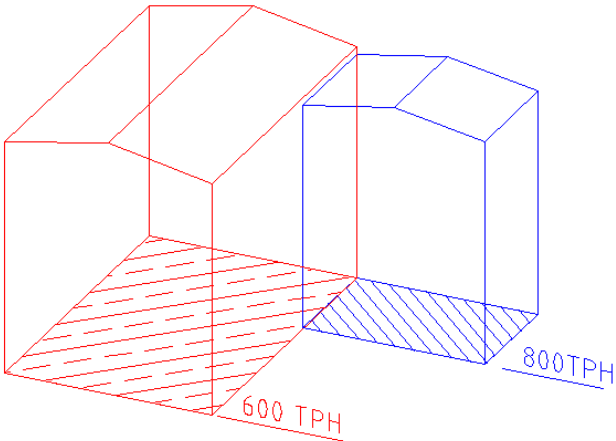


Figure 1 Structural Volume as a Function of the Feed Capacity

In parallel with the change in volume there was also a corresponding reduction in equipment units. These factors resulted in a significant reduction in the manning requirements and an increase in “coal-on” operating hours (>7000 h/annum) which translated into major savings in wash plant operating costs. A typical manning shift crew of 4 to 5 skilled operators are able to successfully operate an 800tph Coal Handling and Preparation Plant (CHPP) facility, from ROM feed to train load-out and tailings disposal.

THE USE OF LARGE DIAMETER DENSE MEDIUM CYCLONES

During the past ten years, Sedgman has designed and installed almost eighty (80) dense medium cyclones with diameters ranging from 1000 to 1450mm. Sedgman’s design experience has also been enhanced through it’s management and operation of a number of coal wash plants within Australia. During 2008, Sedgman’s Operations had management and operations contracts for washing in excess of 35Mtpa of raw coal.

Data gleaned from performance testing of new plants and ongoing plant audits has enabled Sedgman to test the validity of several theories about the performance of large diameter dense medium cyclones that had been widely accepted. Contrary to common theory, the data collected by Sedgman has identified that; there is no evidence that E_p worsens as the cyclone diameter is increased, nor is there a distinct “breakaway” size within the range of particle sizes typically being processed by the dense medium circuit. Figure 2 shows a plot of E_p for both -50 + 4 mm and -4 + 1.0 mm coal feed for a range of cyclone diameters.

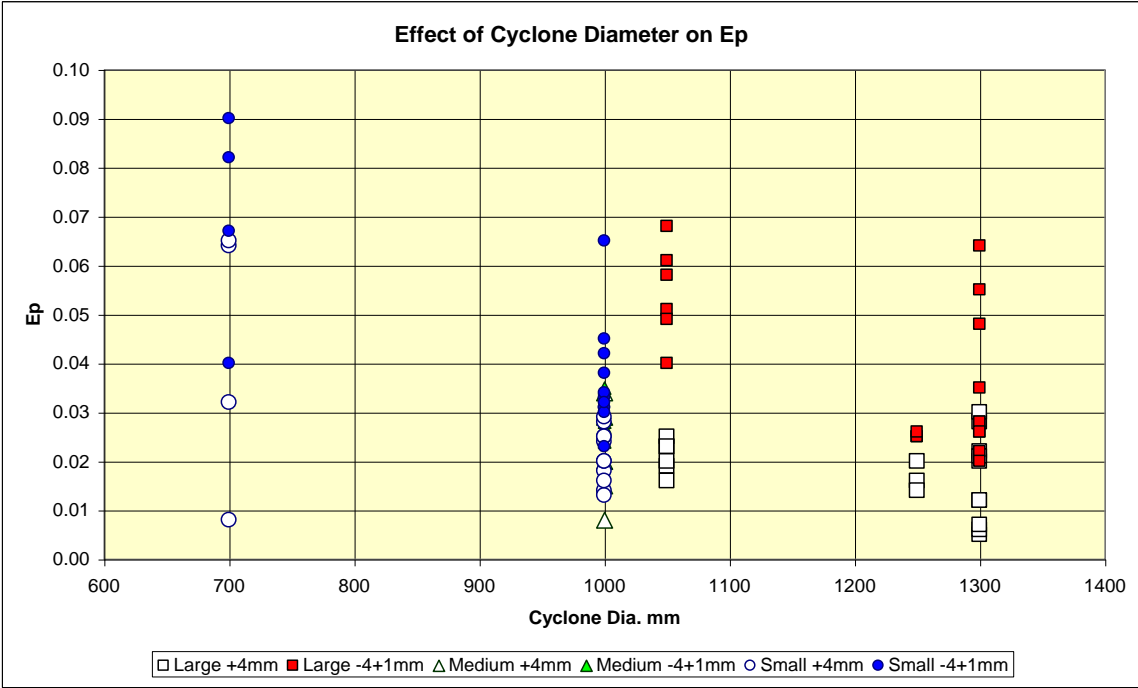


Figure 2 Effect of Cyclone Diameter on E_p (“small”, “medium” and “large” refer to relative medium: coal ratios)

RECENT EXPERIENCES WITH HIGH CAPACITY LARGE DIAMETER DENSE MEDIUM CYCLONES

The utilisation of larger diameter dense medium cyclones has been greatly assisted by the on going development of larger complimentary process equipment, i.e. vibrating multi-slope or “banana” screens, centrifuges, gravel pumps, etc. Deterioration of the new coal resources over recent years has also driven the need for increasing the diameter of dense medium cyclones to handle the extremely wide coal quality envelopes. It is not uncommon for new coal resources to have yield ranges between 40 to 80%, with some two-stage wash plants experiencing primary yields as low as 25%. Variability in plant feed sizing has also resulted in the dense medium cyclone circuit operating with a maximum feed rate up to double that of the nominal tonnage rate.

Similar CPP circuit designs can have vastly different rated feed capacities (600 vs. 925tph) depending on the variability of the coal resource and the mining methods employed.

The challenge has been to try and wash these difficult and variable coal types whilst maintaining acceptable design criteria for an efficient dense medium cyclone operation i.e. medium to coal ratio, spigot loading, feed pressure (head) and operating differential. Our recent experiences have indicated that the cyclone configuration, in terms of inlet size, vortex finder and spigot diameters, have sometimes been designed beyond their optimum limits, thereby resulting in lower than expected separation efficiencies.

Numerous performance tests on different cyclone configurations have confirmed the boundaries of acceptable cyclone design. The data illustrated in Table 2 below confirms that the configuration for a high capacity large diameter cyclone needs to have an inlet ratio of less than 0.3 (preferably 0.20), a vortex finder ratio <0.48, and a spigot to vortex finder ratio between 0.7 and 0.85. For high capacity cyclones with a 0.3 inlet ratio, the vortex finder ratio must be ≤ 0.43 .

Table 2 Cyclone Configuration vs. Cyclone Performance

Cyclone Diameter	Inlet Ratio	VF Ratio	Spigot Ratio	Pressure (D)	Offset	Differential	OF/Feed Ratio	Overall Ep
1300	0.30	0.48	0.83	9.00	0.042	0.075	1.83%	0.040
1300	0.30	0.48	0.83	9.00	0.101	0.095	2.58%	0.036
1300	0.30	0.48	0.83	9.00	0.076	0.170	5.99%	0.032
1300	0.30	0.48	0.83	9.00	0.138	0.080	1.10%	0.032
1300	0.20	0.48	0.85	10.20	0.092	0.380	7.81%	0.025
1300	0.20	0.48	0.83	9.60	0.163	0.360	11.03%	0.016
1300	0.20	0.48	0.83	8.29	0.139	0.240	9.55%	0.026
1300	0.20	0.48	0.85	8.77	0.055	0.380	9.18%	0.025
1300	0.20	0.48	0.86	8.85	0.123	0.340	5.82%	0.029
1300	0.20	0.48	0.87	10.60	0.069	0.483	9.18%	0.030
1300	0.20	0.48	0.85	9.29	0.159	0.407	5.63%	0.020

Operational data from a number of wash plants have also indicated that the spigot capacity of large diameter cyclones is significantly higher than predicted. Data obtained from a detailed performance test on a two stage dense medium cyclone operation enabled Sedgman to accurately measure the primary cyclone spigot capacity. The primary spigot rate is equal to the sum of the secondary cyclone product and rejects tonnage rates. These tonnages were measured using the weightometer readings on the secondary product and reject conveyors. Tonnages were adjusted in accordance with the laboratory moisture analysis. Washability data from primary rejects was used to determine the average particle density, [to allow for the calculation of the volumetric spigot solids discharge rate in m³/h.] which was used to calculate the spigot solids discharge rate in m³/h.

The cyclone tested was a 1300mm Multotec unit with a spigot diameter of 520mm. The cyclone spigot discharge rate measured over a 24 hour period consistently exceeded 400t/h (refer Figure 3 below). This tonnage rate equates to a significantly higher tonnage than provided by the standard spigot capacity equation as derived from the Dutch State Mines (DSM) manual (1968).

$$\text{spigot capacity m}^3/\text{h solids} = (\text{spigot diameter})^2 \times .0626 \times (\text{operating head}/9)^{1/4}$$

Sedgman believe an adjustment in the calculation factor from 0.0626 to 0.10 would be appropriate for large diameter cyclones.

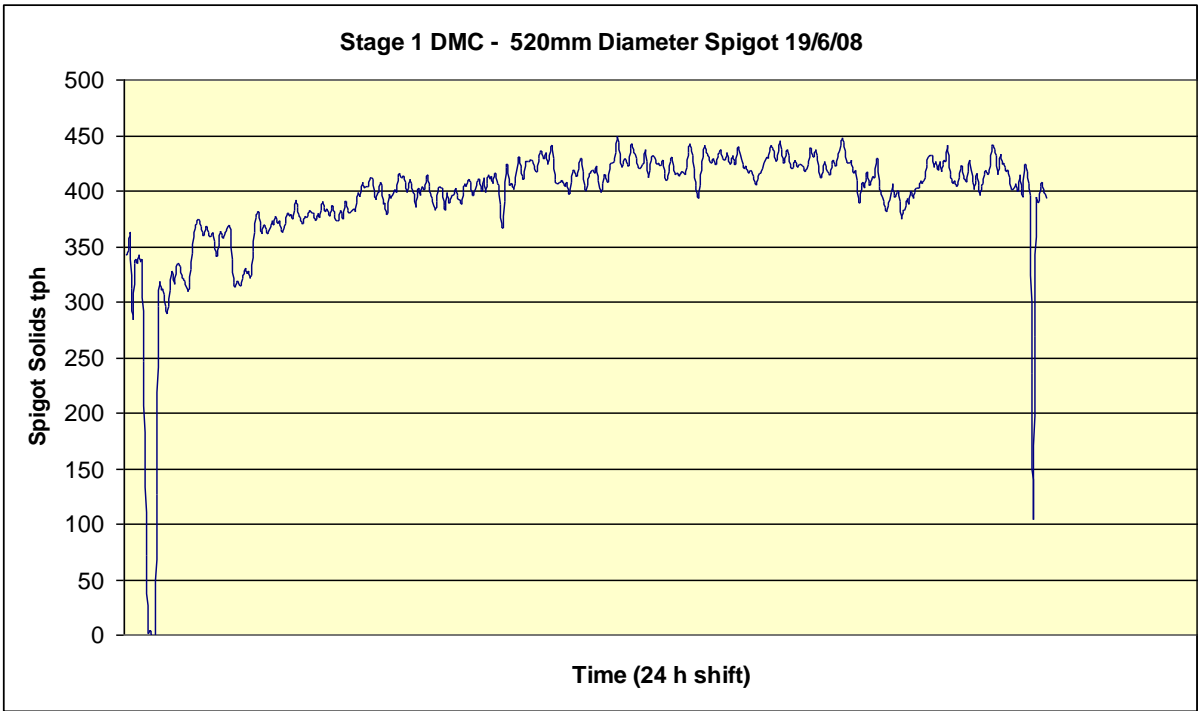


Figure 3 Cyclone Spigot Discharge over a 24 hour period

BENEFITS OF LARGE DIAMETER CYCLONES

The major benefits of using a single large diameter dense medium cyclone are:

- **Density measurement and control.** Only a single density control circuit is required avoiding the need to ensure that calibration of parallel density control circuits is exactly the same.
- **Feed distribution and individual cyclone offsets.** A major cause of inefficiency in parallel circuits is the variable offset (difference between medium setpoint and actual cutpoint) for the different modules, which typically vary from 0.05 up to 0.15 density units. Our understanding of the reason for this variable offset is incomplete, but there is considerable evidence that variation in rejects loading through the spigot is a significant factor (refer Figure 4 below). In practice, it is very difficult to ensure even distribution of raw feed between parallel modules, especially with the common practice of the 1970's and 1980's of using hydraulic distributors. Variation in both feed rate and yield between parallel modules means that spigot loadings will be different for the individual small capacity cyclones, resulting in variable offset and a poorer E_p for the overall plant.

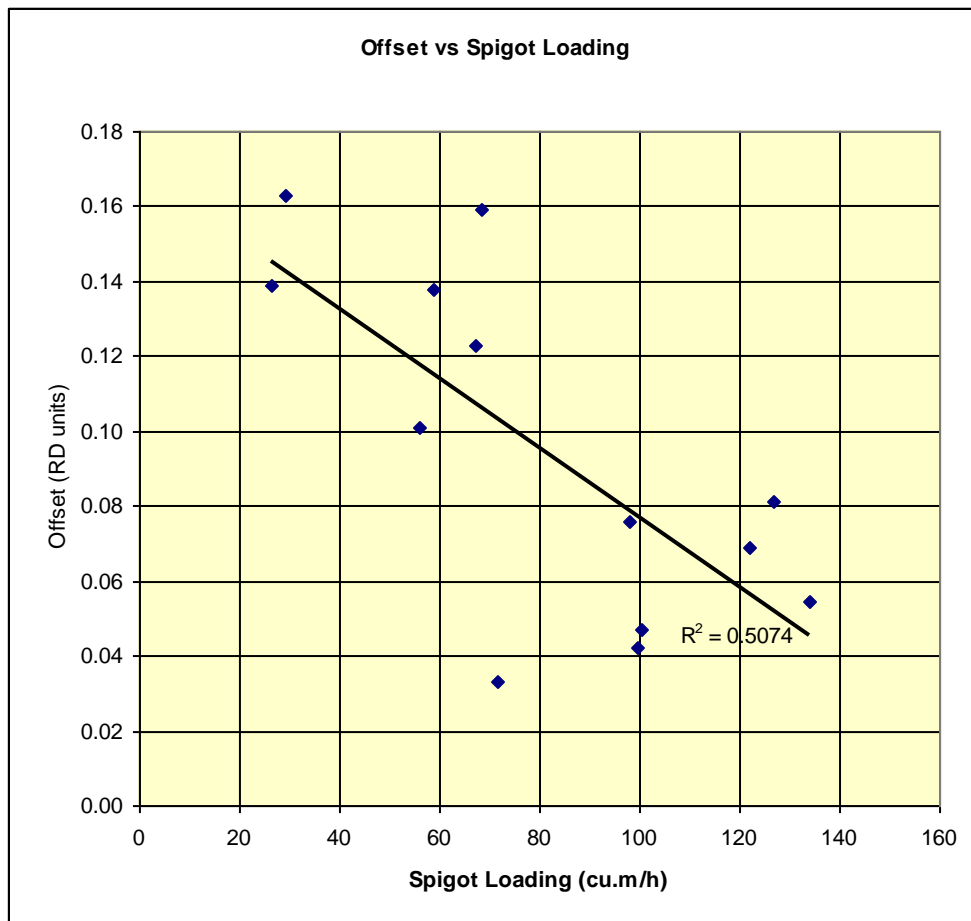


Figure 4 Offset vs Spigot Loading

- **Pressure measurement and pump wear.** Cyclone feed pressure as it relates to volumetric feed rate and hence medium to coal ratio, has been identified as being important for cyclone efficiency. As the feed pump wears the feed pressure and volumetric feed rate will drop, potentially resulting in poorer medium to coal ratios unless compensated through variable pump speed. Differentials in feed volume can become an additional factor on performance when operating parallel loops.
- **Cyclone configuration and wear.** Similarly any differences in cyclone configuration, such as errors during installation and replacement, or wear of the cyclone parts, especially the spigot, will add to the relative differences in performance and cutpoint between parallel modules.

All of the above are critical in ensuring a sustainable, efficient operation for the overall dense medium cyclone circuit.

CONCLUSIONS

The data collected and presented from the wash plant audits clearly illustrate the viable use of large diameter dense medium cyclones in the Coal Preparation Industry and disprove some of the commonly held theories. In particular no evidence was found that the E_p for the full size range worsens as the cyclone diameter is increased, or of a significant “breakaway” point within the size range that is being processed. Even poorly operating cyclones will still outperform all alternatives for the typical size range being processed.

The major process benefit of large diameter cyclones is not absolute unit efficiency but parallel unit inefficiency. Large capacity single module wash plants have major industry benefits in terms of process efficiency, capital optimisation, footprint minimisation, operational availability and reduced maintenance cost. At this stage the only “Real” constraint on cyclone diameter is the throughput capacity of adjoining equipment (pumps, screens and centrifuges).

REFERENCES

Dutch State Mines, 1968, *Guide to the Calculation of Cyclone Washeries and Heavy Medium Float-and-Sink Washeries*.

K R Leach, M Carretta, J Graham and A D Meyers, 1998, Comparison and Efficiency of 1,000mm and twin 710mm dense medium cyclones at Goonyella and Riverside, Proceedings of the *XIII International Coal Preparation Congress*, A C Partridge, I R Partridge (Eds), Australian Coal Preparation Society.