The efficiency of Wemco drums at Kleinkopje coal washing plant over 30 years

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Synopsis

Kleinkopje Colliery has five Wemco drums that were installed and commissioned in 1978. Over the years, there have been remarkable changes in mining and geological conditions at the colliery. First, an increase in the percentage of fines was recorded, which resulted in an uneven split or an imbalance in silo levels between material feeding the cyclone (-12 mm) and Wemco drum (+12 mm) sections respectively. This problem was solved by doing modifications around the banana screens to allow finer material to the drums. The imbalance challenge was then followed by spontaneous combustion that takes place *in situ* and results in low product yield. The results obtained from efficiency tests indicate that although there is a limit in the percentage of -6 mm material in the feed, Wemco drums are still very efficient and applicable to the current mining conditions. These results also suggest that it is essential to lower the throughput when the drums are treating low yielding coal.

Keywords
Wemco drum, Kleinkopje and 30 years.

Introduction

Kleinkopje Colliery is an Anglo American Thermal Coal mine situated about 30 km south of Witbank (eMalahleni) in the Mpumalanga Province of the Republic of South Africa. It is an opencast mine that uses strip and shovel method to mine the remainder of pillars left during underground mining. The bulk of its reserves are found in the number 1, 2 and 4 seams respectively. The number 2 seam, which forms more than 70% of these reserves, is currently under spontaneous combustion and presents several challenges to the processing plant in terms of ease to handle and other difficulties that arise from burning coal. There are several methods that include use of water cannons, cladding and buffer blasting that assist in minimizing the occurrence of spontaneous combustion.

The washing plant is primarily subdivided into Wemco drum, cyclone and fines sections respectively. Feed from run of mine (ROM) is subjected to banana screening to separate at 12 mm cut size. The oversize is fed into a drum feed silo while the undersize reports to a different silo, from which it is fed into a DSM cyclone plant. The final product from the three sections is combined and sent to the rapid loading terminal (RLT) and railed to Richards Bay Coal Terminal (RBCT) at calorific value of 27.40 MJ/kg on air dry basis, top size of 50 mm and total moisture of 8%.

This paper looks at the application of Wemco drums at Kleinkopje plant throughout the history of the mine and under current conditions of spontaneous combustion.

Plant process overview

The layout of Kleinkopje plant commences at the raw coal tipping area, where coal can be tipped either on the A, B or C tip (see Figure 1 below). The tipped material is then sized down to 150 mm through primary crushing Bradford breaker. The oversize is then subjected to a jaw crusher that also reduces the material size to a top size of 150 mm.

The stockpiling is done in chevron pattern to allow proper and even blending of raw material. The bucket-wheel reclaimers are then utilized to reclaim raw coal from the stockpiles through the banana screens which classify coal for the drum plant and cyclone plant silos as indicated in Figure 2 below.

The Wemco drum section is divided into five modules, namely, module 3, 4A, 4B, 5A and 5B. The oversize material reports to Wemco drum plants from which separation according to gravity takes place. After separation, the product and discard material

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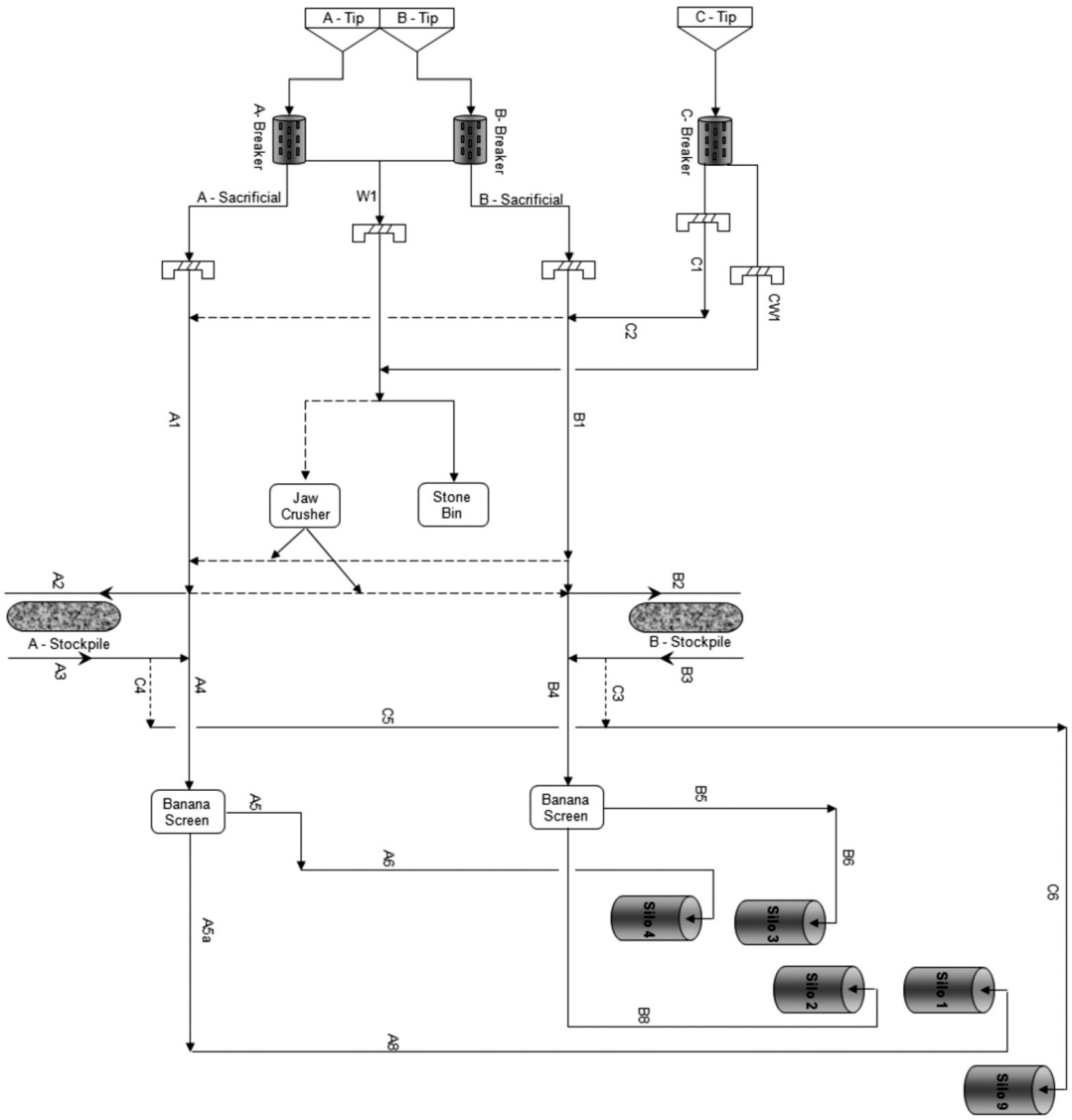


Figure 1—Kleinkopje plant front end

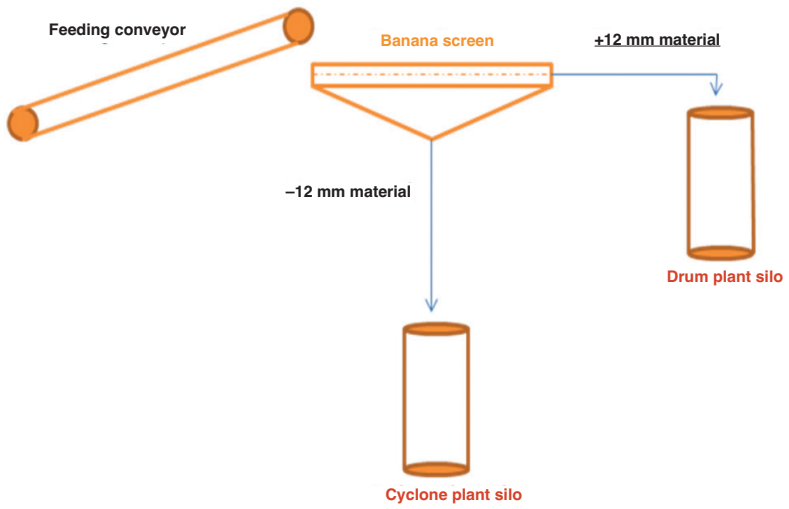


Figure 2—Raw Coal Screening

report to their respective drain and rinse screens where medium recovery takes place before the material is transported either to a product or discard silo. Figure 3 gives a simplified example of coal flow on one of drum modules at Kleinkopje plant.

Theoretical background of Wemco drums

A single compartment Wemco drum is a separation bath that consists of a steel shell typically supported from four rollers in a longitudinal operating position. Inside, the shell is equipped with a set of lifting scoops that are perforated to allow drainage of medium as it rotates. In addition to the lifting scoops, the internal part of the drum consists of a feed chute, sinks launder, steel and rubber skirtings and medium addition points.

Principles of a drum operation for coal application

Raw coal enters in the feed end, into the magnetite-water mixture known as medium. Separation starts taking place immediately, with the heavier material sinking to the bottom of the shell and the lighter material floating. As the drum rotates, and the lifters fitted inside carry the discard to the sinks launder from which it flows onto a drain and rinse screen. The product floats with the medium out on the discharge end of the drum. The maximum size of coal that can be handled in the Wemco drum depends on the size of the whole shell, the inlet and outlet diameters as well as lifting scoops. A top size of 250 mm has been treated in the coal industry, whereas 150 mm seems to be more common (Wills, 2006). The Wemco drum can handle as much as 400 ton per hour feed, with approximately 20–25 ton per hour per m^2 pool area with very good separation efficiencies. Figure 4 summarizes a schematic diagram of a Wemco drum.

Advantages of using a Wemco drum

Wemco drums present several advantages that make it a separator of choice over other dense medium washing baths. These include amongst others the following:

- A sharp separation can be obtained at various relative densities.
- High efficiencies are achievable with large amount of near gravity material.
- The operating density can be easily reached and controlled.
- A large range of particle size can be handled very efficiently.
- Changes in feed rate and quality can be treated with a high level of confidence.
- The drum can handle large quantities of feed per square metre per hour.

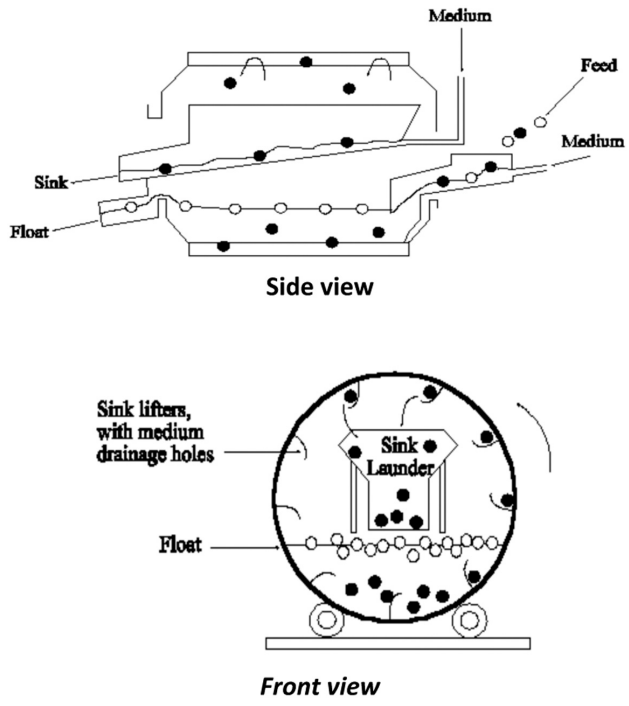


Figure 4—Schematic diagram of a Wemco drum (adapted from Wills, 2006)

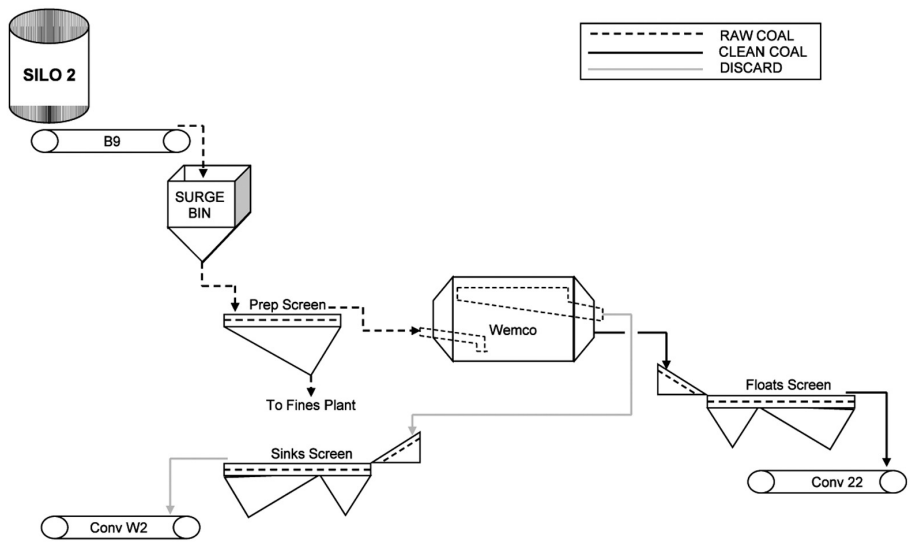


Figure 3—Basic coal flow through a drum plant

- There is minimal turbulence in the bath to hinder separation.

Factors affecting Wemco drum performance

Wemco drum performance can be affected by several factors such as:

- Material misplacement
- Medium reporting to different sections of the vessel
- Solid flow rate and size distribution
- Configuration of the lifters
- Configuration of the skirting
- Type of raw coal
- Density control
- Near gravity material.

Historical overview and results

Figure 5 summarizes the geological history of Kleinkopje colliery and illustrates changes in geological and mining conditions as a function of time. The mine was commissioned in 1978, using opencast methods of mining. This phase was predominantly characterized by 'virgin' coal reporting to the plant. Since the area was also never mined before, there was minimal contamination on run of mine coal.

It was during this period that the plant produced a variety of products ranging from metallurgical to thermal coal. The product qualities were specified as follows in Table I.

The efficiency data obtained indicate that the drums were highly efficient with records of above 95% organic efficiency and Epm of 0.010. This result is expected, because the drums were treating the type ROM that they were designed for. For module 5Aand 5B, the tonnage is not presented, but the report from which this data was extracted specifies that the throughput was excessively high during the sampling period. What was also observed was that these modules were treating a high percentage of near gravity material. That presented a separation challenge to the drums to achieve a sharp separation, hence the lower organic efficiencies of 91.3% and 75.5% respectively.

The second period started in early 1990s when more fines were generated from the pit as a result of overblasting. The plant still produced a range of products presented in Table II

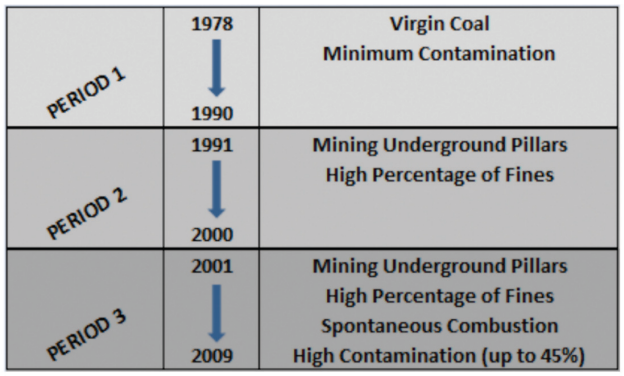


Figure 5—Historical overview of Kleinkopje Colliery

Table I

Product quality specifications

	Thermal coal	Metallurgical coal
Calorific value (MJ/kg)	27.40	N/A
Ash percentage (%)	15.0%	7.0%–11.0%
Swelling index	N/A	2.5
ROGA	N/A	40

above. This situation resulted with a challenge to the plant as the imbalance in ROM coal was encountered. Figure 6 indicates that the plant was designed to handle 40% minus 12 mm size range and 60% +12 mm size range. Instead this split saw ROM becoming 50–55% of -12 mm material. This significant deviation, as indicated in the figure, resulted in unbudgeted downtimes and eventually hindering maximization of throughput to the plant. As this challenge persisted, and alternative solution was applied to minimize the imbalance by allowing a fraction of finer material (-12 mm) to the drum plant.

The results obtained from efficiency test work indicate that finer material has an influence on the overall efficiency of a Wemco drum. It can be seen from Table III that an increase in the percentage of -6 mm material causes a decline in drum efficiency.

Table II

Efficiency results for Period 1

Module	Date	Throughput (TPH)	Epm	Organic efficiency (%)	Near gravity material (%)	Misplacement to	
						Floats (%)	Sinks (%)
3	15/09/1983 01/12/1983	363 400	0.017 0.024	99.3 98.8	6.0 6.0	1.3 0.9	2.2 1.7
4A	05/05/1983 12/10/1983 20/10/1983	210 227 237	0.032 0.009 0.006	96.4 98.6 98.7	6.0 17.0 19.0	1.4 1.9 0.7	3.8 1.2 1.7
4B	11/02/1983 12/05/1983 12/10/1983	180 230 227	0.013 0.019 0.007	99.8 98.1 98.4	15.0 13.0 14.0	0.3 2.0 0.8	4.9 2.2 1.9
5A	23/08/1983		0.010	91.3	33.0	2.0	2.3
5B	23/08/1983		0.007	75.5	30.0	2.7	1.6

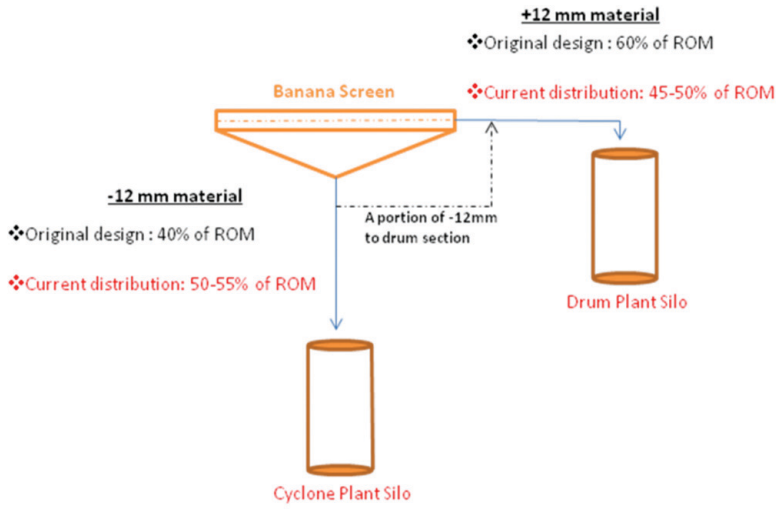


Figure 6—Raw coal screening after modifications

Table III

Efficiency results for Period 2

Plant	3	4A	4B	5A	5B
Operating density	1.70	1.69	1.70	1.69	1.70
Cut point (SG50)	1.61	1.62	1.62	1.55	1.61
Epm	0.046	0.033	0.035	0.011	0.027
–6 mm feed (%)	20.5	10.1	13.7	5.9	3.8

The last period on Figure 5 illustrates the condition of a spontaneous combustion of coal. This condition results from self-ignition of coal and requires three basic components (oxygen, fuel and heat) to occur as indicated in Figure 7.

Degradation in quality of ROM material is one of the main challenges that spontaneous combustion presents. Figure 8 presents a burning stockpile as it awaits reclamation into the plant for washing. The longer it stays burning, the more difficult it becomes to reclaim it to the plant. This is due to its escalated temperature that has downstream negative impacts such as melting of conveyor belts and polyurethane screen panels.

In addition, burning coal combusts an abundant percentage of volatile matter and leaves a small fraction of saleable coal as well as a high ash material. Proven theoretical data shows that spontaneous combustion can reduce product yield and calorific value by 30% and 3.20 MJ/kg respectively. This statement is supported in Figure 9, which compare relationships between yield and ash percentage as well as yield against calorific value of coal.

Results achieved from efficiency test in Table IV shows that although the drums were designed to treat high yielding coal, they are still successfully efficient under the conditions of spontaneous combustion. It is of vital importance though to note that feed to these drums was moderated, to minimize misplacement of material and blocking of discard launder due to high percentage of discard reporting to it.

Misplacement result also signifies that the drums are still generally efficient. Detailed analysis in Figure 10 shows that Wemco drums for module 4A and 5B had several lifting scoops missing, hence the higher percentages in misplacement of floats in sinks, than in other modules.

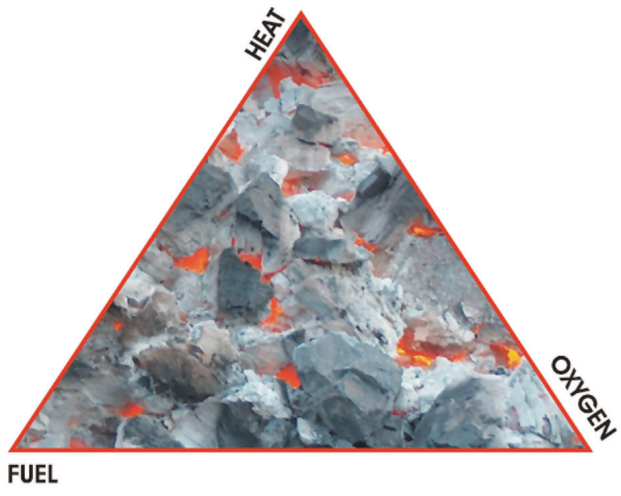
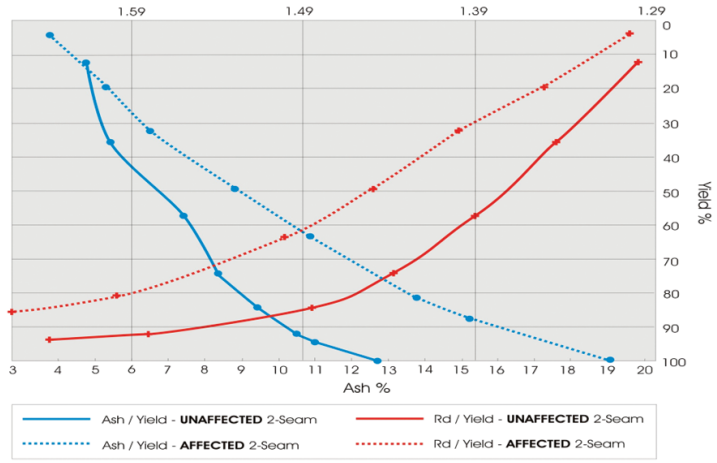


Figure 7—Triangle of spontaneous combustion



Figure 8—Stockpile under spontaneous combustion



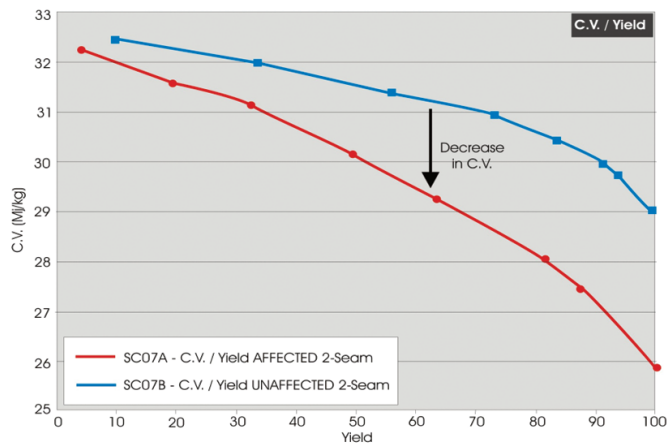


Figure 9—The impact of spontaneous combustion of coal yield and quality (Dhlamini, 2008)

Table IV

Efficiency results for Period 3

Module	Throughput (TPH)	Ep	Organic efficiency (%)	Yield (%)
3	350	0.0203	99.9	46.5
4A	180	0.0106	93.9	59.3
4B	180	0.0171	96.9	48.5
5A	200	0.0110	96.4	37.7
5B	200	0.0265	90.7	42.2

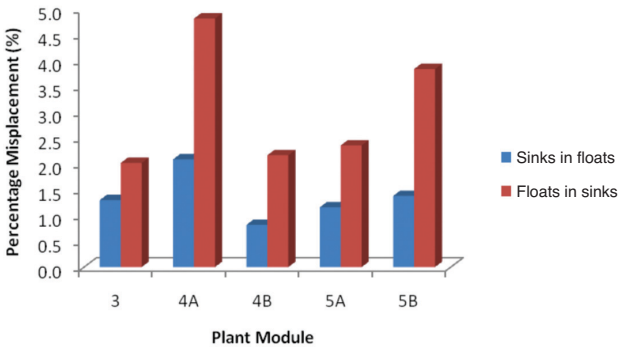


Figure 10—Misplacement of floats in sinks and sinks in floats

Conclusion

Wemco drum efficiency results obtained over a 30-year period confirm that the units are highly efficient when treating both high and low yielding coal. The drums, however, face a challenge when treating high percentage of -6 mm misplaced material. In addition, spontaneous combustion hinders high tonnage throughput into the drums, due to the high fraction of discard material in raw coal. Maintenance of lifters is also critical as it leads to misplacement of floats into sinks and sinks into floats.

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