

Process Design of the new Phola Coal Preparation Plant

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Summary

The 2380 t/hr two module Phola coal preparation plant represents a new era of large plant in the Witbank coal field designed to extend its life to 2020 and beyond. The plant uses the optimum processing model for Witbank coals splitting the coarse and small coal into (50 x 8) and (8 x 0.6) mm size fractions for parallel DMS processing whilst the primary sinks are mixed before processing through a high density DMS section. The plant design incorporates 1150mm large diameter DM cyclones and 4.2m width banana screens representing the largest size equipment used to date in South African coal preparation plants. The fine coal is conventionally processed by gravity spirals whilst the raw coal slimes are filtered using automated plate and frame filter presses. This enables them to be added to the product if the quality is sufficient.

Introduction

The design of the Phola coal preparation has its roots in the late 1980's when there was a requirement for a plant to treat 8 Mtpa coal from Ingwe's (now BECSA's) Klipspruit open cast mine at Ogies, Mpumalanga. The mine is part of the Witbank Coalfield and mines mainly No. 2 and 4 seams with some 5 seam material.

The design brief was for a classic 2 stage Witbank plant producing a prime 27.5 MJ/kg export product and a 21 – 21.5 MJ/kg middlings for the nearby Kendal Power station.

The plant capacity doubled in size when Anglocoal joined the party in a 50:50 JV for a plant which would also treat coal from their new Zondagsfontein underground coal mine, approximately 15km to the south. The advantages of a combined plant lay mainly in the access the Klipspruit plant gave to the Richard's Bay coal terminal railway line and lower operating costs, as a combined plant allowed a larger unit module size whilst still keeping the flexibility of a multi-modular design.

This has resulted in the design, construction and partial commissioning to date, of one of the largest and most modern coal preparation plants for 30 years since the late 1970's early 80's expansion of the Witbank coalfield¹, which in turn was due to the construction of the Richard's Bay Terminal export railway line.

The plant design however is a logical extension of past practices and makes use of advances in equipment size, control systems and design concepts, some of which have been pioneered overseas. This paper discusses those aspects of the design which are innovative and applicable for future plants.

Database

As the Klipspruit mine has been operating for a number of years and trucking its coal to a remote washing plant, there existed an excellent opportunity to take bulk samples and a total of 22 were taken over an 18 month period. Numerous borehole samples were made available as well as three large core samples from Zondagsfontein. The size distributions from the bulk samples are shown below in Figure 1:

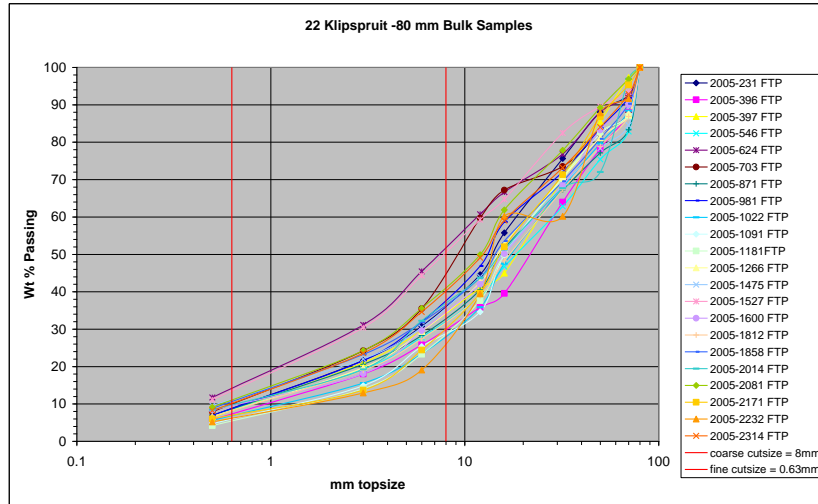


Figure 1: Size distributions from 22 Bulk samples

Most of the bulk samples were screened into two size fractions at 12mm for washability analysis. This provided an invaluable database for not only calculating the yield ranges for the whole plant but investigating the difference in yields that could be expected between the coarse and small coal fractions. For these calculations, use was made of an in-house DMS simulation programme to calculate the expected primary and secondary yields. These are illustrated in Figure 2 below:

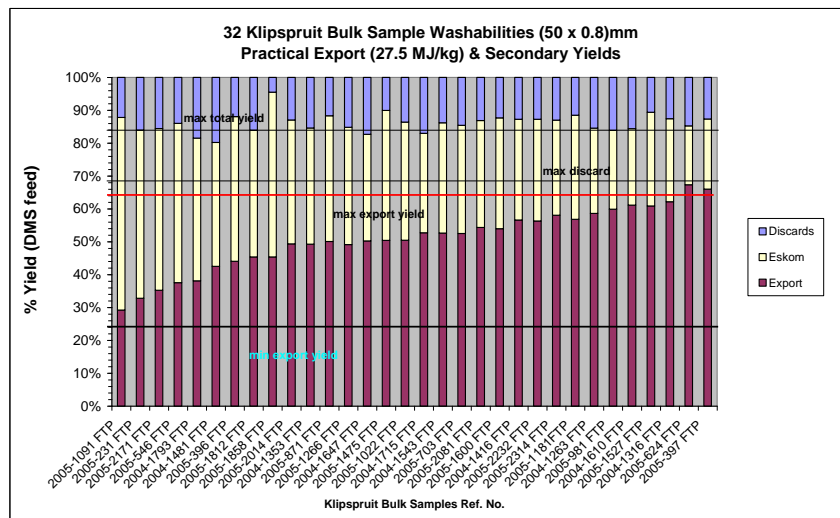


Figure 2: Simulated Primary (export), Secondary (Eskom) & Discard Yields

When the products are simulated for the coarse and small coal fractions, the enhanced small coal yield of approximately 20% can clearly be seen :

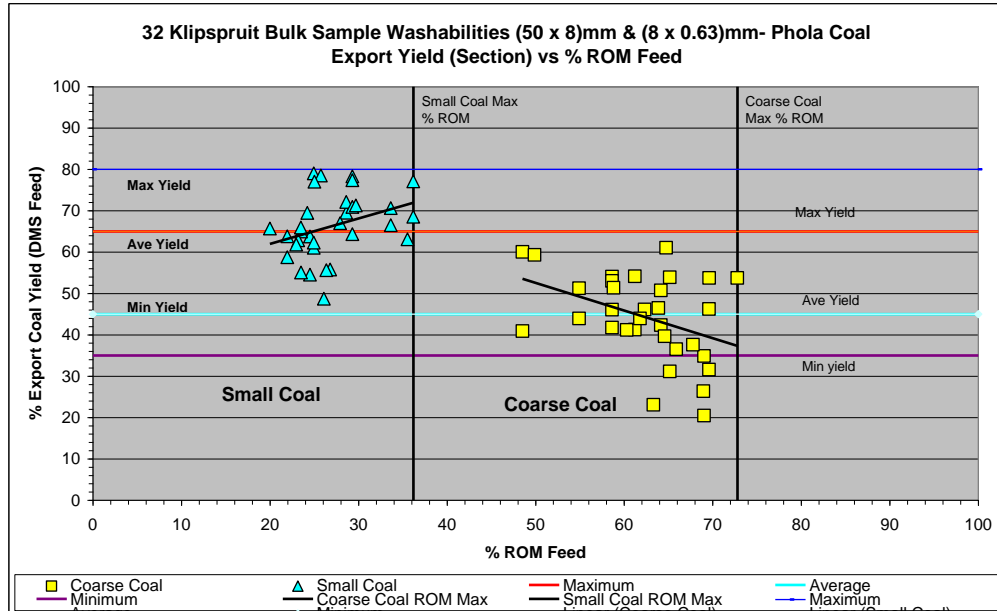


Figure 3: Simulated Coarse and Small Coal Export Product Yields

It is interesting to note that the coarse coal yields are lowest when it constitutes the greatest proportion of the raw coal feed, whilst the opposite is true of the small coal fraction. It is believed that this can be explained by the fact that the lower yields are due to a higher ash content which in turn comes from a harder coal. Thus the higher the ash content, the greater the proportion of coarse coal (50 x 8) mm in the raw coal.

Previous Plant Design Concepts

The overall concept of a two stage low density separation followed by a high density DMS plant was quickly settled upon due to the yield distribution that showed up to 65% of the coarse and 80% of the small coal could become an export product. This process model also allows the density to be set for each product and therefore both product qualities can be directly controlled.

There was also a requirement that the Klipspruit coal be allowed to bypass the plant completely and report to the Middlings product. This “bypass conveyor” cutting through the whole site which as it became quickly apparent, was constrained by the local geography into a long rectangular slot with Klipspruit mine in the East and the rail loadout silo’s approximately 3km to the West, was one of the dominating aspects of the overall layout.

Having settled on the process concept, various studies ranging over 5 years proposed solutions such as using multiple single product modular plants in parallel, to the more conventional solution of a large multi-product plant. The early designs also incorporated the flexibility to take out a primary sinks or “raw middlings” product, to introduce a raw coal directly into the secondary stage as well as a generous allowance for surges. Space

was left in the design for a future flotation plant and throughput expansion by 50%. This coupled with the requirement not to use equipment any larger than was in current South African use, which in practice limited the screen sizes to 3.6m width and the DM cyclone to 1000mm diameter, led to a large and expensive final design for the Klipspruit plant.

Final Plant Design Concepts

When the plant size was effectively doubled by Anglocoal's Zondagsfontein Colliery output joining the project, the design team quickly concluded that the design had to start from scratch as a simple doubling up of the plant size led to almost insurmountable materials handling problems.

The key to reducing the plant footprint and significantly lowering the capital costs lay in two relatively simple concepts – firstly the maximum equipment size allowed was extended to include proven sizes from overseas (principally Australia where many reference sites were visited) and secondly to simplify the process such that all the coal was washed and no intermediate product was allowed to be withdrawn or added. The key concept of separating the coarse and small coal fractions in order to optimize the yield was retained, as this allowed the module size to increase in overall throughput.

The maximum equipment size settled upon was 4.2m Width banana screens and 1150mm DM cyclones for the coarse coal and secondary high density separation. These sizes were well proven in Australia at the time – early 2005. This allowed the plant to be enormously simplified into a two module plant of 2 x 1180 t/hr capacity per module. It was interesting to note that the footprint of this final 16 Mtpa plant design was smaller than the previous 8 Mtpa plant which consisted of 5 major processing sections.

The final flowsheet is given in Figure 4 and overall mass balance in Figure 5:

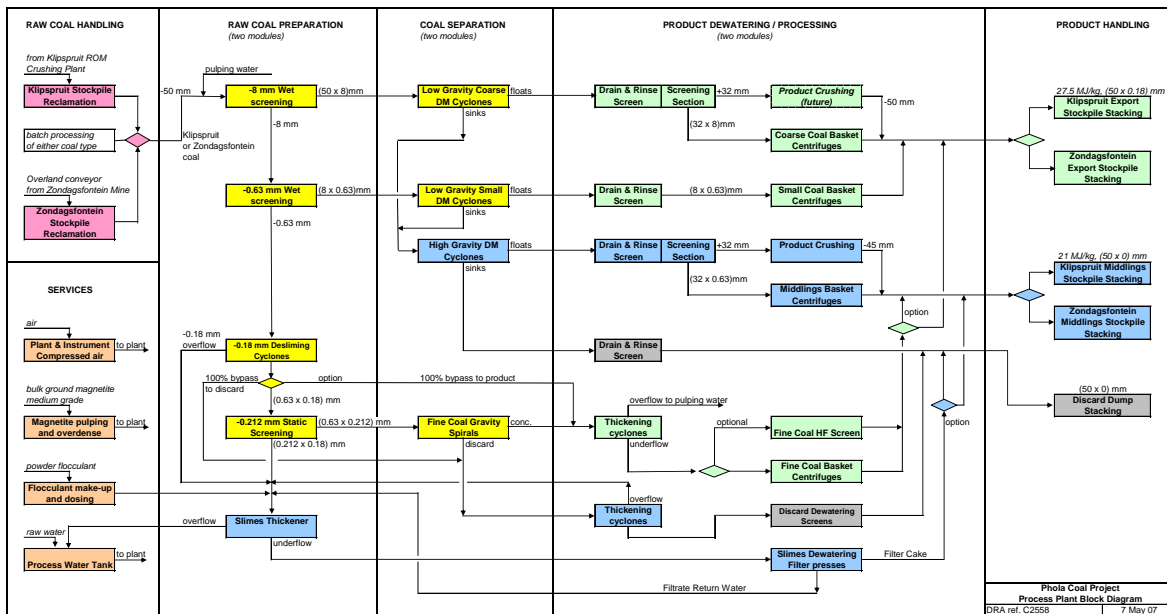


Figure 4 – Final design concept Block Diagram

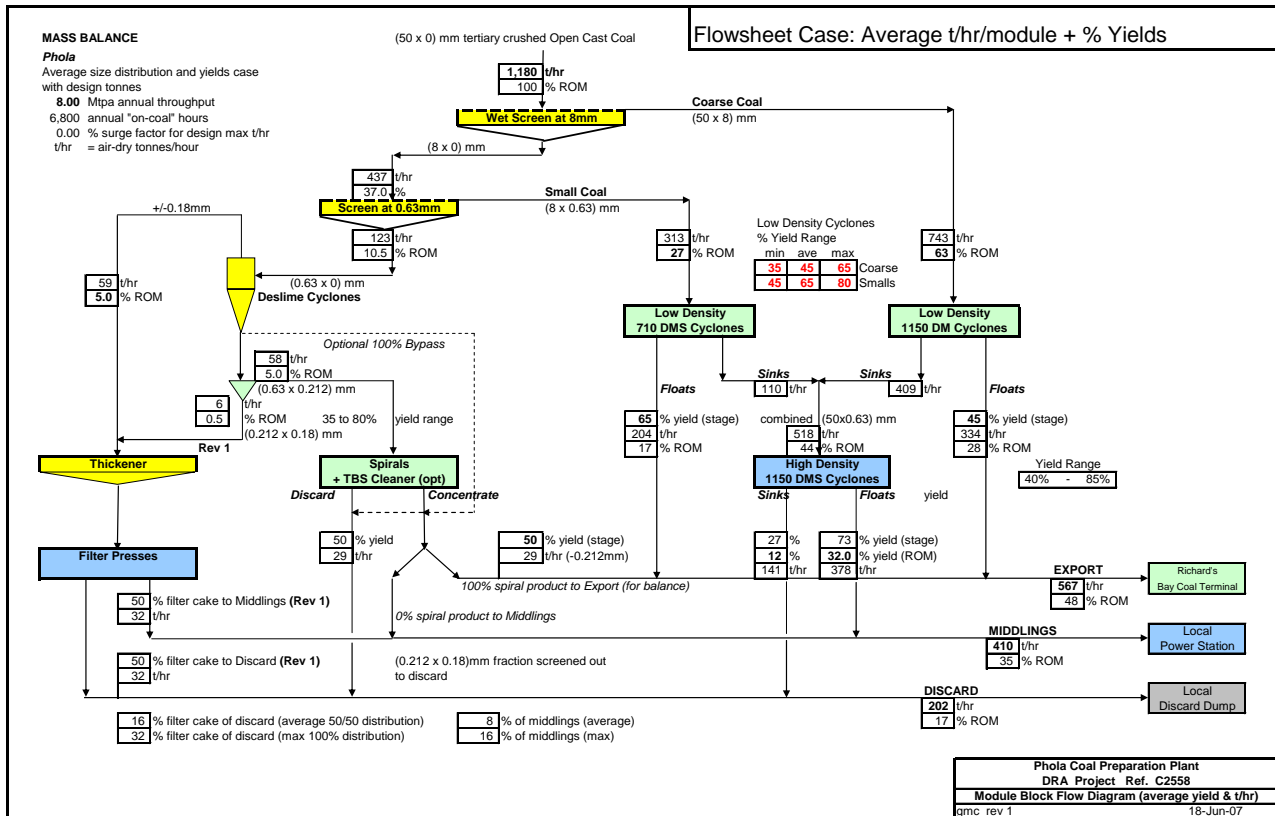


Figure 5 – Overall average mass balance

Innovative Plant Design Concepts

Primary Sinks Static Panels

A key point in the final plant design was the internal arrangement to combine the primary sinks from both coarse and small coal sections and deliver them to the high gravity section mixing box. This is achieved by the use of static drain panels (the old DSM method was to use double sieve bends) rather than vibrating screens, as the advantage lies in not only the saving in equipment and vibrating load on the structure, but in the fact that on a crash stop (which are all too frequent in the Highveld summer lightning storms) the coal will sit in on the screen rather than be discharged into mixing box feed launder and potentially block it.

Having agreed on the concept the design problem is what angle to set them at and how much drainage capacity to allow for, as provision needs to be made for the coal to sit on the screen whilst the medium drains and then gently drop off into the collecting launder.

Note was taken of the method adopted at the Mafube plant where a similar design concept was used but the screen height is adjustable and linked to the raw coal feed control system. At Phola where the tonnage is at least 25% greater, having an adjustable screen would have been an unwieldy option, so instead a generous 50% extra area was allowed for in the design for the coal to settle on. The main design

challenge here was not so much the concept or equipment sizing, but the layout due the huge volume of material going through the module.

This is illustrated below:

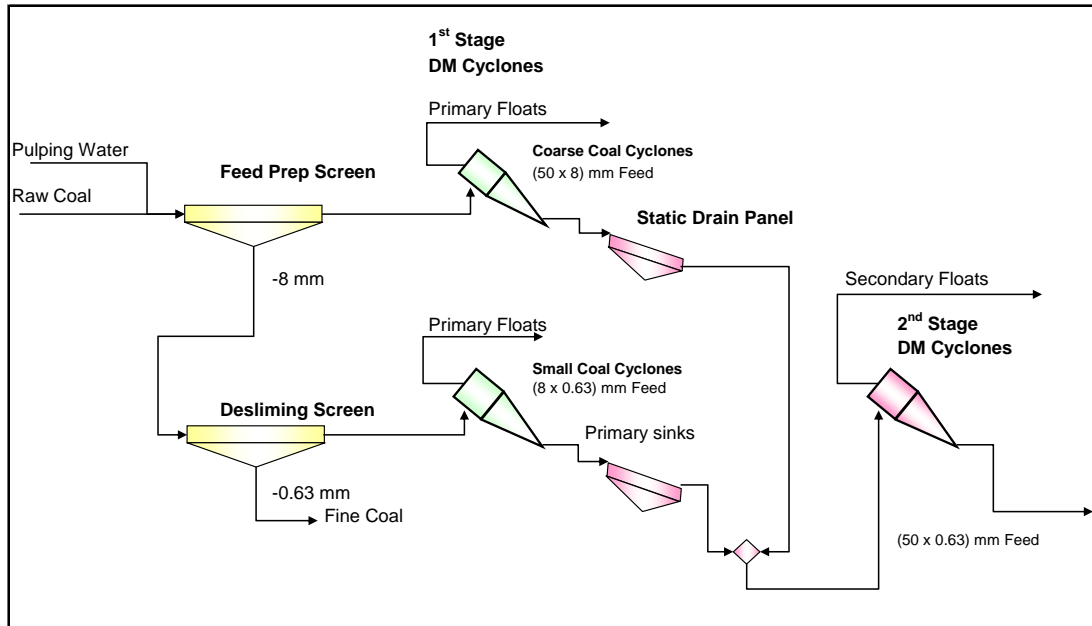


Figure 6 – Primary Sinks Process Concept

Elevated Cyclone feed pumps

When laying out a pump fed DM cyclone plant, there is generally scope to elevate the DM cyclone feed pumps as the height of the plant is dictated by the gravity flow of material from the DM cyclone floats to the drain panel, drain & rinse screen, dewatering centrifuge and product conveyor. Given the size of the Phola plant, there was an opportunity to save approximately 15m in pumping head by elevating the pumps and mixing box above the ground floor. There is also the considerable advantage of being able to drain the mixing box directly into the CM sump on a crash stop, allowing for a quick start-up.

Protection Panels above the CM Sumps

This is an Australian idea which involves gathering all the return flows into the sumps which could contain coal into a box and then allowing the combined flow to enter the sump through a static drain panel. The idea being to firstly stop any large coal entering the medium, then for this coal to be shovelled over the side of the sump in a controlled manner onto the floor for pick up. Normally return lines are routed directly back into the sump, but if this concept is followed it has a considerable impact on the layout, not necessarily adding height but complexity in gathering all the drain lines into a single discharge box immediately before the CM sump.

Use of “Pachuca” valves for Medium Sump agitation

These air agitation valves are situated in the bottom of the sump with the air being fed to them through the sump or preferable under the sump if the layout allows. They are self sealing and introduce agitation air in a more efficient way into the middle of the sump rather than at the sides.

Filtration of the Slimes

It was integral in the design concept to filter the slimes and then add the filter cake to the Middlings or Discards. Given the maximum design tonnage involved, the different qualities of the raw coal slimes from the two different mines and the requirement produce as dry as possible filter cake when it can be added to the middlings, the duty was split equally between two filter types – the TH filter with its single cloth per plate and the continuous cloth Lasta filter which also incorporates a membrane squeeze in its operation. Both these filters are relatively new models in the South African coal industry.

The filters are laid out at right angles to the product belts and by using reversible conveyors the filter cake can be fed to either the discard or middlings belt. There are six filter cake conveyors and 9 filters and given the variability in the time they can take to complete the filtration cycle, a dynamic simulation modeling exercise was carried out to calculate the maximum filter cake that could be added to the products and the optimum speed the filter cake conveyors should run at.

Plant Mass Balance

A detailed coal / water / magnetite mass balance was calculated for the wet plant using an Excel spreadsheet. Besides being used for pump and pipe sizing, it was used to calculate the maximum flow conditions for the many variables that the plant could experience e.g. average flowrate, min / max medium densities, maximum yield for the maximum coarse, smalls, fines and slimes sections, the “no coal” condition and the gravity spirals bypass condition. This had been calculated by simulation for the coal solids as shown above, but these simulations gave the maximum volumes and allowed the pump and pipe sizes to be finalised.

The mass balance was split into the five main sections of the plant – Coarse Low gravity, Small low gravity, High gravity, Fine coal and slimes. The balance for each section was calculated and finally the overall balance.

Process Equipment Selection

As stated earlier the original design brief was not to use any equipment or size of equipment not fully proved in South Africa, therefore the type of equipment selected tended to be conservative in terms of manufacturer.

The most notable area in which the design boundaries were pushed were the screen capacities through the use of modern banana screens. These screens with their multiple angle decks allow previous capacity standards in terms of t/hr coal / m² screen area to be greatly exceeded due to the velocities achieved on the screens and the thin bed layers. Particular care was taken in the design of the feed boxes ahead of the screens in order to spread the feed slurry as evenly as possible across them. In this area in

particular, the designs from previous plants built by DRA such as Mafube were carefully scrutinized.

The most conservative equipment selection was in the filter presses where 50% extra design capacity was allowed since there is no slimes dam. Filter cake surface moistures between 18 and 22% are expected from the units.

Use of Autocad during design

Full use was made of an Autocad 3D model during the design phase in order to optimize the layout. The model allows a “walk” through the plant which is invaluable in seeing where access needs to be allowed for maintenance for the efficient running of pipes through the plant.

Linings and pipe materials

All boxes, lower sections of pump sumps and the pump suction that are in contact with coal were ceramic lined varying up to 50mm thick for spigot boxes. All pipes handling magnetite medium were basalt lined while other slurry pipes used HDPE.

All screen and drainage panels are of HDPE construction.

Plant Control

The plant is fully automated with a SCADA system allowing the control room operators to run the full plant from the raw coal crushing plants, through the stockpiles, process plant, product stockpiles and rail load out.

Plant Construction, Safety and Commissioning

The plant construction was notable for the very poor ground conditions it encountered. In effect the plant was built upon a series of concrete rafts supported on 15m piles. The peak of construction effort for the civils and then a year later for mechanical erection, coincided with the heaviest monthly rainfall experienced for many years. This led to an abnormal number of claims for rainy days.

Despite the conditions there were only 2 LTI' (Lost time incidents) during construction and an LTI frequency rate of 0.14 has been achieved to date over 2 800 000 construction manhours. (Industry average 0.5).

Commissioning has proceeded relatively smoothly. The main problem being to get the slimes flocculation system working in the face of crash stops and uneven feed. This has led at times to running only filter cake out of the plant which in turn has meant a re-look at the design of the discard bin discharge system. It is currently being changed from a swing chute to a full width clam shell gate to counter filter cake hangup which can stretch over a 3m gap.

Final Plant Performance vs. Design

To date Module 1 has run at 90% of design capacity and processed 230 000 t of raw coal. Plant efficiency tests are scheduled for later in the year. The plants sets new limits in terms of screen drainage capacity

Conclusions

Although not completely finished, the Phola plant is well on its way to becoming one of the largest throughput capacity plants in the Witbank coalfield. It has been designed using the latest concepts in integrated plant layout and whilst breaking new boundaries in terms of throughput capacity has lent heavily on lessons learnt during previous plant designs.

Acknowledgements

The plant design was a collaborative effort by Anglocoal, Becsa and DRA Mineral Projects. The inputs to the design from the coal metallurgists at Anglocoal - D Power and K MacMillian; Becsa - P van Heerden and P Lidgate as well as my colleague M Salter are gratefully acknowledged.

ⁱ Design of a new era of DMS Coal Preparation Plants for the South African Witbank Coalfield” GM Cresswell, M Salter; XVth International Coal Preparation Conference, Beijing 2006