Exploring the performance of an Air Plant

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Abstract. The global depletion of high-quality coal reserves necessitates a paradigm shift in coal processing. Traditional methods have focused primarily on wet processes; however, the industry requires alternative methods that are fit for purpose and cost-effective while still yielding the desired outcome. This project explores the alternative method of dry processing of coal with air as a separation medium using Air Plant technology. In this study, bulk samples of different coal sources and blends were utilized, and various tests were conducted across different sites. From a feed coal of -50mm + 12mm that was beneficiated, the quality of the product streams was investigated. An improved coal quality of 30% ash content and total sulphur of 0.58% was achieved from a feed coal of 36.9% and 1.03% total sulphur. The demonstration shows a 5-7% ash upgrade to the coal feed tested. Furthermore, the findings reveal an EPM value of 0.082. The project demonstrated the efficiency of Air Plant technology for destoning, as the results indicate quality improvement with minimal yield losses. Air plant has indicated great potential as an alternative method for preconcentrating coal, while also promoting sustainable practices that contribute positively towards ESG (Environmental, Social, and Governance) principles.

1 Introduction

Globally, dry processing was used extensively in the United State and in the United Kingdom in the period between 1930 and 1980. Approximately 20 to 93 million tonnes per annum was processed through the dry process technology in the United States and United Kingdom respectively. The discovery of the dense medium separation shifted the focus, however in the past decade the focus on dry processing has expanded. Dry processing has been adopted since early 2010 and has become more popular recently due to its benefits of not using water to separate. China adopted the first generation of the FGX. The 'FUHE GANFA XUAN MEI' known as the FGX, meaning 'compound dry type of washer' is a Chinese owned technology to process coal [1]. China adopted this technology due to scarcity of water and with temperatures reaching sub-zero levels, using dense medium separation to process coal is a challenge. Dry processing is suitable for China considering the weather conditions, environmental concerns and the economic benefit.

In 2010, commercial dry processing technology was introduced at Middlekraal Colliery with two modules at a capacity of 240 t/h. The mine beneficiated 14.4 Mt through the FGX. The FGX plant was constructed and operated by Genet Mineral Processing. Genet Mineral Processing has since modified Air Plant technology. Genet Mineral Processing has been constructing and operating Air Plants across the Witbank coal region. Some of these operations are:

- In 2023, Onverdacht Colliery Air Separation module was constructed with a beneficiation capacity of 120 t/h. A total of 1.7Mt of run of mine was processed.
- In 2015, Klipfontein Colliery established and commissioned an Air Plant with capacity of 120 t/h. A total of 2.9 Mt run of mine was processed.
- In 2017, Matla Colliery Air Separation modules were commissioned at a capacity of 240 t/h. A total of 1.8 Mt run of mine was processed.
- In 2020, Klipfontein Colliery with two Air Separation modules of 400 t/h were installed. To date, 10.8Mt has been processed.
- In 2022, HCI's Palesa Colliery installed two Air Separation modules with total capacity of 400 t/h. To date, 5.6 Mt has been processed.
- Later, in 2024 Dec, the Klipfontein Air Plant extended with one module, giving capacity for the three modules at 600 t/h.

Fig.1. Klipfontein Air Plant

Over the years Genet mineral processing has improved the FGX technology, to the current plants operating at Klipfontein and Palesa mine. Air Plants in South African can beneficiate raw coal for domestic use. The beneficiated coal meets the domestic required grade for most power stations in South Africa.

Although dry processing is growing in industry, it does not substitute the wet processing techniques applied in coal processing. Depending on the market, demand at hand or the specifications required from coal, different techniques can be applied. In South Africa, dense medium separation is widely used to process coal. This technique widely suits the export market which demands low ash content in the coal.

Dense medium cyclones have proven over the years to remove impurities or shale in coal to meet a low ash content specification. The processing, however, requires water and medium (magnetite) to separate the coal from shale. It is recommended that a costing study be done prior to processing to determine the most effective and profitable option between dry and wet processing for the different specifications or targeted grade for the market.

Dry processing has its own benefits compared to wet processing. Different aspects should be considered prior to the final selection of the beneficiation process. The suitable process can be reviewed against the criteria on what product quality is targeted and how costly the process is against the revenue of the project. Past comparison of the dry and wet processes has been reviewed and have shown that the dry processing of Air Plants achieve good revenue at lower cost [2]. The high demand for coal in South Africa still exists in generating energy with more focus on renewable energy in the next decade [3]. Dry processing of coal eliminates the use and contamination of water, showing a key milestone towards the growing demand for clean coal processing technologies.

Table 1. Comparison of wet processing and dry processing *[2]*

Description	**Wet Beneficiation**	**Dry Beneficiation**
Water	Requires water for separation	Does not require water
Construction	Complex construction with higher cost	Easy and less costly construction
Capital cost	High capital	Less capital required
Operating cost	High operating cost	Low operating cost (about 30% lower)
Feed	ROM and Feed preparation are the same	ROM and Feed preparation are the same
EPMs	0.001-0.010	0.03-0.08
Slurry handling	Thickeners, filter press or slurry cells	No slurry handling process
Environmental Licensing	Onerous	Limited implications/law & regulations

1.1 Klipfontein Air Plant technology

The run of mine coal mined is fed through the tip from the pit. The tip is equipped with a jaw crusher that reduces coal particles sizes 600mm top size to -120mm. The coal goes through the Bivitec double deck screen from which three product sizes are obtained; +50mm which is fed to the roller crusher, -50mm +12mm which is fed to the air plant and -12mm which can either blended back into the final product or discarded. Chinese coal does not require screening out fines as the Chinese coal has a clear cut-point of separation, whereas the South African coal is of high near dense material characteristics which introduces high misplacements if not managed well. Due to nature of the South African coal, the finer

fractions must be screened out. The attributes are due to the near dense material. The -50mm; +12mm coal particles are fed through the Air Plant.

The coarse coal is usually 75% of the ROM. It is processed through the Air Plant for destoning and the discard is thrown out on a stockpile for disposal to the mining discard facility. The middlings collected are re-introduced as feed to ensure product is not misplaced into the discard. The product is collected and blended with the initially screened out fines to build stockpiles for customer off-take. Stockpiles are of batches of 7,000t each and once approved by the customer, the final product is trucked to the destination. Fig 2 below shows the Klipfontein process flow diagram illustrating the Air Plant process configurations.

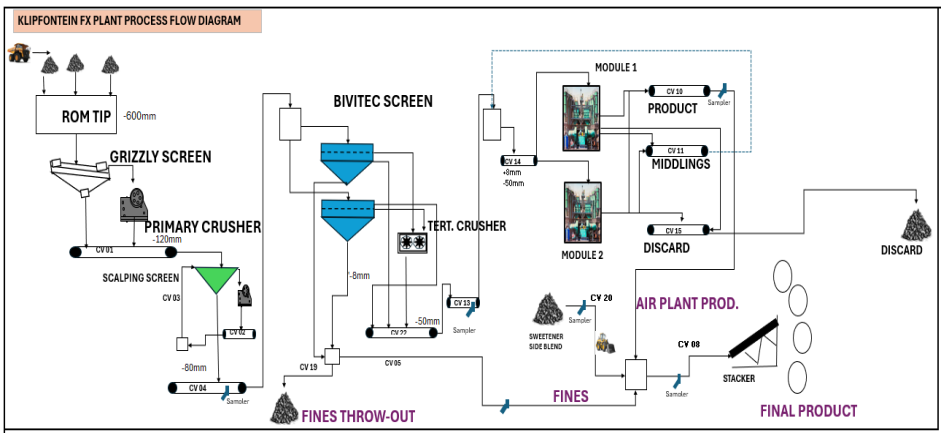

Fig. 2. Process flow diagram for Klipfontein Air Plant

2. Air Plant technology

2.1 Separation mechanics

Run of Mine coal is introduced into the Air Plant after screening out the -12mm material. Air is blown from the main fan at the required air flow rate. The separating bed is equipped with perforated pores to allow air to flow thought from the bottom of the bed, creating a fluidized bed on the incoming coal on top of the deck. Due to the characteristics of good quality coal, being lighter than the shale and heavy stones, it is lifted by the air and collected through lined and tilted segments into the first compartment as the primary product out of the Air Plant. Coal that is heavier continues to move through the fluidized bed and collected as middlings while the rock and shale is collected last as the discard (Fig 3) [4].

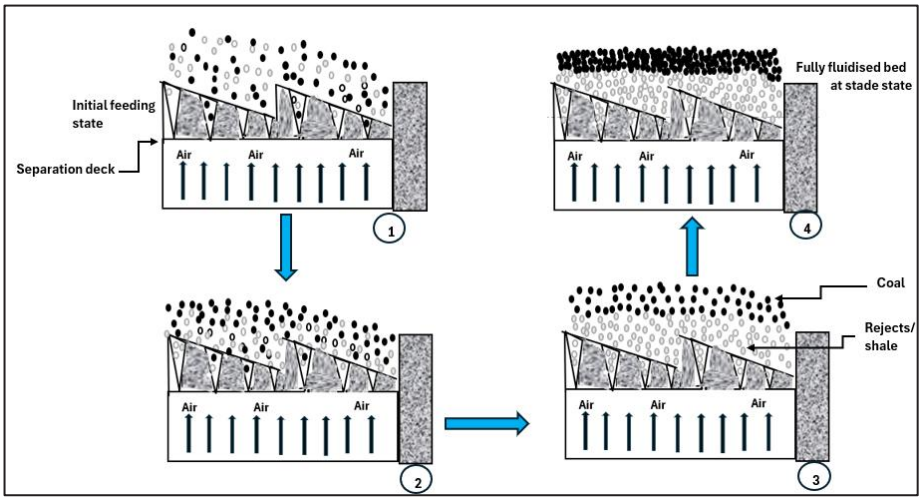

Fig. 3. Fluidized bed of air separation

The collection of products all depends on the type of separation used, which would differ by how the separating deck is angled seen in Figure 4. The segments and line lifters can be seen in Figure 4. Depending on the angle of the separation, the product is collected, and shale is collected as discard as seen in Figure 5.

Due to nature of the coal in South Africa, Genet Minerals Processing developed the Air Plant to create a higher separation force on the coal. The middlings material is then circulated to cater for the potential misplacements that could occur during separation.

Fig. 4. Air Plant separation bed

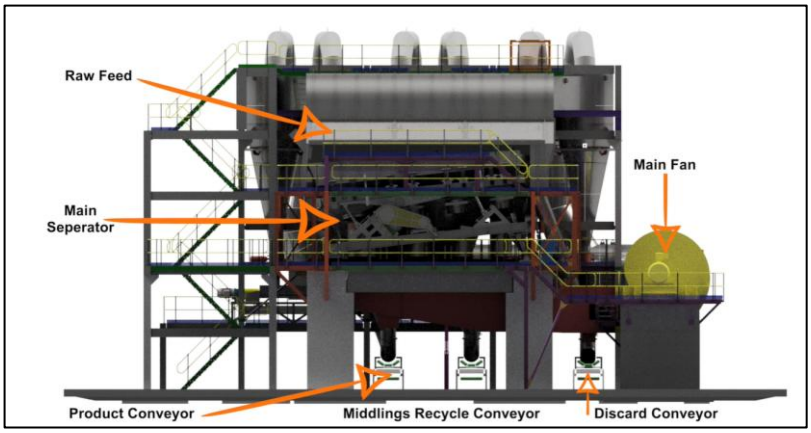

Fig. 5. Illustration of the Air Plant separation

2.2 Air Plant performance results

An efficiency test campaign was performed at Klipfontein during Aug-Sept 2024. Feed, Product and Discard of the Air Plant were sampled and analyzed in the certified laboratory for washability and particle size distribution. During the sampling period all Air Plant settings were noted and recorded. The samples were taken at 7.5 minutes interval over a period of 1 hour. Particle size distribution test was done on the ROM* and Feed to Plant samples to determine the ratio of percentage of fines fed into the Air Plant.

The particle size distribution was tested with fractional calorific value (CV) and Ash content. The results depicted in Table 2 and Table 3 show that the unprocessed fines of -12mm are around 25% of the ROM. The 25% of ROM regarded as fines is of good quality of 29.8-32% ash content is later combined with the processed product from the Air Plant. The combined processed coal and processed product from the Air Plant meets the domestic market grade specifications.

Table 2. ROM PSD, CV & Ash

PSD Fraction	Mass(kg)	%	ASH	CV
+50mm	39.6	40%	49.4	14.77
+40mm	5.2	5%	27.1	22.07
+30mm	7.7	8%	31.0	20.26
+25mm	4.9	5%	31.1	20.29
+20mm	7.5	8%	29.3	21.14
+15mm	5.6	6%	28.9	21.22
+12,5mm	4.1	4%	28.7	21.13
+6,3mm	11.0	11%	28.5	21.24
+3mm	4.7	5%	30.5	20.41
+1mm	5.4	5%	30.2	20.81
-1mm	4.4	4%	32.1	19.22
	100	100%		

* ROM- Run of Mine

Table 3. Feed to plant PSD, CV & Ash

PSD Fraction	Mass(kg)	%	ASH	CV
+50mm	3.6	4.6%	30.4	21.19
+40mm	8.6	11.0%	36.4	17.96
+30mm	13.0	16.6%	29.8	21.24
+25mm	6.5	8.3%	37.4	17.24
+20mm	7.7	9.8%	37.6	18.02
+15mm	10.7	13.7%	36.7	18.22
+12,5mm	6.3	8.0%	42.2	16.12
+6,3mm	4.4	5.7%	30.5	17.79
+3mm	7.6	9.7%	33.5	18.36
+1mm	1.5	1.9%	33.2	18.55
-1mm	4.5	5.7%	34.1	18.36
-1mm adjusted	3.9	5.0%		
	78.27	100%		

In the event where the fines are of high ash content, the fines are stockpiled separately as per Figure 2 to avoid contamination of the product sent to domestic grade. In other instances, when economically proven, a sweetener is added to the combined fines and Air Plant product to meet the domestic grade specifications.

The +8mm; -50mm is fed into the Air Plant for processing. The feed consists of 75% fraction of the ROM. The sampling campaign shown in Table 4 shows a raw feed of 34.1% ash content. The washability test includes proximate analysis as per (ASTM, ISO & AS)† standards [5]. Proximate analysis is analysis done on coal to determine the moisture content, volatile matter, fixed carbon and ash content.

Table 4. Typical washability test of feed to the Air Plant

Cumulative								
Density	**Mass kg**	**Yield %**	**CV MJ/kg**	**Inherent Moisture %**	**Ash %**	**VM %**	**F.C %**	**T.S. %**
F1.30	33.6	0.3	29.1	3.2	9.9	32.2	54.7	0.2
F1.35	33.1	2.5	28.6	3.1	11.5	31.6	53.8	0.2
F1.40	32.1	5.3	28.4	3.1	12.1	30.9	53.9	0.3
F1.45	30.9	13.6	27.4	3.0	14.7	29.6	52.7	0.3

† ASTM – American Society for Testing and Materials
ISO- International Organization of Standards
AS- Australia Standards

F1.50	27.5	24.4	26.8	3.0	16.5	28.0	52.5	0.4
F1.55	22.9	38.1	25.9	3.0	18.5	26.7	51.8	0.4
F1.60	17.2	51.3	25.0	3.0	20.7	25.6	50.7	0.4
F1.65	11.7	59.9	24.3	2.9	22.1	24.9	50.0	0.4
F1.70	8.1	69.0	23.6	2.9	23.8	24.2	49.1	0.5
F1.75	4.3	75.3	23.0	2.9	25.1	23.7	48.2	0.5
F1.80	1.7	79.3	22.7	2.9	26.1	23.5	47.6	0.5
F1.85	2.1	80.2	22.6	2.9	26.3	23.4	47.4	0.5
F1.90	3.5	83.6	22.2	2.9	27.2	23.1	46.8	0.5
F1.95	4.8	86.7	21.9	2.9	28.1	22.9	46.1	0.5
F2.00	5.6	88.7	21.6	2.8	28.9	22.7	45.5	0.6
S2.00	10.3	100.0	19.5	2.7	34.1	21.5	41.7	0.9

‡

The Air Plant d50, cut point, shows at 1.99 relative density. The partition factors are not as high as that of dense medium processing as seen Table 5. The ash balance yield is calculated at 82.7% and discard 17.53%. The theoretical yield from the Feed washability data shows a 90.92% achievable for 29.9% ash content. The organic efficiency calculated:

$$\frac{Product\ Yield}{Theorectical\ Yield} x\ 100$$

$$\frac{82.47}{90.75} x100 = 90.8\%$$

The near dense material is 17.8%, a reasonable and acceptable amount of separation. Showing 7.37% of sinks in float and 10.35% of floats in sinks. A composite sample of the weekly discard is taken to laboratory for washability test. Over the period of 10 months the misplaced product into the discard ranged between 8-10%.

Table 5. Efficiency data

Reconstituted Feed							
RD	**% Weight**		**% of Feed**		**Calc Feed Recon**	**Mean RD**	**Partition Coeff**
	Product	**Discard**	**Product**	**Discard**	**%**		
1.30	0.3	0.3	0.3	0.1	0.3	1.30	84.1
1.35	1.6	0.6	1.3	0.1	1.4	1.33	91.9
1.40	3.2	1.0	2.5	0.2	2.8	1.38	94.0
1.45	8.0	1.9	6.6	0.3	6.9	1.43	95.1

‡ CV-Caloric Value
Ash – Ash content
VM- Volatile Matter
FC -Fixed Carbon
TS – Total Sulphur

1.50	12.7	3.6	10.5	0.6	11.1	1.48	94.3
1.55	14.9	4.8	12.3	0.8	13.2	1.53	93.6
1.60	15.8	6.9	13.0	1.2	14.2	1.58	91.6
1.65	10.5	5.5	8.7	1.0	9.6	1.63	89.9
1.70	9.2	5.8	7.6	1.0	8.6	1.68	88.2
1.75	6.8	3.2	5.6	0.6	6.2	1.73	90.8
1.80	3.1	3.5	2.5	0.6	3.2	1.78	80.4
1.85	1.8	1.8	1.5	0.3	1.8	1.83	82.4
1.90	0.7	0.3	0.6	0.1	0.6	1.88	91.1
1.95	1.6	0.8	1.3	0.1	1.5	1.93	90.3
2.00	1.6	2.0	1.4	0.4	1.7	1.98	79.2
2.20	8.1	57.8	6.7	10.1	16.8	2.10	39.8
	100.0	**100.0**	**82.47**	**17.53**	**100.0**		

The EPM was calculated to be 0.082 according to the partition curve concept of developing efficiency from the data [6]. The partion curve shown in Fig 6 shows that the cut-point density for Air Plant is high such that when performing washability high relative density points should be considered in the laboratory. The EPM value of 0.082 shows a significant improvement over the previous test work conducted at Middlekraal in 2012, found to be around 0.306 [7].

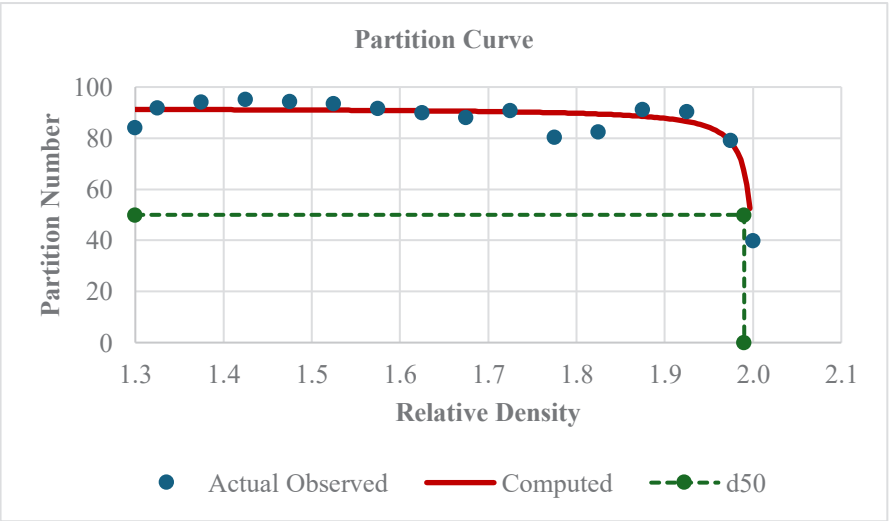

Fig. 6. Partition curve - Air Plant Aug 2024

The results show that the Air Plant performance is effective in upgrading coal with 34% ash content to 29% ash. Over the years a generic 5-7% lowering of ash content has been observed in the Air Plants currently in operation in the Witbank region.

Table 6. Air Plant performance

Air Plant Performance		
	UOM	**Value**
Feed Ash	%	34.14
Product Ash	%	29.82
Discard Ash	%	54.51
Product Yield	%	82.47
Discard Yield	%	17.53
D50		1.9900
Epm		0.0827
Theoretical yield	%	90.7
Organic Efficiency	%	90.8
NGM	%	19.78

Data compiled over 12 months of the Air Plant operation shows that at a feed of 36.9% ash content the Air Plant will beneficiate coal to 29% ash content, thus 7% upgrade on the fed material as per Fig 7 and Fig 8. It is important to note that the Air Plants primarily removed stones/discard. The higher the unwanted stone in the feed, the higher the upgrade of the ash content in the coal.

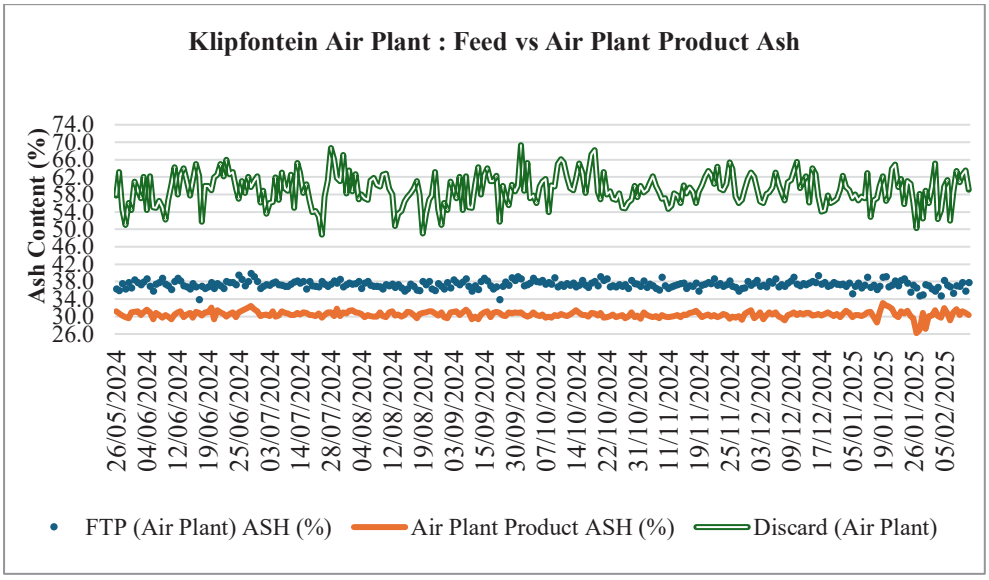

Fig. 7. Klipfontein Air Plant ash

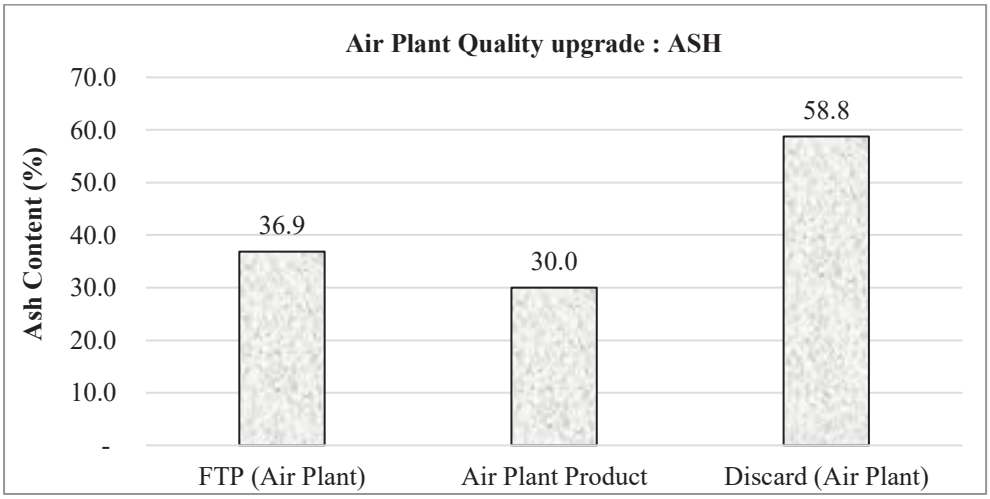

Fig. 8. Air Plant ash upgrade

Data also shows that the Air Plant can improve the sulphur content of the coal. Fig 9 and Fig 10 shows data collected over 12 months of a feed of 1.03% total sulphur upgraded to 0.58% total sulphur, a significant upgrade for both domestic and export coal grades.

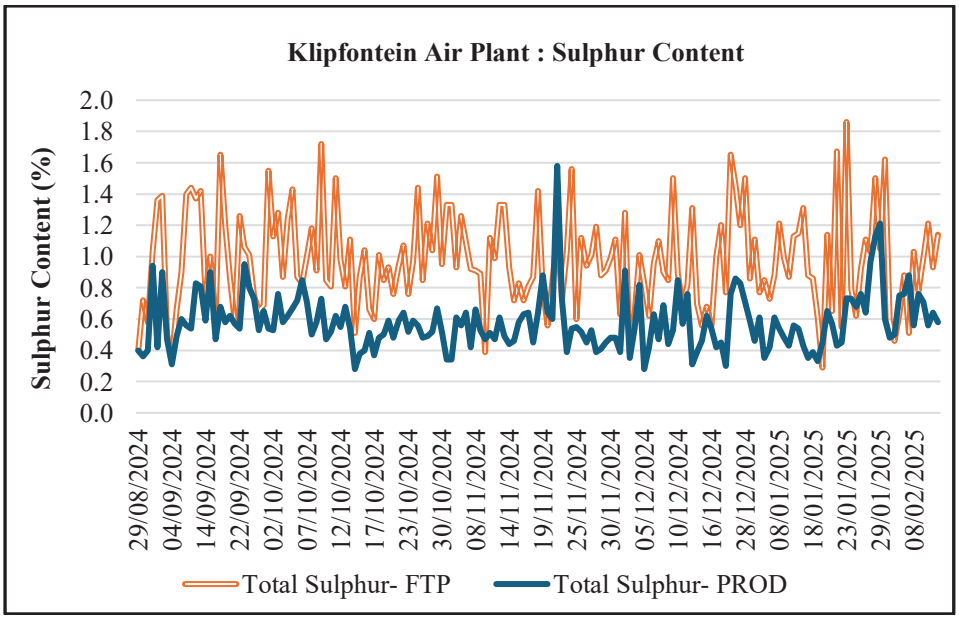

Fig. 9. Klipfontein Air Plant sulphur

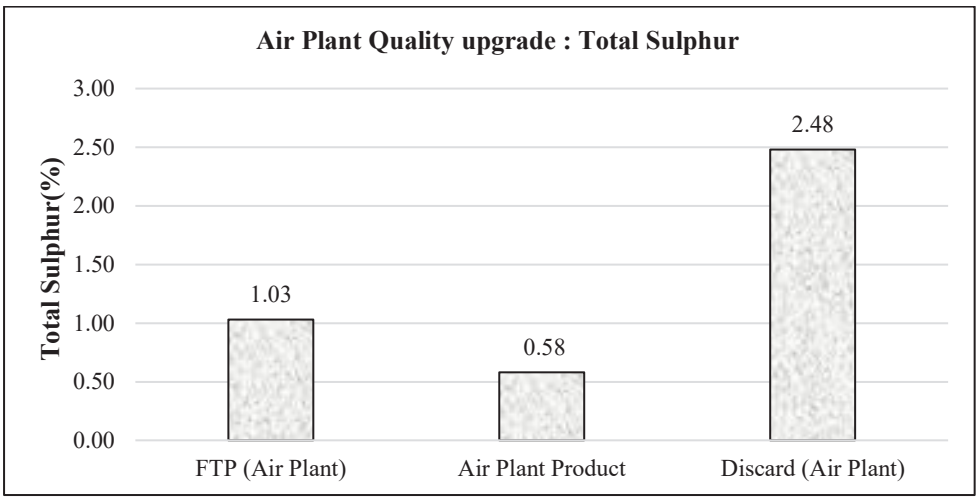

Fig. 10. Air Plant total sulphur upgrade

Abrasive index is also upgraded by the Air Plant. A feed of approximately 521 mg/kg of metal is upgraded to 405mg/kg and the discard is at 1335 mg//kg as seen in Fig 11 and Fig 12.

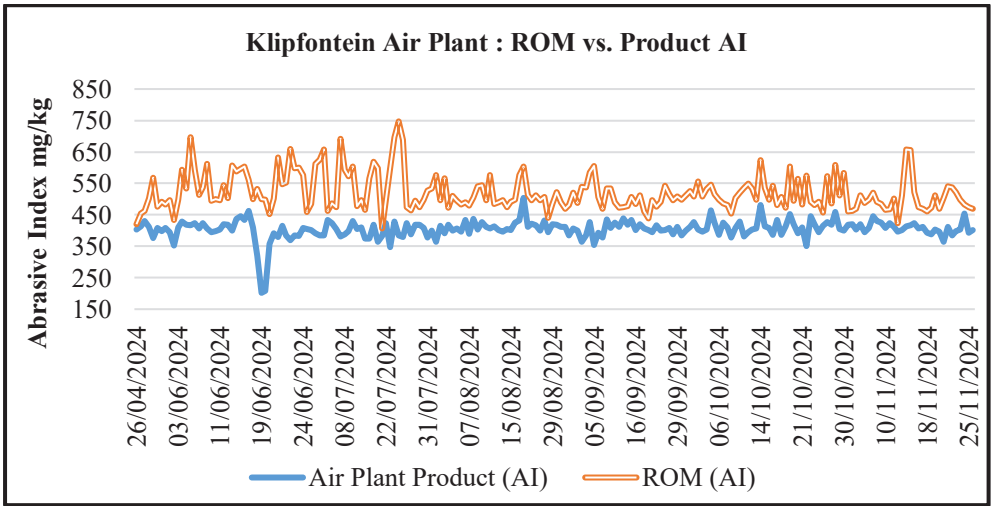

Fig. 11. Klipfontein Air Plant abrasive index

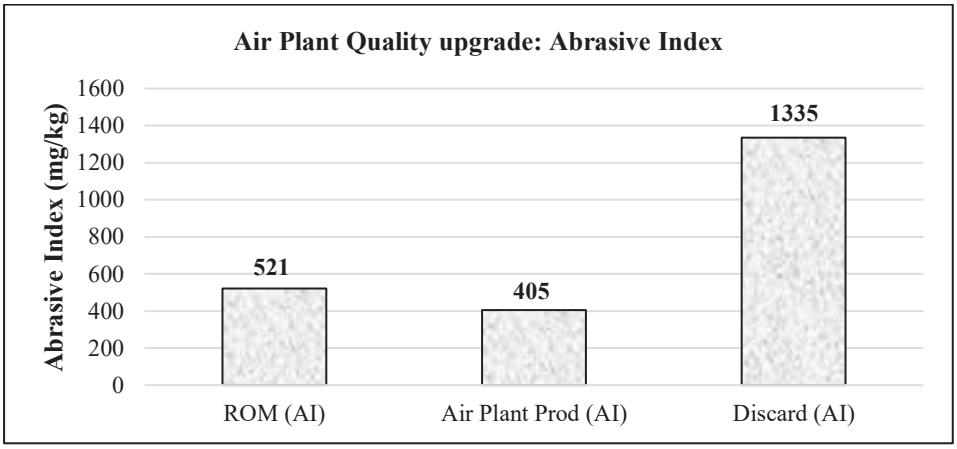

Fig. 12. Air Plant abrasive index upgrade

3. Research and development

There are coal reserves that have the -8mm fraction with very high ash content which if directly added to the Air Plant product would contaminate the final product sent as domestic grade. There is a strategic blending process to manage the amount of fines added to the final product in this case. Table 7 shows a typical example of the case where the fines(-8mm) have high sulphur content which cannot be added or combined with Air Plant product for final dispatch.

Table 7. Typical plant PSD, CV & ash

Fines 10mm PSD	Ash content (%)	Calorific value (MJ/kg)	Total sulphur (%)
GENET fines +10mm (27/11/2024)	34.2	19.0	1.2
GENET fines +8mm (27/11/2024)	28.6	21.2	1.2
GENET fines +6mm (27/11/2024)	30.7	20.0	1.4
GENET fines +3mm (27/11/2024)	31.7	20.0	2.0
GENET fines +1mm (27/11/2024)	28.3	21.0	1.4
GENET fines +63 µm (27/11/2024)	28.1	21.0	1.8
GENET fines0.5 µm (27/11/2024)	26.9	21.7	1.4
GENET fines 212 µm (27/11/2024)	26.2	21.3	1.5
GENET fines 106 µm (27/11/2024)	28.1	20.9	2.0
GENET fines 75 µm (27/11/2024)	27.5	21.0	1.8
GENET fines 53 µm (27/11/2024)	29.1	20.7	1.9
GENET fines 45 µm (27/11/2024)	30.9	20.1	1.9
GENET fines -45 µm (27/11/2024)	31.2	20.0	1.9

There is potential value to be unlocked out from beneficiating fines. A further study and trial of the Air Plants is well recommended to beneficiate the fines of less than 8mm particle sizes. Genet Mineral Processing has small scale plant to beneficiate 0 X 50mm particle sizes. The plant is in the research stage to beneficiate both fine and coarse particles.

Fig. 13. Genet Mineral Processing 0x50mm plant in construction (April.2025)

4. Conclusion

Over the decade Air Plants technology has widely grown in the coal processing industry. The Air Plant technology has proven to be successful in destoning coal to meet the specifications required or desired for the industry. The Air Plant has shown an upgrade in ash content by 5-7%. Total sulphur upgrade of 0.5% with improvements on abrasive index of approximately 116mg/Fe. The efficiency test performed shows an epm of 0.082 with organic efficiency calculate to 90.8%. The efficiency test done on the Klipfontein Air Plant shows the air plant equipment has good efficiency capabilities improve ore grade to domestic market. The Air Plant technology is well recommended to destone, improve coal qualities and eliminate the high usage of water for beneficiation.

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