OPERATIONAL PAPER

THE BENEFITS OF INSTALLING MUD BELT FILTERS IN THE SIMUNYE SUGAR MILL IN THE 2024/25 SEASON

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Abstract

The extraction of pol from sugar cane mud through filtration is a fundamental process for boiling house recovery of a sugar mill. The Royal Eswatini Sugar Corporation's Simunye mill had been experiencing high losses of pol in the filter cake between 2020 to 2022, reaching a maximum of 4.76%. The mill had four rotary Dorr Oliver filters at the mud filtration station. As part of its continuous improvement initiatives, an investigation was undertaken, with the objective of arresting the high losses in pol through equipment optimisation and process improvements.

Before the start of the 2024/25 crushing season, the mill procured and installed two Córdoba-type mud belt filters to replace two Dorr Oliver filters. The combined capacity of the belt filters is 400 tons of filter cake per day, i.e. 200 t/day for each unit. The filters were sized based on a filtration area of 0.3 m^2/per ton of cane. By the end of the crushing season, the mud belt filters decreased the filter cake pol losses by close to 40% and reduced the moisture % filter cake by 3%. This improvement resulted in improved boiling house recovery of the mill, as well as the reduction of filter cake transportation costs by more than 60% of the previous season.

However, the high volume of wash water from the belt filters is a challenge. This has had a serious impact on the crush rate at the mill, due to the increased hydraulic loading on the evaporators. Currently the mill installed a wash water recirculation tank, which has improved the crushing rate.

Keywords: boiling house recovery, rotary vacuum filters, mud belt filters, moisture % filter cake, wash water recirculation tank

Introduction

The Simunye sugar mill, one of the three cane mills in Eswatini, produces about one-third of the country's sugar. The mill has relied on conventional Rotary Vacuum Filters (RVFs) for the recovery of sucrose in mud filtration. For decades, the traditional RVFs have proven to be robust and efficient in maximising the recoveries. The mill had previously installed four rotary vacuum filters with a capacity of 0.4 m^2 per ton of cane. However, the limitations of the RVFs have driven the Simunye factory to consider alternatives for optimising sugar recoveries. The RVFs failed to cope with the high mud volumes, due to the high rainfall between 2020 and 2022, and this resulted in high sucrose losses in the filter cake. The filter cake pol was as high as 4.76 % and the moisture % filter cake was above 70%. The high rainfall was a result of the La Niña triple dip, which affected the southern African region for three consecutive years, from 2020 to 2022.

Ng Lung Kit *et al*. (2023) also highlighted the fact that the clay soil type exacerbated the operating conditions at the filter station. The cane fields of the Simunye estate are dominated by clay soil, which is generally characterised by its low permeability. The resultant filter cake is not easily scraped and requires manual scraping by the filter operators. During wet conditions, the resulting high volumes of mud affected the throughput from 440 to 397 tons cane per hour (tch), which led to an extended crop season of 39 weeks (Lung Kit *et al*., 2023). Alternative technologies, such as the decanter, were considered by the mill, but proved to be unsuccessful. The decanter operates by using centrifugal force for solid-liquid separation. The decanted juice is collected continuously through a central opening. The settled solids are discharged by a scroll towards the narrow end of the decanter. One of the advantages of the decanter is that it has a high solids retention, which means that juice clarification improves, due to less solids recirculated. In addition, the moisture and pol of the filter cake is considerably less, when compared to the rotary vacuum filters (Joshi *et al*., 2016). However, one of the disadvantages of the decanter is the high usage of flocculant for mud preparation.

The solid bowl decanter centrifuge (prototype 450 mm × 1100 mm) was loaned to the Simunye mill in 2018.The decanter operates at a high speed of about 2000 rpm, with a design gravity factor of 1000. The recoveries at the filtration station improved, and the moisture % filter cake was reduced to 60.2 %, compared to 73.1% in the RVFs. In addition, the usage of bagacillo was no longer needed in the mud decanter. The only chemical cost was the high dosage of various flocculants on the feed, namely 23 ppm to 50 ppm. Nonetheless, the high operational costs were not economical for the mill, and hence the decanter was discarded (Ng Lung Kit *et al*., 2023).

Vacuum Press Filters (VPFs), also known as mud belt filters, were also considered by the mill. The first reported studies of belt filters in sugar industry were at Maidstone sugar mill in South Africa. The results of the pilot scale plant were positive, even though this had little influence on the sugar industry (Kruger, 1984). In 2009, the Bois-Rouge sugar (refinery) mill in Reunion upgraded the filtration with a single belt filter from the manufacturer, Technopulp. Later, in 2010, an additional two vacuum belt press filters were installed by the Bois-Rouge mill, due to the positive impact of the first unit that had been installed (Petit, 2014). However, the low filtrate brix that was recycled into the raw mixed juice had a serious impact on the energy balance of the mill (Petit, 2014). Despite this, the Bois-Rouge mill reported good recoveries, due to the belt filters. Hence, the Simunye sugar mill investigated the possibility of installing mud belt filters to replace the conventional rotary vacuum filters.

In 2024, the Simunye mill installed two Córdoba vacuum press filters to solve the challenges of the high pol losses at the mud filtration station. The performance and robustness of the belt filters has vastly improved the mill recoveries at the filter station; decreasing disposal costs of filter cake; reducing electricity and maintenance costs. However, the mill also had issues with low filtrate brix (screen wash water) which could not be sent back for imbibition due to high traces of pol, was directed to the weighed juice tank. Similarly to Bois-Rouge mill, this impacted the mill crush rate, resulting in reduced throughput for the whole of the 2024/25 crushing season. As a quick solution, the mill designed a wash water recirculation tank that had a high-water retention, to allow for the settling of the suspended mud in the wash water. Only the settled mud is automatically purged from the recirculation tank to the weighed juice tank. This set-up was commissioned during the last off-crop and significant results have been achieved, with the mill now operating at its design capacity.

Operation of mud belt filters at the Simunye mill

The mud-belt filters (from the manufacturer Córdoba) were installed at the beginning of the 2024/25 crop season. The belt filters replaced two rotary vacuum filters (with a total filter area of 136 m^2). The two remaining rotary vacuum filters are currently not in use, but have been kept as a contingency, in case of breakdown on the belt filters. In total, the mill had four rotary vacuum filters with filter area of 167 m^2 before installation of the two Cordoba filters. The production capacity of the mill is 10 560 tons of cane per day. Each belt filter is specified at a minimum capacity of 200 tons of filter cake/day.

Figure 1 below shows the process flow diagram of the belt filter installed in Simunye sugar mill.

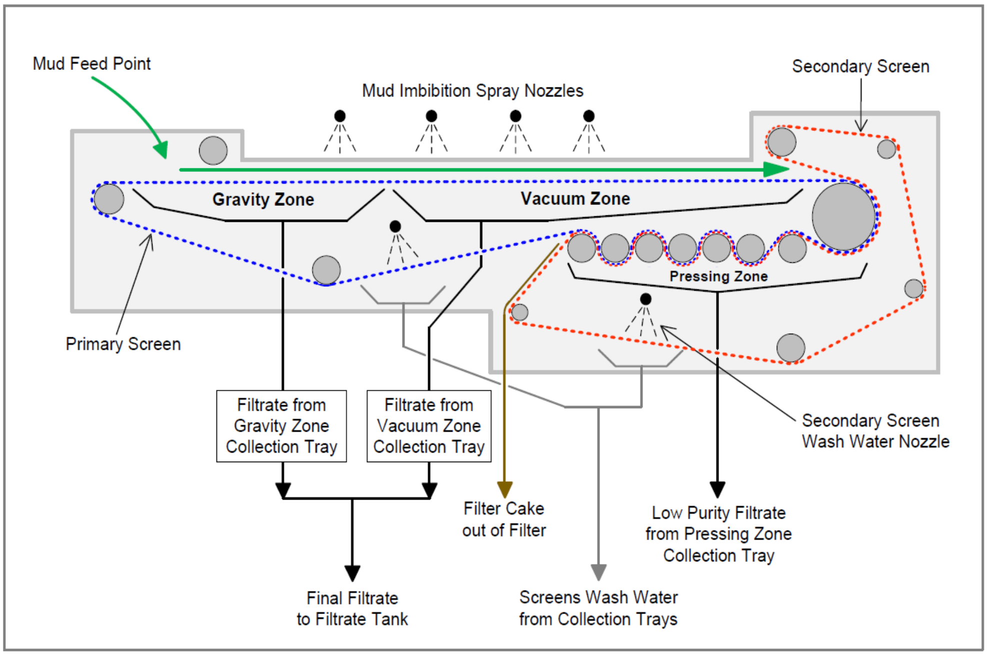

Figure 1. Process flow diagram of a belt filter.

Mud pumps

Mud is pumped to the dynamic mixer, which feeds the two belt filters, by one of the two installed progressive cavity pumps on the variable speed drive (VSD), each having the capacity to deliver a maximum flow rate of 60 m^3/hr. One pump is on standby. A milk of lime is dosed at the delivery side of the pumps.

The lime, which is drawn from the existing lime tank, is adjusted in a dedicated filters' lime preparation tank to a concentration of 5º to 7º Baumé, as recommended by the equipment manufacturer. The lime dosing pumps are on the VSD to allow for controlled lime dosing.

Mud preconditioning

The limed mud is preconditioned in the dynamic mixer by the addition of a polymer. The mixer has a horizontal stirrer/agitator for the homogeneity of the polymer in the mud. This mixer has no steam injection points, since steam is added to the old mud mixer for the RVFs.

The polymer that is currently in use is LT27 AG (anionic high molecular weight polyacrylamide flocculant), which was recommended by the filter manufacturer. The polymer is prepared in the polymer preparation tank to a concentration of 0.1% on a w/v basis (1 kg of polymer per m3 of water). The mixing of the polymer salt/powder and water is done through air sparging. This was chosen over a conventional agitator mixer, to maintain the quality of the polymer.

Once the polymer has been mixed and matured, it is transferred to the polymer dosing tank by gravity. From the dosing tank, the polymer is pumped to the dynamic mixer by a dosing pump on the VSD, to control the feed. This pump is also a progressive cavity type that is suitable for pumping sheer-sensitive polymers.

The quality of the preconditioned mud influences the performance of the mud belt filters. The higher the concentration of solids, the less residual sucrose there is in the filter cake, and the less wash water is used. Overdosing of the polymer (and lime) is not only uneconomical, but it can affect the performance of the filters. Correctly 'flocculated' mud improves the drainage in the filter's feed supply box.

The concentration of the polymer dosed into the mud mixer is controlled between 2.5 to 5 ppm. The adjustment of the polymer concentration is made to achieve the required solids concentration of > 45% in the mixer. On the other hand, the pH of the mud is carefully monitored between 7 and 9 for the mud quality and the preservation of the belt screens.

The ratio of mud, lime and polymer mixture is achieved by adjusting the speed of the pumps for the three respective process streams on the VSDs through the Distributed Control System (DCS) interface, since the pumps are classified as positive displacement pumps. However, maintaining a balance of the three for a sustained period is difficult, due to the varying process conditions, such as the concentration of mud from clarification. Therefore, regular visual inspections are carried out at the mud feed box at the end of the filters mud feed pipes from the dynamic mixer (the filter supply box in Figure 2).

The use of bagacillo in the mixer is currently limited; it is not required, since the preconditioning of the mud with polymer and lime improves the porosity of the filter cake.

As the preconditioned mud enters the top of the filters from the feed box, it is spread across the width of the belt screens by a homogeniser (levelling) roller, to maintain a uniform cake thickness across the belt's screen surfaces, as seen in Figure 2.

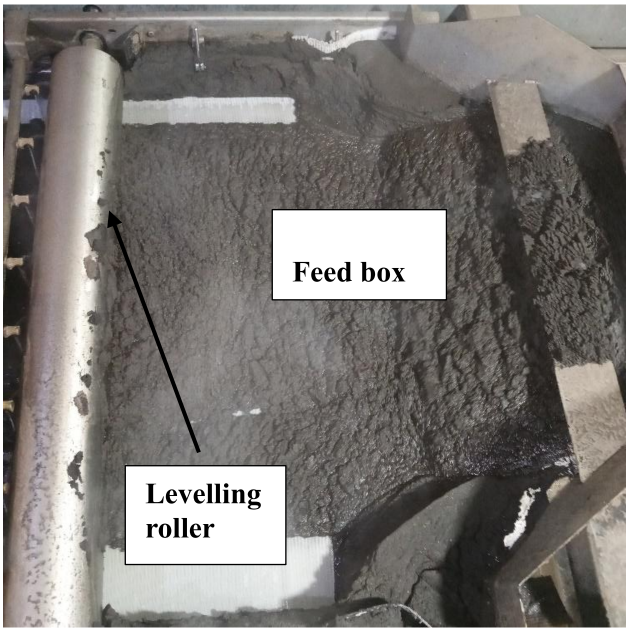

Figure 2. Feed box of the mud belt filter.

Primary and secondary screens

Two screen belts are used in the belt filter, namely, the primary and secondary screens. The screen sizes are shown in Table 1. The speed of the belts is adjusted, depending on the pol % filter cake and clarifier mud levels. The primary screen transfers the mud from the feed area through to the vacuum box of the filter. The filtrate collected is the high brix filtrate (gravity filtrate) in the feed box. This filtrate is almost similar to the clear juice obtained from clarification. The turbidity of the gravity filtrate is dependent on good mud preconditioning. The vacuum box collects the second filtrate in the vacuum zone before the mud is transferred to the secondary screen. The primary and secondary screens intersect between a series of rollers, to press the last remaining filtrate (press filtrate) in the filter cake. After pressing the filter cake, it is discharged into a filter cake discharge conveyor. Scrapers are found below the manifold of the unit to remove any filter cake that sticks to the screens.

The screens are washed by using pressurised water (5 bar for the Simunye mill) at the sections, after separating at the discharge of the filter cake. This wash water gravitates to a wash water tank.

Table 1. Screen sizes for belt filters.

Screen	Size
Primary belt	1400 ×13400 mm
Secondary belt	1400 × 10500 mm

Figure 3. Clear juice from clarifiers (two test tubes on the left) and gravity filtrate (test tubes on the right).

Table 2 compares the brix, purity and reducing sugars ratio between the clear juice and filtrate for the Simunye mill.

Table 2. Comparative data for clear juice and filtrate from the mud-belt filters.

	Clear Juice	Filtrate	Mixed Juice
Brix	13.4	7.6	13.8
Purity	87	85.2	87.63
RSR	5.1	4.4	-

The belt filter is operated at maximum speed to counter the high clarifier mud levels during wet conditions, even though this increases the filter cake pol losses. The mill has planned to install another belt filter to increase the filter station's capacity and to reduce the pol loss in the filter cake during high-rainfall seasons.

A photograph (Figure 4) of the belt filters station with the dynamic mixer and vacuum generators is also shown below:

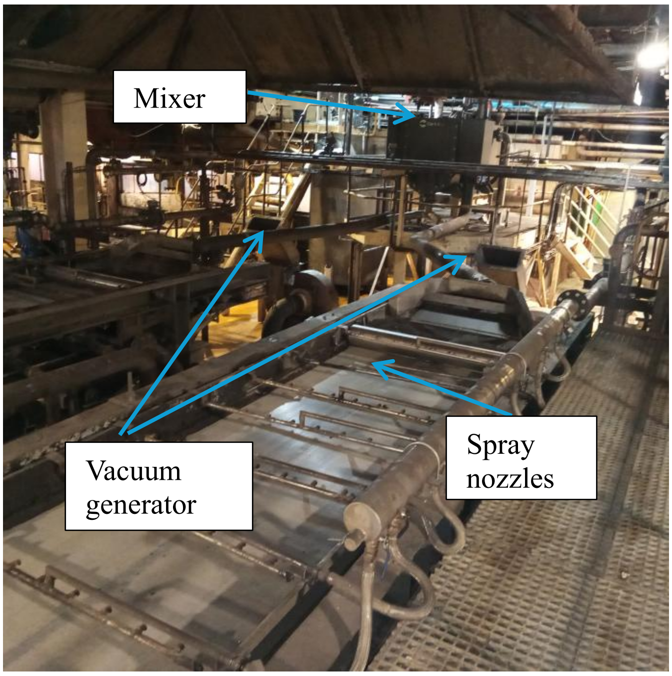

Figure 4. The mud belt filter station at Simunye sugar mill.

Imbibition water and screen wash system

Hot wash water is added in the vacuum zone to increase recoveries of sucrose through a series of nozzles. The wash water is pumped at a high-pressure (5 bar) with a centrifugal pump from the mill supply tank. The water is filtered through a water filter before pumping it to the distribution manifold of the filters. About 15 to 30 m^3/hr of wash water is used on the filter cake for each unit. Separate nozzles are also used for cleaning the screens, with one set for each screen. The cleaning nozzles deliver 10 to 15 m^3/hr of water to the screens. The total water usage on the belt filters is 25 to 45 m^3/hr.

The wash water for the belt is stored in a wash water tank, before recycling it back to the weigh juice tank. The mill had attempted several options to manage the wash water from the screens, and reduce filtrate returns to the weigh juice tank, including:

- to use the water as imbibition water for the milling tandem; and
- to use the wash water in the dynamic mixer to precondition the mud, instead of using flocculant.

Both attempts were unsuccessful, due to the residual pol in the wash water. The first option increased the pol factor of the mill, as the water had traces of sugar in it. The second option increased solids concentration in the mud mixer, which affected the filtration operation, as the mud was very ‘slack’ and flooded the drainage table. Eventually, the mill recycled the wash water to the weighed juice tank.

Vacuum generator

The filter unit requires a vacuum of -15 to -20 kPa(g) that is generated with a vacuum generator (centrifugal fan type). The generator is linked to the manifold of the unit (below the vacuum box). Each unit also has a vacuum receiver that connects to the final filtrate tank.

Troubleshooting the vacuum loss in such a unit is less complex. The loss of a vacuum in the belt filters is mainly affected by a high solids concentration in the final filtrate tank. Applying a vacuum on the belt filter reduces the flooding on the screens.

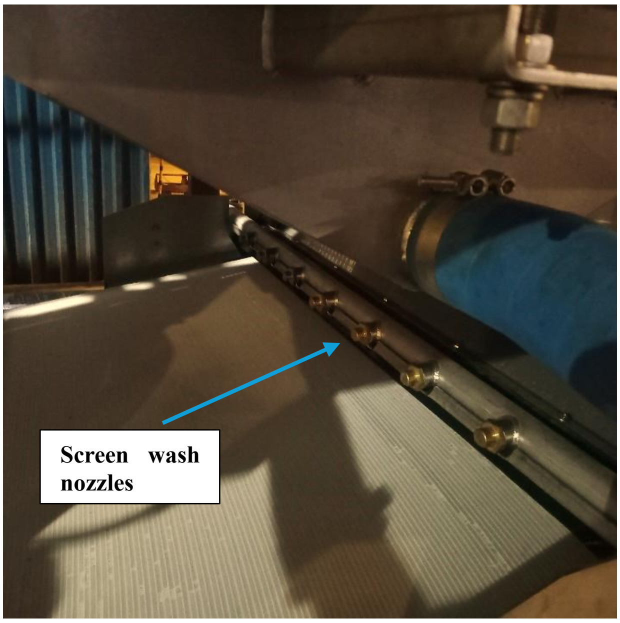

Figure 5. Primary screen wash water spray nozzles.

Final filtrate tank

The gravitational, vacuum and press filtrate are collected in the final filtrate tank. The design of the tank is such that it has an overflow section for solid-liquid separation before the filtrate is pumped to the weighed juice tank. The solids are drained from the tank on stop-days, as this may cause clogging in the barometric columns and it may compromise the vacuum system. Once the vacuum of the system is compromised, the filter cake porosity is reduced, and the drainage on the table is very poor. If this happens, the filter station is stopped immediately, as pol is lost in the filter cake.

The operating conditions of the mud belt filter

The operating conditions of the mud belt filter are summarised in Table 3 below**:**

Table 3. Operational parameters for the mud belt filters.

Parameter	**Target Value**	**Simunye (Typical actuals)**
Brix of filtrate juice	>7.0	8.2
pH mud in dynamic mixer	7 to 9	8.5
pH of the imbibition water	> 7.0	8.0
Cake thickness	8 to 12 mm	10 mm
Water hardness for polymer solution	< 30 ppm	18 ppm
Mud temperature	> 85 ºC	90 ºC
Minimum air pressure for operation under load	>5.0 bar	5.0 bar

The benefits for the 2024/25 crushing season

Data was gathered from factory balance software for the 2024/25 crop season. The data for the 2023/24 crushing season was sourced from SAP system that had been in use the previous season. The Key Performance Indicators (KPIs) of interest included the filter cake pol, moisture % filter cake, filtrate brix, Overall Recoveries (OR) and the Boiling House Recovery (BHR). The data were analysed on Excel, by using statistical methods.

Filter cake pol

The mill target pol for filter cake is specified at 1.5%. The data for the filter cake pol were gathered for the 2023/24 and 2024/25 crushing seasons. The average pol % filter cake for mud belt filters is relatively closer to the target pol of 1.5%. On analysis, higher sucrose recoveries are anticipated from the mud belt filters.

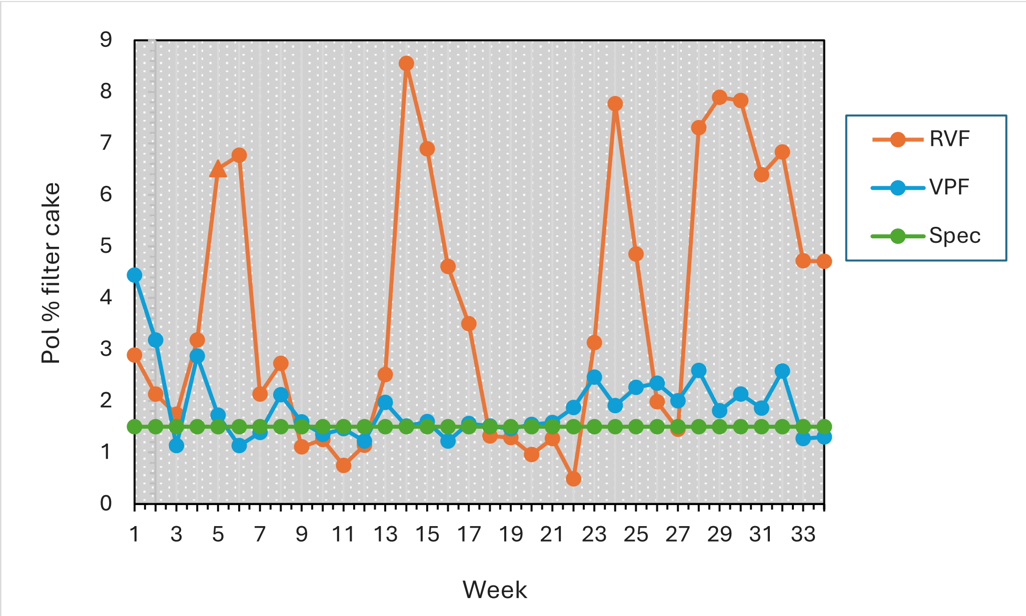

Figure 6. Weekly filter cake pol for crop RVF (2023/24) & VPF (2024/25).

Filter cake moisture

The average weekly moisture of the Oliver filters ranged between 63 and 78%. Compared to the mud belt filters the average was between 60.9 and 73.3% from the trends in 2024/25. The trends, as depicted in Figure 7 showed that there was a significant improvement with the belt filters. The moisture decreased by 3% from the previous season. The lower limit and upper limit for the moisture content was 65% and 70%, respectively. The reduction in moisture content of the filter cake, decreased filter cake disposal costs which significantly benefitted the business. The trend is shown in Table 5 below.

Table 4 also shows the season-to-date figures of the mill for moisture % filter cake and pol % filter cake.

Table 4. Summary of year-to-date values for parameters.

Year	Moisture % filter cake	Pol % filter cake
2023/24	72.2	3.8
2024/25	69.4	1.9

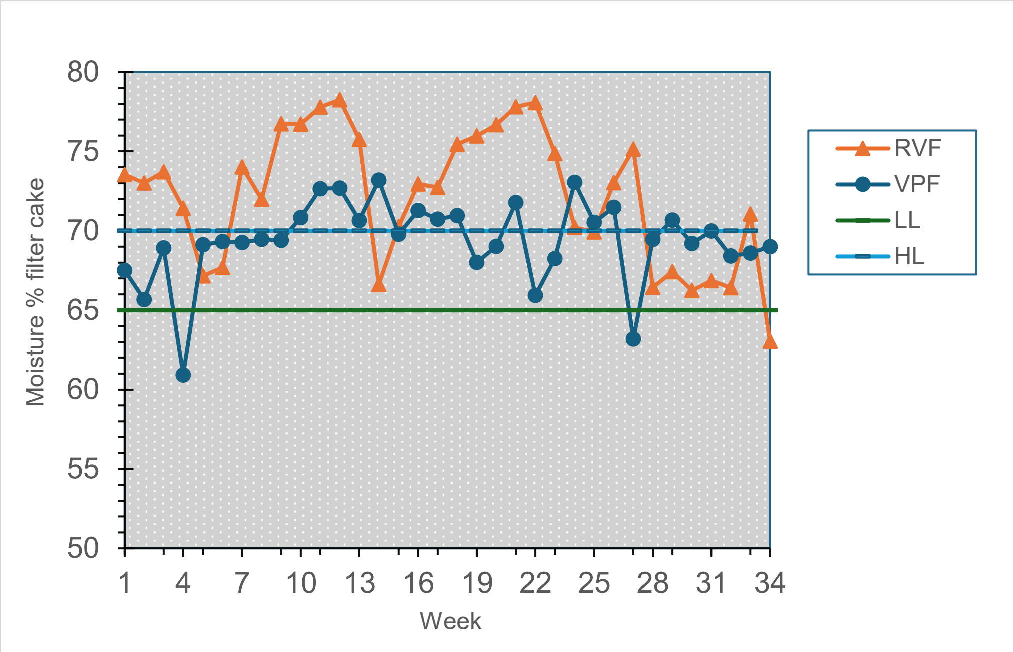

Figure 7. Weekly averaged moisture % filter cake for 2023/24 and 2024/25 seasons.

Filter cake disposal cost

In 2024/25, the mill saved 62.37% of the previous season's filter cake disposal costs. Table 5 below shows the transportation costs of the filter cake that were incurred in 2023 and 2024.

Table 5. Transportation cost of filter cake comparison between the filters for the 2023/24 and 2024/25 financial years (in Rand).

Month	2023	2024	Variance
April	370,350	176,651	193,698
May	898,557	526,734	371,823
June	701,484	169,315	532,169
July	791,222	168,824	622,398
August	1,142,553	255,041	887,512
September	651,304.	300,659	350,645
October	939,223	220,707	718,516
November	592,182	472,675	119,507
Total	6, 086, 875	2,290,606	3 796 268

Overall recoveries and boiling house recovery

The improvement in the filter cake pol has contributed to a better overall recovery and boiling house recovery for the mill. The effect of the drop in performance of the Oliver filters (in 2022 to 2023) on overall recovery and boiling house recovery is also shown in Table 6.

Table 6. Overall recoveries and boiling house recoveries for the Simunye sugar mill between 2022 and 2024.

Year	Boiling house recovery	Overall recovery
2022	86.57%	83.47%
2023	88.48%	85.22%
2024	90.76%	87.38%

Power savings and reduction in bagacillo usage

The belt filters are currently operated with no bagacillo. The additional bagacillo is available for power generation in the mill. Furthermore, the belt filters require less power for vacuum generation than the rotary vacuum filters.

Table 7. Installed power on vacuum and bagacillo usage.

	Rotary vacuum filters	Mud belt filters
Power required/installed on vacuum system	477 kW	150 kW
Total bagacillo [tons]	7 000*	Currently not in use

*Bagacillo usage from 2020 to 2023.

Improved hygiene and housekeeping

The Oliver filter station was prone to bacterial degradation, due to a drop in temperature in the mud boot (Ng Lung Kit *et al*., 2023). It was difficult to maintain good hygiene, especially during rainy conditions. As shown in Figure 8, the assistant filter operator is scraping the mud on the drum to improve the filter capacity. The filter cake spillage can be seen on the walkway grating between the Oliver filters.

Figure 8. Oliver filters in operation at Simunye sugar mill.

The effect of high filtrate returns

Throughput

The mud belt filters have filtrate returns as high as 82 m^3/hr, due to the high volumes of wash water for cleaning the screens. The mixed juice flow rate is normally 500 m^3/hr (mixed juice % cane of 115%) at the maximum crushing capacity of 440 tons of cane/hr for the mill. Hence, the maximum mixed juice flow to the clarifiers is 583 m^3/hr. The Simunye mill has two Dorr clarifiers that are designed for a maximum mixed juice flow of 560 m^3/hr. An additional 23 m^3/hr of mixed juice flow has been added, due to filtrate returns from the belt filters. The hydraulic loading increased in the evaporators, which resulted in a low syrup brix and a drop-in the crush rate during the 2024/25 crushing season.

The mill crush rate for the 2024/25 crushing season was 402 TCH, on average, against a baseline target of 440 TCH. On average, the mill stops amounted to 11.62 hours, due to the high volume of filtrate returning into the weigh juice tank. The total water usage on the mud belt filters is summarised in Table 8 below.

Table 8. Total water usage for the mud belt filters.

Description	Maximum Flow [m^3/hr]
Water in Lime	0.8
Water in Flocculant (and to clean the tank)	22.0
Wash water for filter cake	30
Belt wash water	30

The maximum total water usage on the mud belt filter is 82.8 m^3/hr. This implies that an additional 5.1 tons/hr of steam is required at the evaporator station, based on the quintuple effect.

Filtrate brix

The filtrate brix indicates that there is a high usage of water on the mud belt filters. A significant amount of the water is used for washing the belts, to prevent the clogging of the screens. For each screen belt, the spray nozzles can deliver between 15 and 30 m^3/hr of wash water, as mentioned earlier. This high water usage has increased the hydraulic loading on the evaporators, which caused a drop in the syrup brix and which, in turn, has had a negative impact on the crush rate.

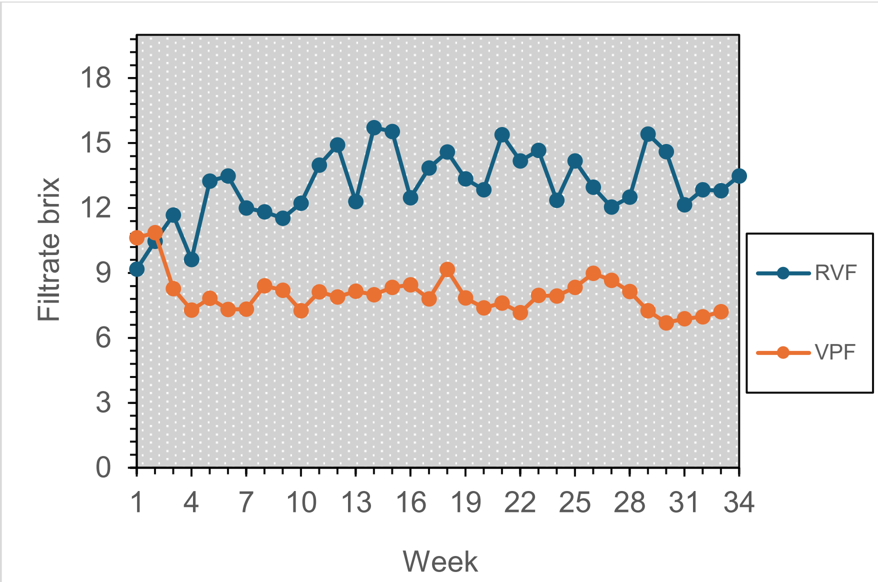

Figure 9. Filtrate brix for the belt and rotary vacuum filters.

Table 9. Comparison of the filtrate brix and wash index of rotary vacuum filters and mud belt filters (season-to-date).

Parameter	Rotary vacuum filters	Mud belt filters
Filtrate brix	13.1	8.0
Wash index	92.3	99.8

Although retention of solids is not considered by the mill in the analysis of the filtrate, the reported figures from the literature studies indicate high figures for the belt filters, in comparison to the conventional rotary vacuum filters (Petit, 2014). A high retention of solids benefits clarification and filtrate turbidity.

Increased cost and usage of flocculant

The belt filters require the addition of flocculant, to precondition the mud before filtration. This has increased the flocculant usage at the clarification and filtration station, and subsequently, also the operational costs of the belt filter station. Table 10 shows the data extracted from the 2024/25 season for Weeks 18 to 21.

Table 10. Weekly flocculant usage for clarification and the belt filter unit.

	Week 18	Week 19	Week 20	Week 21
Tons of cane crushed	66 694	59 941	57 829	66 096
ppm flocculant per ton cane[1]	3.4	3.8	4.3	3.8
ppm flocculant per ton cane[2]	5.3	5.8	5.2	4.5
Cost of flocculant R/ton cane[1]	0.35	0.39	0.45	0.39
Cost of flocculant R/ton cane[2]	0.65	0.71	0.64	0.55

[1]Without belt filter flocculant usage. [2] Includes clarifiers and filters.

Discussion

The results above show that the mill has benefited from the installation of the mud belt filters. This is because of the filter cake pol, which decreased significantly from 4.76 % during the La Niña period (2020 to 2023) to 1.91% in 2024. The figure is still marginally above the target of 1.5%, but it is expected to improve, since it was compromised during high mud-level conditions. The wash water for the screens and the filter cake were reduced to a minimum, especially during dry conditions, when recoveries were favourable. This was done to improve the mill crush rate by reducing the filtrate returns to the mixed juice tank. The filter speeds were increased when the filter capacity was exceeded under wet conditions. When it rains, the mud levels tend to be high in the clarifiers, which necessitates high speeds in the filters to prevent carryover and which, in turn, can affect the clear juice quality.

However, the operational costs have increased, due to the high usage of flocculant to precondition the mud. This has been offset by the reduction in the filter cake disposal costs and the reduced power consumption from the belt filters.

The mill is in a better position to manage mud volumes, due to the belt filters. The disadvantage of the mud belt filter has been the high filtrate returns that are recycled into the mixed juice tank. The mill has designed and installed a recirculation tank for the wash water used on the primary and secondary screens. The recirculation tank was installed during the 2025 off-crop season; and it was designed as a settling tank with three compartments, in which the solids are purged to the mixed juice stream. The purging is done through a timer which opens or closes on/off valves installed in the three compartments.

Currently, the mill crush rate has improved with a season-to-date throughput at 424 TCH, due to the installation of this settling tank. Filter cake pol recoveries have also improved from 1.9% to 1.7%, as shown in Table 11. The effects of the high rainfall between 2020 to 2023 can also be seen in Table 11. It is also anticipated that the mill will add a third belt filter, for redundancy at the filter station.

Table 11. Comparison data for filter cake pol between 2019 to 2025.

Season	2019	2020	2021	2022	2023	2024	2025*
Filter cake % cane	4.02	4.5	4.62	4.87	4.69	2.92	2.58
Pol % filter cake	1.23	2.52	2.41	4.76	3.72	1.91	1.71
Filter cake pol loss [tonnes]	916	2150	1960	3754	3013	802	303
g pol in filter cake/ton cane	0.49	1.13	1.17	2.32	0.17	0.50	0.32

*Season-to-date values.

Conclusion

The implementation of mud belt filters at Simunye sugar mill has greatly improved the filter cake pol and moisture of the filter cake. This improvement has contributed to increasing the overall recoveries of the mill to about 90.76% (pol-based). In the previous season, the mill struggled to achieve the filter cake pol and moisture % filter cake targets, due to the high rainfall received during the La Niña triple dip period. The filter cake transportation costs have also decreased significantly due to the reduction in the filter cake moisture. Hence, the overall benefits of the belt filters outweigh the drawback of increased operational costs, due to the additional flocculant and lime usage. With optimisation, the mill can reduce the wash water usage on the belt filters even further, to improve the mill crush rate and to increase the recoveries at the filter station.

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