

OPERATIONAL PAPER

ROTARY VACUUM FILTER OPERATION UNDER RAINY CONDITIONS AT SIMUNYE

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Abstract

Cane harvested under wet conditions contains an increased quantity of mud. The process of recovering bagacillo from the bagasse to blend with the filter mud, also adds to the amount of soil that is introduced to the filter mud. Clay soil is dominant in the Simunye lowveld. Typically, the clay particles swell when wet, and the introduction of bagacillo, which has high levels of clay particles, makes the filter cake impervious, which prevents washing at the rotary vacuum filter and results in a high filter cake pol. Soil, which contains a high level of bacteria (unlike the diffuser), is not sterilised during milling. This microbial action continues until the mixed juice/filtrate mixture is sterilised at the juice heaters. The addition of flocculant and biocide to the filter mud has improved the throughput, with slight improvement to the filter cake pol.

The mud belt filter operates on a different principle, and it could help to improve the operation under rainy conditions. The belt filter does not require bagacillo, hence it will not introduce additional clay and bacteria into the filter mud.

Keywords: Rotary Vacuum Filter, clay soil, filter cake washing, bagacillo, wet conditions

Introduction

The Royal Eswatini Sugar Corporation operates two of the three sugar mills in Eswatini and it produces two-thirds of the country's sugar. These sugar mills are all situated in the lowveld and the cane is harvested during the winter months. Simunye, which is the third mill built in the country, started operating in 1980; it is presently capable of crushing two million tons of cane and producing 240 000 tons of very high pol sugar annually. The tons of cane per hour (tch) have gradually increased over the years, from 250 tch in 1980 to 450 tch at present.

Normally, harvesting is carried out after the rainy season and the bulk of the cane is harvested under dry conditions (April to November); the ripening process, which includes the use of cane ripeners, as well as the interruption of irrigation, all contribute to the dry harvesting conditions.

However, with climate change, we now experience unseasonal wet conditions during cane harvesting. The year 2022 was the sixth-wettest year in Eswatini since 1981 (Anon). There was also unseasonal rain during the dry winter months of July to October. The high rainfall was attributed to the La Nina phenomenon, which affected the southern African area for the third year in a row. The World Meteorological Organisation considers the three consecutive years (2020, 2021 and 2022) as the first 'triple-dip' La Nina of the 21st century. It is only the third time since 1950 that there has been 'triple-dip' La Nina (WMO, 2022).

The factory was unable to receive a steady cane supply. The out-of-cane hours, which is the time when there is a complete stoppage of the factory as there was no cane to crush, amounted to a staggering 1 462 crushing hours. Furthermore, the average through.hput was reduced by 12% to 397 tch, which led to the crop being extended to 23rd January 2023 i.e., a crop duration of over 39 weeks (275 days).

The difficulties experienced at the rotary vacuum filters and the action taken to mitigate the high filter cake losses are highlighted in this paper.

Operating Conditions in Simunye

Cane harvesting

Burnt cane is cut manually and echanically loaded onto trailers, which is then either transloaded to trucks or sent directly to the factory.

Normally, harvesting starts after the rainy season and it is usually done under dry conditions. The ripening process, which includes spraying with ripeners and the interruption of irrigation eight weeks before harvest, all contribute to the dry harvesting conditions.

Soil characteristics of the Simunye lowveld

The soil type in the lowveld of Eswatini is predominantly clay; it has been classified in different sets (C, D, N, Q, S, T and Z) by Nixon (2006) and by soil type, as depicted in the soil map of Eswatini. Appendix 1 shows the soil types of the Simunye sugarcane fields in Sections 1 to 9, which are superimposed on the soil map of Eswatini. Clay is the dominant type of soil in the lowveld of Eswatini. The traditional reference of this type of soil is 'Libumba', which is the clay soil that is used to make pots by some of the villagers. The soil in many sections of the Simunye cultivation area, e.g. Sections 2 and 13, are of the Vertisol type, with their clay content reaching 30% to 40% . (Nkambule 2022)

Clarification

Simunye has two Dorr 4 x 4 type juice clarifiers. The clarifier mud gravitates to the mud mixer and is mixed with bagacillo before going to the rotary filter station, where it is filtered in a similar manner to all the rotary vacuum filters round the world. The rotary drum picks up the filter mud at a low vacuum, and as it rotates into the high vacuum segment, the sugar is washed with hot water and the moisture is reduced, before the cake is scraped off. Figure 1 shows the flow in the filtration station at Simunye.

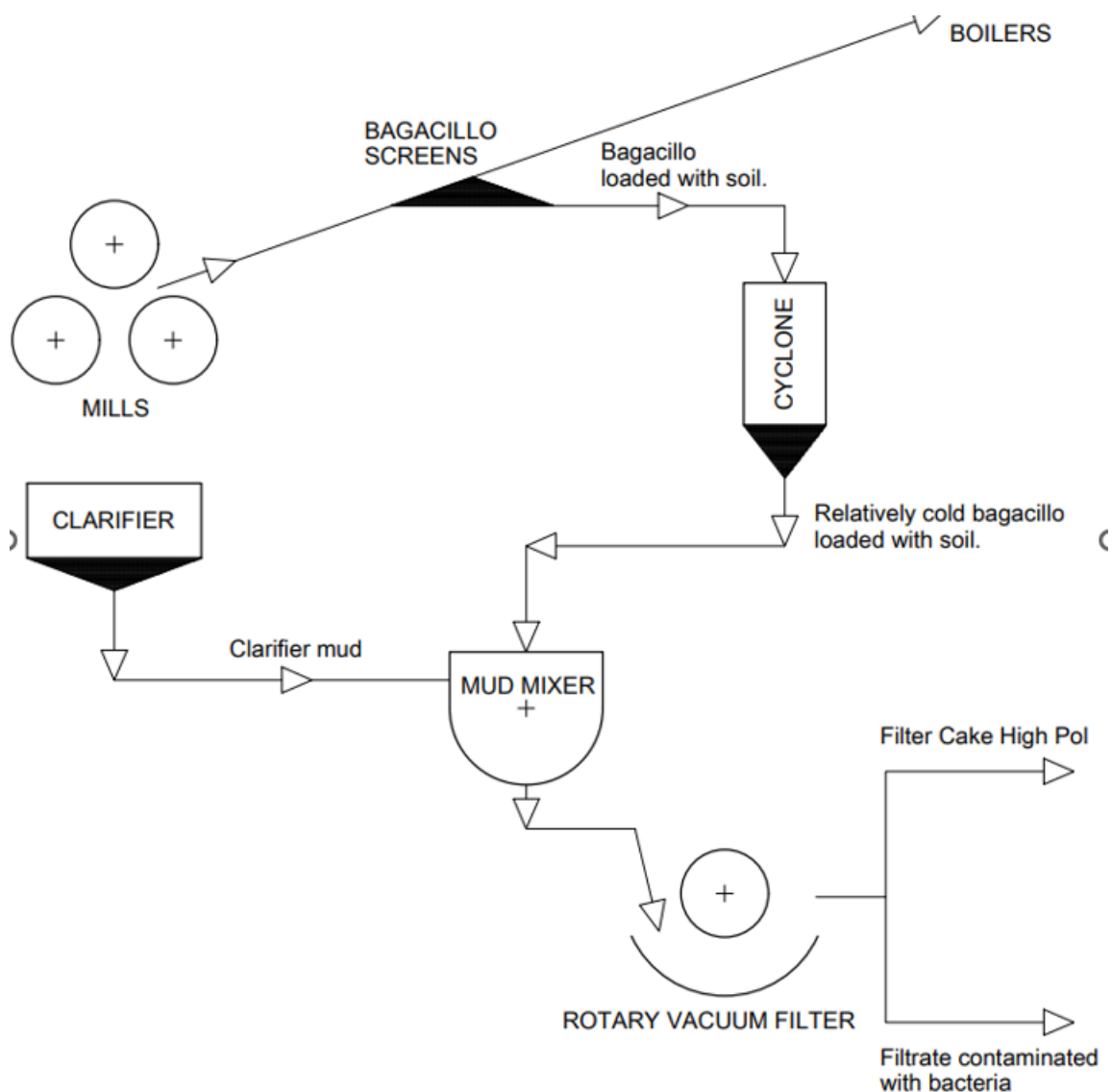


Figure 1. Flow diagram of the bagacillo and filter station

Under dry conditions, the pol losses are low, but the same operating conditions under muddy conditions give vastly disparate results.

The operating parameters for the filter station

The equipment in use and the operating parameters are summarised in Table 1.

The capacity of the rotary vacuum filters, in terms of the filter area per ton of cane per hour of 0.6 m² per tch, is very much in line with other milling factories. The filter screen open area and screen perforations are similar to those used in standard rotary filters.

In the light of the 2022 crop experience, the mixer mud outlet and the filter mud trough temperatures are now more closely monitored, and adjustments have been made by manually operating the steam injection valves.

Equipment	Parameter	Units	Target	Actual
Mud Mixer	Speed	RPM	27	27
Mud Filter-screen	Perforation	mm	0.8	0.8
Mud Filter-screen	Open area	%	56 - 74	60
Mud filter area/tch	Area/tch	m ² /tch	0,6	0,58 - 0,61
Mud pH	pH		7	6.8 – 7.2
Mud Brix	Brix	°Bx	12 - 14	13
Mud temp at Mixer outlet	Temperature	°C	>85	85
Mud Trough Temperature	Temperature	°C	>75	77
High vacuum	Pressure	kPa	-60	-60
Low vacuum	Pressure	kPa	-20	-45
Cake thickness	Thickness	mm	10	10
Wash water temp	Temperature	°C	80 – 85	87
Mud drum rotation	Speed	RPM	2.5	3-4
Amount of bagacillo	Mass	Kg/ TC	5 – 7	8 - 9
Bagacillo screen area	Area	m ²	2 x 2.5	2 x 2.5

Table 1. Operating parameters for the filter station

Operation of the filter and observations during rainy conditions

Soil ingress and its impact on filtration

The bagacillo is separated from the bagasse by using two screens (1.25 m x 2 m each and non-vibrating) situated at the base of the bagasse conveyor; one has a 12.5 mm aperture, and one has a 5 mm aperture. Initially, both had a 5 mm aperture, but with the muddy cane, the 5 mm diameter holes got blocked and it was replaced by one with a 12.5 mm aperture. This improved the quantity of bagacillo, but at the same time, it increased the clay soil that was extracted together with the bagacillo. Soil is a very high carrier of bacteria which is not totally eliminated during its short residence in the mud mixer.

When there is an excessive ingress of soil with the bagacillo, the soil tended to deposit in the mud trough, which at times tripped the mud agitator; when this occurred, the trough would be emptied and washed into the drains. The mud in the filter trough is about 4 m³ and the estimated pol loss is half a ton of pol.

The soil in the lowveld of Simunye is predominantly of the Vertisolic type, which has a clay content of about 30-40%; the clay is of the Montmorillonite type, which can absorb more than 10 times its own weight in water. The clay soil renders the filter cake impervious to the wash water and, as the sugar is not washed away, the pol % filter cake can be as high as the filtrate. However, in the oil industry, Montmorillonite clay characteristic is used advantageously in the oil drilling as a component of the drilling mud, which makes the mud slurry viscous, helps to keep the drill bit cool and removes the drilled solids (Wikipedia, 2022).

The sticky filter cake cannot be scraped off easily and it must therefore be scraped off manually, in order to maintain the filter capacity. If manual labour is inadequate, the mud remains on the screen of the drum and is circulated round and round, which reduces the effective screen area.

Towards the end of the 2022/23 crop, flocculant (LT 27) was dosed into the mud mixer. The permeability of the filter cake improved, its thickness increased, it was less sticky and could be scraped off by the filter scraper. Biocide was dosed manually into the mud mixer. Unfortunately, no quantitative data were compiled at that time.

Evaporative cooling and reduced temperature of mud in the filter trough

The water sprays are of the fan type and offer good coverage; at the same time, they promote evaporative cooling (assisted by the vapour extraction hood), which reduces the temperature of the mud in the trough when the wash water runs down the drum to the mud trough. While only a small film is required to maintain the seal as the rotating drum emerges from the trough; the excess wash water running down the side of the filter drum contributes to the temperature drop in the trough.

Critical temperature to control losses:

A number of factors, working in combination, led to a drop in the temperature of the filter mud in the rotary vacuum filter trough. These factors were:

- the high soil (clay) content in the mixed juice and in the bagacillo;
- the filter mud being impervious because of the clay ingress above it; and
- the poor filterability of the filter mud, which led to the evaporative cooling of the wash water.

This indicated that the drop in mud temperature down to 65°C (Table 2), caused by clay ingress, has a major impact on the filter operations, which leads to high sugar losses. This was confirmed by other observations that bacterial growth is promoted below the critical 75°C, and that waxes and gums in the filter mud also solidify, which further aggravates its filterability (Rein, 2007). A high clear juice-filtrate purity drop is a good indicator of bacterial activity, and a purity drop above 2.0 is a cause for concern.

The filter cake at the discharge was found to be around 63°C (Table 2) and, in the event of the filter cake sticking to the filter screen, it would go round and round on the drum and contribute to the cooling of the mud in the mud trough.

Heating the mud by steam was a logical solution; therefore, a steam injection to the mud mixer was installed during a maintenance stop-day during the 2022 crop and the steam injections to the filter troughs were done at the end of the year during the off-crop.

	Temperature
	°C
Mud Mixer	87
Hot water wash	73
Mud trough	65
Filter cake discharge	63
Bagacillo used at mud mixer	27
Ambient temp	21

Table 2. Temperature profile of filter station prior to steam injection

Filter operations under different weather conditions

The impact of the first two years of the ‘triple dip’ of La Nina (2020 and 2021) on factory operations, were relatively mild compared to the last year of the ‘triple dip’ (2022). During the third year of the ‘triple dip’ factory operations were badly affected, However, what the Eswatini lowveld experienced was less severe (but nonetheless significant) when compared to the disastrous flooding in KwaZulu-Natal in April 2022, which led to a declaration of a national state of disaster, in order to deal with the fall-out of the flooding.

A comparison was made between 2019 (138 hours) and the three La Nina years (Table 3); the out-of-cane hours increased significantly from 239 hours to 956, and to 1462 hours for the crops in the three ‘triple dip’ years (2020, 2021 and 2022/23). This is also reflected in the lower rainfall for the 2019 crop and it should be noted that the rainfall then was mainly in the summer month of November just before the end of the crop. However, during the La Nina years, the rain fell during the winter harvesting months and the fields took longer to dry out.

The increase in the clear juice minus the filtrate purities over the four years are illustrated in Figure 2. To prevent crowding in the graph, the clear juice minus the filtrate data were grouped into periods of five weeks for the four years. The step increase from the dry crop in 2019 to the progressive deterioration of the ‘triple dip’ crops is clearly illustrated in Figure 2. The increasing out-of-cane hours and the pol loss in the filter cake are also linked to the increase in rainfall during the harvesting season (see Table 3).

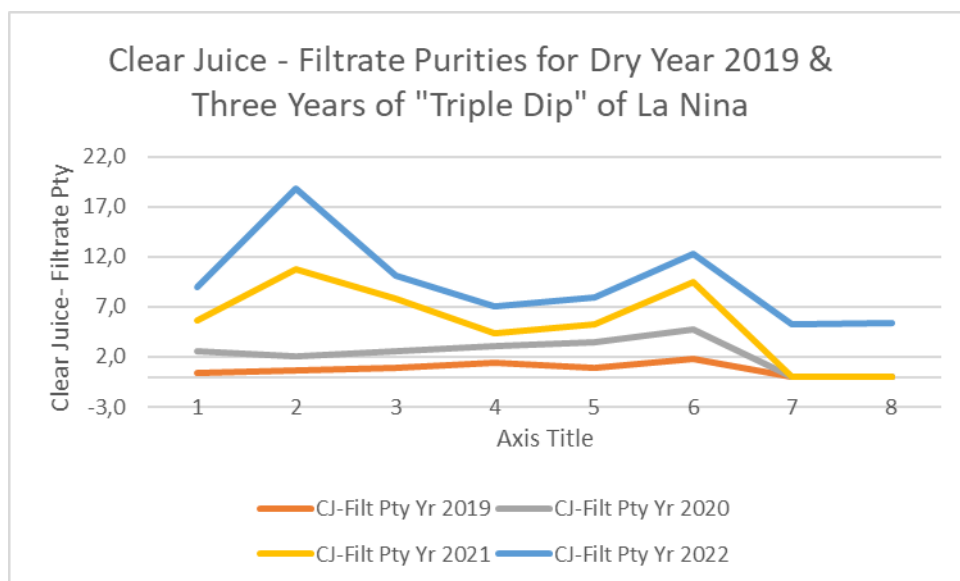


Figure 2. Increase in clear juice minus filtrate purities from 2019 to 2023

The losses in filter cake in kg pol per ton of cane can be as low as 0.49 kg in 2019, to a high of 2.32 kg in 2022/3 (Table 3), which is nearly five times higher. The losses in 2020 and 2021 were more than double that of 2019; this can be explained, to some extent, by the effect of the temperature of the mud in the trough (65°C), which affected the filterability through the combined action of solidifying the wax and gums and bacterial activity.

Crop	2019	2020	2021	2022/23
La Nina Triple Dip	Dry season No La Nina	First Year of La Nina	Second Year of La Nina	Third Year of La Nina
Cane t	1 852 354	1 896 784	1 671 715	1 618 611
Filter cake % cane	4,02	4,5	4,62	4,87
Pol % filter cake	1,23	2,52	2,41	4,76
Filter cake pol loss t	916	2150	1960	3754
Rain mm during crop	108	240	243	382
Out- of-cane hours	138	239	956	1462
Kg pol in filter cake per ton cane	0,49	1,13	1,17	2,32

Table 3. Filter cake losses under different crop conditions from 2019 to 2022

For this 2023 crop, each of the four filters was equipped with steam heating injection to the troughs, in order to maintain the temperature above 75°C. An isometric drawing of the steam injection is shown in Figure 3. Three two-inch steam injection lines, as well as a temperature gauge, were installed in the mud mixer.

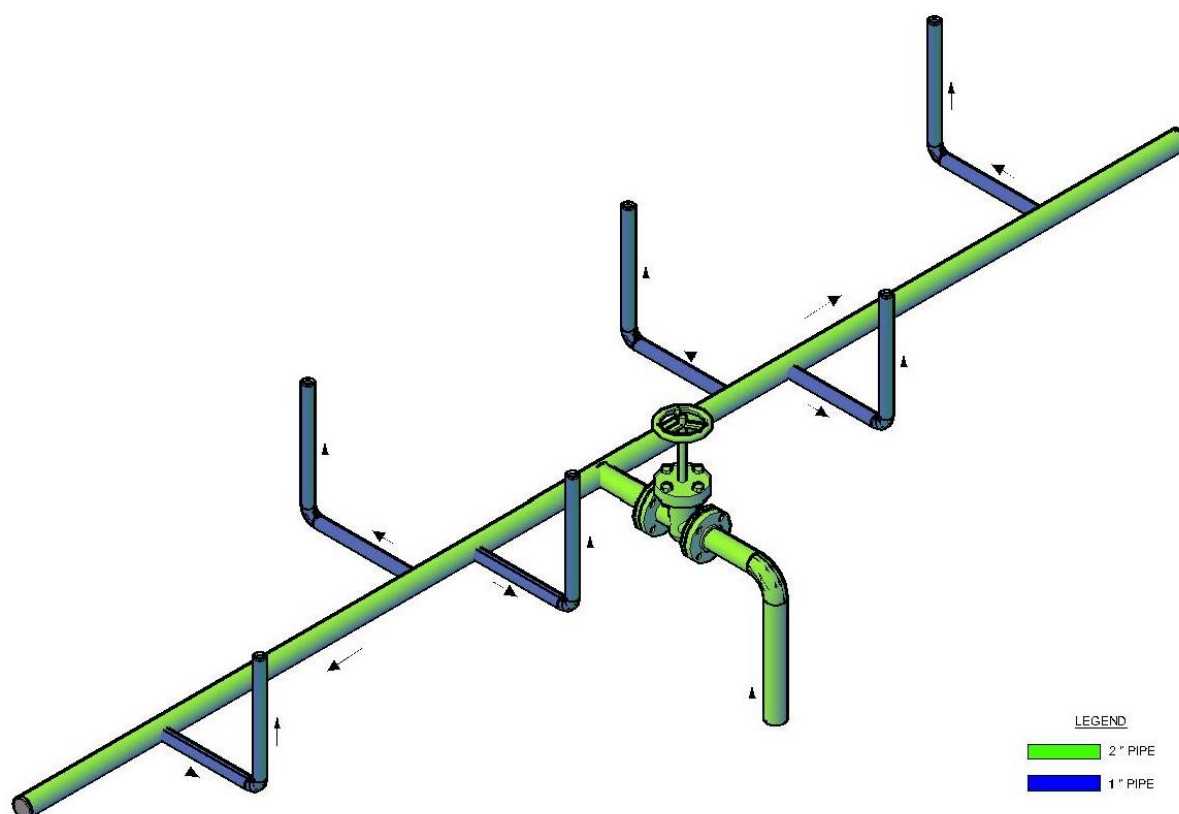


Figure 3. Isometric drawing of steam injection system to the mud trough of the rotary vacuum filter

Differences in the operation of filters in the dry and wet periods

For the purpose of classifying a wet or dry week during the 2022/23 crop, an arbitrary weighted average of the Simunye cultivation area, namely a week's rainfall of 5 mm or greater, was taken as the criterion, as it also relates to the clarification of the problems. The factory week at Simunye is unlike a calendar week, as the crushing week starts on a Friday at 6.00 am to the following week Thursday at 6.00 am. For example, if there is rain on a Thursday, the muddy cane could be delivered on a sunny Friday or Saturday of the following week; thus, in a 'dry week', the factory could still be receiving muddy cane. However, this classification of wet and dry weeks gives an insight into the filtration problems of muddy cane.

The classification into wet and dry weeks highlights the vastly-different operating conditions and their impact on the same filter (Table 4). The wet conditions during the 2022/23 crop was about 45% of the duration of the crop.

Surprisingly the moisture % of the filter cake went down from 72.61 to 69.37% under wet conditions, maybe as a consequence of the drastic reduction in the application of wash water, as the cake was impervious.

Crop 22/23	Dry	Wet	Crop
	Weeks	Weeks	2022/23
Number of crushing weeks	21	17	38
Cane total tons crushed	1 082 986	535 626	1 618 611
Ave Cane per week t	51 571	31 507	42 595
Rain/wk mm	1,8	20,0	10,1
Rain total mm for dry/wet period	37	345	382
Filter cake % cane	4,7	5,21	4,87
Pol % Filter cake	4,06	6,06	4,76
Moisture % filter cake	72,61	69,37	70,89
Filter cake pol loss t	2064	1690	3754
Kg pol in filter cake per ton cane	1,91	3,16	2,32
Clear Juice - Filtrate purity	3,03	4,65	4,34
Ash % Cane	1,56	2,22	1,78
Estimated soil % Cane	0,96	1,62	1,18
Ash % Bagasse	3,67	3,83	3,68
Estimated soil % Bagasse	3,07	3,23	3,08
Suspended solids in Mixed Juice	1,03	1,18	1,08

Table 4. Filter cake losses in the dry and wet weeks of the 2022/23 crop

Table 4 shows a significant drop in cane supply of 20 000 tons per week and a 65% increase in the loss of filter cake, from 1.91 kg pol per ton cane to 3.16. A clear juice-filtrate purity of 3.03 in the dry weeks clearly indicates a microbial problem, which is most likely related to the temperature of 65°C and soil ingress.

The ash % cane was measured as per the analytical methods detailed in the SASTA Laboratory Manual for South African Sugar Factories (SASTA 1985). The ash % cane also gave a good indication of the soil % cane by subtracting 0.60% from the ash % reading (SASTA 1985). There was an increase of nearly 70% in the soil content of cane during the wet period. It should be noted that the total quantity of soil brought with the cane (1.18%) for the 2022/23 crop can amount to over 19 000 tons of dry soil sent to the factory.

Discussion

The bagasse carrier section is fitted with adjustable perforated screens to control the screen area for the collection of bagacillo (see Figure 1, which shows the bagacillo collection and filter station); in the process, soil is inevitably drawn in, together with the bagacillo. Soil is a major carrier of bacteria which is then introduced into the mud mixer. The mud feed from the clarifier was 90°C. It should be noted that if the temperature of 90°C is good at the mud mixer, it does not necessarily mean that the mud temperature will be the same at the filter. The low wash water temperature and evaporative cooling of the sprayed water, assisted by the extraction hood, as well as the recirculation of filter mud sticking to the drum, all contribute to dropping the temperature to below 65°C. At this temperature, the bacterial content and solidification of wax now become dominant factors (Table 2).

The dimensions of the mud mixer are as follows: length 3.1 m x width 1.3 m x height 1.3 m, with an operating volume of 4 m³, gives a residence time of under three minutes, which is inadequate for the sterilisation of the bacteria brought in by the soil in the bagacillo. The microorganisms will still be growing when the mud reaches the filter trough, where the temperature will be lower at 65°C (Table 2). The steam injection (Vapour I) installed in the filter troughs for the 2023 crop should be able to maintain the temperature to above 75°C.

The absence of steam injection in the filter troughs would explain the high losses, as well as the high clear juice minus the filtrate purities in the relatively dry crops in 2020 and 2021 (Table 3). The critical control parameters for operators would be a temperature of 75°C in the trough and a clear juice minus filtrate purity of less than 2.0 units.

New technologies not requiring the use of bagacillo

Soil ingress is inevitable with the present bagacillo collection system. It was thus necessary to consider a different technology that does not require bagacillo for filtration. The mud decanter and mud belt filter were both considered by Simunye.

Mud decanter:

In 2018, Simunye received a prototype (450 mm x 1100 mm) solid bowl decanter centrifuge on loan, which operated at 2000 rpm and developed a gravity factor of 1000 (Figure 4).

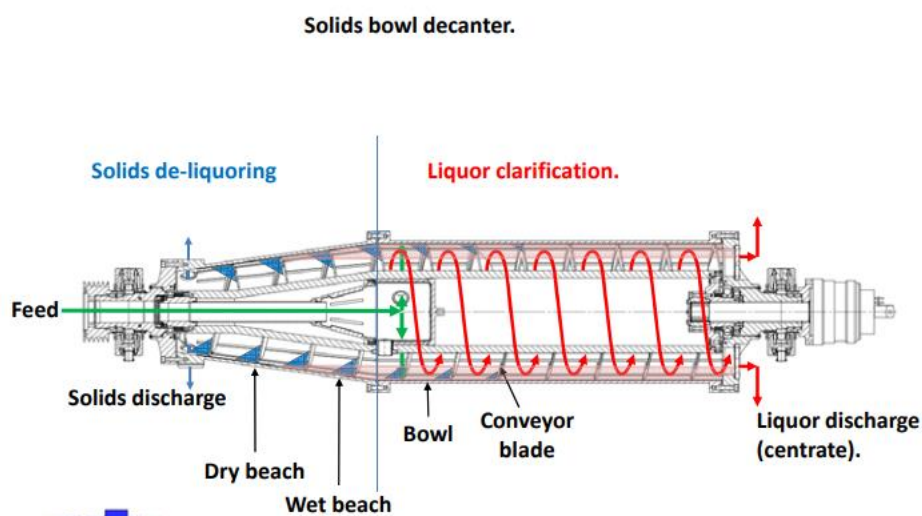


Figure 4. Solid bowl mud decanter

This unit did not require the use of bagacillo and the moisture % of the cake was 60.2% against the Rotary Vacuum Filter (RVF) of 73.1%. The liquor obtained from the mud by centrifugal action of the mud decanter is called the "centrate"; the quality of the 'centrate' was comparable to the filtrate of the RVF. The various flocculants and blends that were dosed were 23 ppm to 50 ppm on feed. The filter cake is used in the cane fields as a soil conditioner, thus the lower cake moisture is economic and convenient for transport and field spreading. However, because of the high operating rpm, the mechanical/operating inputs and operating costs were deemed to be high, and the mud belt filter was favoured.

Mud belt filter:

Similar to the mud decanter, the mud belt filter does not require the use of bagacillo. The moisture of the mud belt filter cake is about 68% and the transport disposal costs are expected to drop by 35%, from a combination of moisture reduction and not using bagacillo as a filter aid. An additional 15 000 tons of bagasse would be made available to the boilers annually, which has the potential of reducing the use of woodchips as a supplementary fuel.

The operating costs of the mud belt filter is expected to be lower than those of the mud decanter, as it operates at a much lower speed. Flocculant is added to the clarifier mud at a rate of 5-8 ppm on cane. The working principle of the mud belt filter is illustrated by Figure 5.

OPERATIONAL DIAGRAM OF SVP-200A

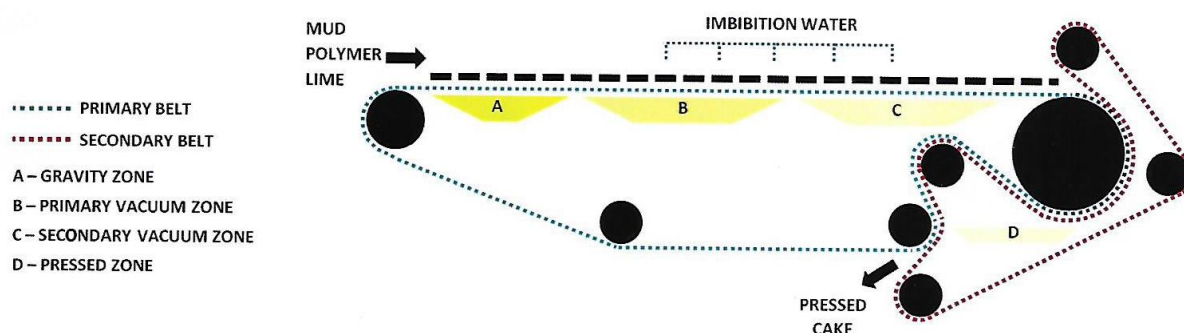


Figure 5. Drawing of a mud belt filter

Conclusion

In order to operate the rotary vacuum filter, it is very important to know the types of soil that are delivered with muddy cane. Clay soil (unlike sandy soil) makes the filter cake impervious and difficult to wash. The sprayed wash water, which is not used effectively by the filter cake flows down the side of the drum and contributes to the lowering of mud temperatures to below 75°C by evaporative cooling, thereby solidifying the waxes and increasing bacterial growth.

It is thus necessary to use steam injection at the mud mixer and the rotary vacuum filter trough to ensure that the mud temperature stays above 75°C.

New filtration technologies, such as the mud belt filter and mud decanter, do not require bagacillo as a filter aid, and they therefore eliminate the soil portion that comes from the bagacillo collection system.

The lower filter cake moisture, as well as the elimination of bagacillo as a filter aid, will reduce the transport disposal costs of filter cake, and about 15 000 tons of additional bagasse will be available annually as a boiler fuel.

Management has given its approval for the installation of two mud belt filters; the two units will be installed during the off-crop at the end of 2023 and will be operational for the 2024 crop. The mud belt filter will address the issue of soil ingress that comes with the reclaim of bagacillo for this current 2023 crop, and steam injection to the mud mixer will address the issues of bacterial growth and the solidification of wax and gums.

Acknowledgements

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SOIL SETS mapped during the National Soil Reconnaissance 1963-1967

MAIN PROFILE FEATURES
usually of modal soil series within each soil set
AND BROAD SOIL MAPPING UNITS
mostly after J. L. D'Hoare (1964)

A	Deep yellow loam, very acid: Ferralitic
B	Deep pale brown sandy old alluvium: Weakly Developed Soil
CH	(Highveld) — Deep dark brown clay, acid: Ferralitic
CL	(Lowveld) — Dark brown clay, neutral: Vertisolic
DH	(Highveld) — Shallow black hill peat: Organic Soil
DL	(Lowveld) — Yellow loam to clay, slightly acid: Fersialitic
E	Deep pale grey sand on clay or iron pan: Regosolic
F	Orange loam on soft iron pan: Fersialitic (to Ferralitic)
G	Grey sandy loam on hard iron pan: Lithosolic
H	Grey sandy loam on mottled clay pan: Pseudopodzolic
I	Marsh soil, mottled sand to clay, acid: Hydromorphic
JH	(Highveld) — Grey loam on thick stoneline on red loam: Ferralitic
JL	(Lowveld) — Deep pale red sand: Fersialitic (to Regosolic)
K	Black clay, calcareous: Vertisolic
L	Deep red loam, slightly acid: Fersialitic
M	Deep red loam, very acid: Ferrisolic (and Ferralitic-Fersialitic)
N	(Highveld) — Deep yellow on red loam, very acid: Ferralitic
O	Shallow grey sand to sandy loam on hard rock: Lithosolic
P	Grey sandy loam on mottled soft rock: Lithosolic
Q	(Highveld) — Grey on orange gravelly loam: Ferralitic
R	Red clay, slightly acid: Intertropical Brown Soil
SH	(Highveld) — Dark brown clay, acid: Ferrisolic
SL	(Lowveld) — Shallow brown or black loam to clay: Lithosolic
TH	(Highveld) — Pale red sandy loam on rotten rock: Ferralitic (to Regosolic)
TL	(Lowveld) — Dark grey clay on soft iron pan: Vertisolic
U	Rock outcrops and stony ground: Raw Mineral Soil
V	Marsh soil, deep black clay, calcareous: Vertisolic
W	Deep orange loamy old alluvium: Juvenile (to Fersialitic)
X	Pebbly or gravelly young alluvium: Weakly Developed Soil
Y	Deep dark brown clay, saline: Halomorphic
ZH	(Highveld) — Shallow red loam, acid: Ferralitic (to Lithosolic)
ZL	(Lowveld) — Dark grey sandy loam on clay pan: Solodized Solonetzic

N (Lowveld) is mapped with R set and Q (Lowveld) with H set.
Sets suffixed (Highveld) or (Lowveld) may be abbreviated to e.g. CH and CL, TH and TL.

As used above terms have the following modal values: shallow about 40 cm. of soil, deep 150 cm. and more: sand about 7% clay-size particles, loam 30% and clay 50%; very acid about pH 5.2 (water) in the diagnostic horizon, acid pH 5.8, slightly acid pH 6.4 and neutral pH 7.0. Reference is made to soil reaction only where it is a distinguishing feature between otherwise rather similar sets.